PHYSICS 12 AGS

PROVINCIAL EXAM

WORKBOOK

2005 EDITION

VECTOR KINEMATICS

IN TWO

DIMENSIONS

AND

DYNAMICS AND VECTOR

DYNAMICS

Vectors and relative Velocity
Motion with constant acceleration
Forces
Two-dimensional dynamics

Outcomes	Questions
It is expected that students will use the concepts of two-dimensional dynamics to analyse common situations.	
It is expected that students will:	
A1. identify scalars and vectors	1, 2
A2. identify the resultant vector and component vectors on vector diagrams	
A3. write vector equations describing the vector addition of two or more velocities or displacements	
A4. write vector equations describing the subtraction of two velocities or displacements	
A5. use graphical methods to resolve a vector into two perpendicular components	
A6. resolve a vector into components using trigonometry	
A7. use graphical methods or trigonometry to add or subtract vectors	
A8. describe relative velocity	
A9. use vector analysis to determine velocities, displacement, and time of travel for navigation problems	3
A10. gather and organize data, produce and interpret graphs, and determine relationships between variables	
B1. identify situations involving the use of kinematics	
B2. solve problems involving:	4
• displacement • initial velocity • final velocity	
• average velocity • acceleration • time	
B3. describe the shape of the path taken by a projectile fired at some angle above the horizon if friction is negligible	
B4. determine from experimental data that the horizontal motion of a projectile is independent of its vertical motion if friction is negligible	
B5. demonstrate that the horizontal velocity of a projectile is constant if friction is ignored	
B6. state that a projectile experiences a constant downward acceleration due to gravity if friction is negligible	
B7. resolve a projectile's velocity into horizontal and vertical components	
B8. solve projectile motion problems involving:	5, 6
• range • maximum height • time of flight	
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C1. state Newton's laws of motion	7
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C6. define gravitational field strength	
C7. solve problems involving:	10
• the force of gravity (weight)	
• gravitational field strength	
• mass	
C8. solve problems involving:	11, 12, 13
• force of friction • coefficient of friction • normal force	
D1. resolve a force into two orthogonal components	
D2. determine the magnitude and direction of a force given its two orthogonal components	
D3. determine the net force from two or more forces	14
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D6. solve problems involving objects on inclines	18, 19, 20

Vector Kinematics and Dynamics

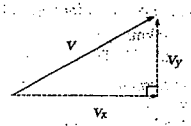
Vector Kinematics

A1 Identify scalars and vectors

A scalar is a quantity that only has magnitude. Some examples of scalar quantities are heat, temperature, and speed. A vector has both magnitude and direction. Examples of vector quantities are displacement, force and velocity.

A2 Identify the resultant vector and component vectors on vector diagrams.

A vector v, that lies on a plane, may be disassembled into components. This is called resolving the vector. The vector components are perpendicular to each other and parallel to either the x-axis or the y-axis.



The component vectors are labelled v_x and v_y for vectors in horizontal or vertical directions respectively.

A3 Write vector equations describing the vector addition of two or more velocities or displacements.

To add or subtract vectors v and v':

1. Resolve into components v_x and v_y, and v'_x and v'_y, with

$v\sin\theta = v_y \qquad v'\sin\theta = v'_y$

$v\cos\theta = v_x \qquad v'\cos\theta = v'_x$

2. Add components

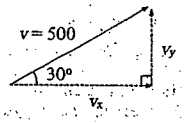
$v + v' = (v_x + v_y) + (v'_x + v'_y)$

$= v_x + v'_x + v_y + v'_y$

The resultant vector $(v_r) = v_{xr} + v_{yr}$

The direction is found by $\tan\theta = \dfrac{v_y}{v_x}$

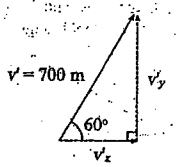
The magnitude of the vector $= \sqrt{(v_x)^2 + (v_y)^2}$



Example: From point P, a man walks 500m 30° north of east. He then walks 60° north of east for 700m. How far away and in what direction is he from point P?

$v_y = \sin\theta = (500)\sin 30° = 250\text{m}$

$v_x = v\cos\theta = (500)\cos 30° = 433.0\text{ m}$



$v'_y = v'\sin 60° = (700)\sin 60° = 606.2\text{m}$

$v'_x = v'\cos 60° = (700)\cos 60° = 350\text{m}$

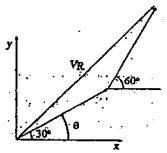
$v_{xr} = v_x + v'_x = 433.0 + 350.0 = 783.0\text{m}$

$v_{yr} = v_y + v'_y = 250 + 606.2 = 856.2\text{m}$

$v_r = \sqrt{(783.0)^2 + (856.2)^2} = 1160.2\text{m}$ (magnitude)

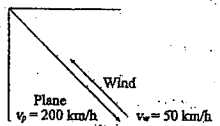
$\tan\theta = \dfrac{856.2}{783.0}$ (direction)

$\theta = 47.6°$ north of east



A4 Write vector equations describing the subtraction of two velocities or displacements.

Example: A plane travels at a velocity of 200km/h 45° south of east. A headwind blows directly against it at a velocity of 50 km/h. What is the resulting velocity of the plane?

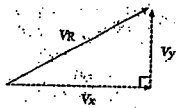


$v_R = v_p - v_w \qquad = (200 - 50)\text{km/h} = 150\text{ km/h}$

Since the vectors directly oppose each other, simply subtract one from the other.

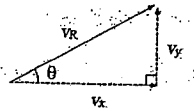
A5 Use graphical methods to resolve a vector into two perpendicular components.

A vector's components in two-dimensional motion run in a vertical direction, v_y, and a horizontal direction v_x. They meet at a 90° angle.



To construct the components graphically, draw a line horizontally from the resultant vector's tail. This horizontal line will intersect the line drawn vertically from the resultant vector's tip.

A6 Resolve a vector into components using trigonometry.



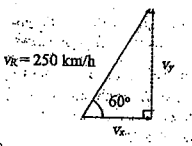
Recall that $\sin\theta = \dfrac{v_y}{v_R}$

$\Rightarrow v_y = v_R\sin\theta$ (vertical component)

And $\cos\theta = \dfrac{v_x}{v_R}$

$\Rightarrow v_x = v_r\cos\theta$ (horizontal component)

Example: Resolve $v_r = 250$km/h travelling 60° north of east into its components using trigonometric methods.



$v_y = v_R\sin 60°$

$= (250\text{km/h})(\sin 60°)$

$= 217\text{km/h}$

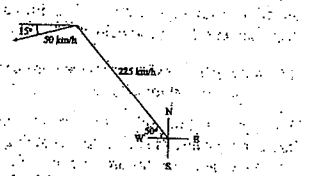
$v_x = v_r\cos 60°$

$= (250\text{km/h})(\cos 60°)$

$= 125\text{km/h}$

A7 Use graphical methods or trigonometry to add or subtract vectors.

Example: A plane travelling 50° north of west at 225km/h experiences a 50km/h wind blowing 15° south of west. What is the plane's resultant magnitude and direction?



Solution (algebraic).

Plane: $v_x = 225\cos 50°$ wind: $v_x = 50\cos 15°$

$= 145\text{km/h}$ $= 48\text{km/h}$

$v_y = 225\sin 50°$ $v_y = 50\sin 15°$

$= 172\text{km/h}$ $= 13\text{km/h}$

Resultant vector

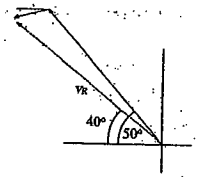
$v_x = 145 + 48\text{ km/h} = 193\text{ km/h west}$

$v_y = 172 - 13\text{km/h} = 159\text{ km/h north}$

$v_r = \sqrt{v_x^2 + v_y^2} = \sqrt{193^2 + 159^2} = 250\text{km/h}$

$\tan\theta = \dfrac{v_y}{v_x} = \dfrac{159}{193} = 39.5°$ north of west

Solution (graphical)



Draw the vectors together, placing the tail of a vector onto the head of the second vector. Draw the resultant vector from the tail of the first vector to the tip of the second one. Measure using a ruler and an appropriate scale. To find the direction, use a protractor, measuring from the appropriate axis.

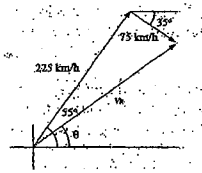
A8 Describe relative velocity

Relative velocity depends on the perspective of the observer. For example, two cars are travelling in opposite directions at 110km/h. To the occupants of either car it will appear that the approaching car is travelling at 220km/h. To an observer at the side of the road, either car passing by will have a speed of 110km/h.

A9 Use vector analysis to determine velocities, displacement, and time of travel for navigation problems

A10 Gather and organize data, produce and interpret graphs, and determine relationships between variables

Example: A plane travelling at a velocity of 225km/h 55° north of east experiences a 75km/h wind blowing 35° south of east. How long will it take for the plane to travel 400km?



Plane $v_x = 225\cos 55°$
$= 129\text{km/h}$
$v_y = 225\sin 55°$
$= 184\text{km/h}$

Wind
$v_x = 75\cos 35°$
$= 61\text{km/h}$
$v_y = 75\sin 35°$
$= 43\text{km/h}$

$v_R = \sqrt{190^2 + 141^2} = 237\text{km/h}$

$\tan\theta = \frac{v_y}{v_x} = \frac{141}{190}$ $\theta = 37°$ north of west

$v = \frac{d}{t}$ $t = \frac{d}{v}$ $= \frac{400\text{km}}{237\text{km/h}}$
$= 1.69$ hours or 1 hour and 41 minutes.

Vector Kinematics in Two Dimensions (Motion with Constant Acceleration)

B1 Identify situations involving the use of kinematics

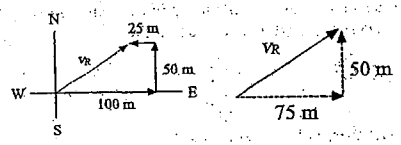
The study of object motion, using force and energy, comprise the field of mechanics. Dynamics is the study of what causes objects to move. Kinematics is the study of how objects move. In kinematics, we solve problems of time, velocity and distance.

B2 Solve problems involving:

- *displacement*

The displacement of an object is its change in position.

Example: A woman walks 100m east, 50 m north and 25m west. What is her displacement?



$v_R = \sqrt{50^2 + 75^2} = 90\text{m}$

- *initial velocity and final velocity*

Example: The final velocity of a car after decelerating 2m/s^2 over 5 seconds is 80km/h. What was the car's initial velocity?

$v = v_i + at$, $a = 2\text{m/s}^2$, $t = 5\text{s}$, and $v = 22.2\text{m/s}$

$22.2\text{m/s} = v_i - (2\text{m/s}^2)5\text{s}) = v_i - 10\text{m/s}$

$v_i = 32.2\text{m/s} = (32.2\text{m/s})(\frac{1\text{km}}{1000\text{m}})(\frac{3600\text{s}}{1\text{h}})$

$= 116\text{km/h}$

Example: A motorbike accelerates from rest at a rate of 8m/s^2 for 6 seconds. What is its speed after 6 seconds, in km/h?

$v_f = v_i + at = 0 + (8\text{m/s}^2)(6\text{s}) = 48\text{m/s}$

$= (48\text{m/s})(\frac{1\text{km}}{1000\text{m}})(\frac{3600\text{s}}{1\text{h}}) = 172.8\text{ km/h}$

Example: A car travelling at 100km/h accelerates at 100km/h^2 over 5 minutes. What is the car's final velocity?

$v_f = v_i + a_{av}t$,

where $v_i = 100\text{km/h}$, $a_{av} = 100\text{km/h}^2$, and $t = \frac{1}{20}\text{h}$

$(5\text{min} \times \frac{1\text{h}}{60\text{min}} = \frac{1}{20}\text{h})$

$v_f = 100km/h + (100km/h^2)(\frac{1}{20}h)$

$= 100\text{km/h} + 5\text{km/h} = 105\text{ km/h}$

- *average velocity*

Example: A car decelerates from 120km/h to 70km/h in 10s. What is the car's average velocity?

$v_{av} = \frac{v_f + v_i}{2} = \frac{70 + 120}{2} = 95\text{ km/h}$

- *acceleration*

Example: A motorbike starts from rest and reaches a final velocity of 200km/h in 5 minutes. What is the average acceleration of the motorbike?

$a = \frac{v_f + v_i}{t} = \frac{200\text{km/h}}{\frac{1}{12}\text{h}}$

$= (200\text{km/h})(12/\text{h}) = 2400\text{km/h}^2$

- *time*

Whenever there is a change in position, time is also part of the equation. The time factor produces a rate which is a measure of how quickly a change is produced. Time is also used in calculations of how far an object has travelled or the amount of change that has occurred.

Example: A freight car is travelling at an average speed of 2.00m/s. How long does it take to travel 15.0m?

$v = \frac{d}{t}$ $t = \frac{d}{v} = \frac{15.0\text{m}}{2.00\text{m/s}} = 7.50\text{s}$

B3 Describe the shape of the path taken by a projectile fired at some angle above the horizon if friction is negligible.

From Galileo's work, we learned that projectile motion may be split into horizontal and vertical components. The horizontal component remains constant as there is no friction, but the vertical component does change. The projectile has an initial velocity, v_i, which decreases uniformly due to gravity to 0m/s. At this point the projectile changes direction and begins to descend. The altitude at which the projectile's vertical velocity is equal to v_i coincides with the altitude at which that the projectile received its initial velocity.

B4 Determine from experimental data that the horizontal motion of a projectile is independent of its vertical motion if friction is negligible

B5 Demonstrate that the horizontal velocity of a projectile is constant if friction is ignored

B6 State that a projectile experiences a constant downward acceleration due to gravity if friction is negligible

A projectile is under uniform and constant acceleration due to gravity. Gravity is a force that acts on all mass. For large bodies such as Earth, the force is measurable and constant. Projectiles are under constant acceleration unless another force such as friction acts upon it. Most commonly, friction would be due to air. In the absence of friction, the projectile experiences constant acceleration due to gravity.

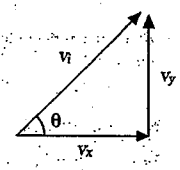
B7 Resolve a projectile's velocity into horizontal and vertical components

The direction of a projectile can be measured by its angle to the horizon since its velocity has both a horizontal and vertical component. These components can be resolved through trigonometry.

Vertical:

$\sin\theta = \frac{v_y}{v_i}$

$\Rightarrow v_y = v_i \sin\theta$

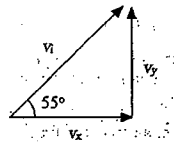


Horizontal:

$\cos\theta = \frac{vx}{v_i}$

$\Rightarrow v_x = v_i \cos\theta$

Example: A baseball is hit with an initial velocity of 30.0 m/s at an angle of 55° with the horizontal. Find the initial vertical and horizontal components of the velocity.



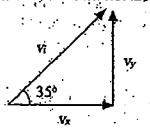
Vertical:	Horizontal:
$v_y = v_i \sin\theta$	$vx = v_i \cos\theta$
$= (30.0)(\sin 55°)$	$= (30.0)(\cos 55°)$
$= 24.6\text{m/s}$	$= 17.2\text{m/s}$

B8. Solve projectile motion problems involving:

- *range*
- *maximum height*
- *time of flight*
- *displacement*
- *velocity*
- *acceleration*

Example: A football is kicked from the ground at an angle of 35° with the horizontal at an initial velocity of 25m/s. Find the following:

i. vertical and horizontal velocity



Vertical:	Horizontal:
$v_y = v_i \sin 35°$	$vx = v_i \cos 35°$
$= 25\sin 35°$	$= 25\cos 35°$
$= 14.3$m/s	$= 20.5$m/s

ii. time of flight

Vertical: $v_{iy} = 14.3$m/s (from previous calculation)

$a = -9.8$ m/s^2 (acceleration due to gravity)

$v_{y\text{-}peak} = 0$ (when the football reaches its highest point)

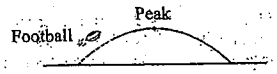
Therefore, $v_{y\text{-}peak} = v_{iy} + at$

$0 = 14.3\text{m/s} - (9.8\text{ m/s}^2)(t)$

$14.3 = 9.8t$

$t = 1.46$s

This is the time for the ball to reach its peak, which is half of the total flight of the ball.



The total time of the flight is $2(1.46)$s $= 2.92$m/s.

iii. Maximum Height

$$d = v_i t + \frac{1}{2}at^2$$

$$= (14.3\text{m/s})(1.46\text{s}) - \frac{1}{2}(9.8\text{m/s}^2)(1.46\text{s})^2$$

$= 10.4$m

iv. Displacement

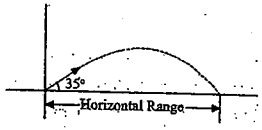
The distance from the initial point to the maximum height as the ball is rising is the same as the distance from the maximum height to the ground as the ball is falling. Therefore, the vertical displacement is zero. The horizontal displacement is:

$d = v_x t = (20.5\text{m/s})(2.92\text{s}) = 59.86$m

The total displacement is the vertical displacement plus the horizontal displacement.

$= 0$m $+ 59.9$m $= 59.9$m

v. Range



$d = v_x t$

$= (20.5\text{m/s})(2.92\text{s})$

$= 59.9$m is the total range.

vi. Acceleration

The acceleration of any object, not accounting for wind resistance, is 9.81m/s^2, which is the constant acceleration due to gravity.

Dynamics (Forces)

It is expected that students will analyse forces acting on an object and predict their effects on it.

It is expected that students will:

C1 State Newton's laws of motion

First Law: A body continues in its state of rest or of uniform speed in a straight line unless acted upon by a non-zero net force.

Second law: The acceleration of an object is directly proportional to the net force acting on it and is inversely proportional to its mass. The direction of the acceleration is in the direction of the net force acting on the object. $F = ma$

Third Law: Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

C2 Identify workplace and community situations involving Newton's three laws

C3 Apply Newton's laws of motion to common situations

Newton's First Law can be illustrated by an example of a person skating on ice. The force of friction between the skates and the ice is very low, allowing the person to glide a long distance before friction with the ice or any wind brings the skater to a stop.

Newton's Second Law can be illustrated by an example of a person pushing a car that has run out of gas. It will take some effort but the car (mass) can be made to roll (accelerate) in the direction that it is pushed (net force).

Newton's Third Law can be illustrated by an example of a hammer as it hits a nail. At some point the hammer's motion slows to zero as the force applied to the hammer by the nail is equal to the force applied by the hammer to the nail. If there was not a force acting opposite to the pounding of the hammer, the motion of the hammer would not stop.

C4 Solve problems involving:

- *force*

Example: Calculate the force required to uniformly accelerate a 900kg car 2.0m/s^2.

$F = ma$

$= (900\text{kg})(2.0\text{m/s}^2)$

$= 1800$ kg·m/s^2

$= 1800$N

- *mass*

Example: What is the mass of an object that requires a force of 2500N to slow at a uniform rate of 3m/s^2?

$F = ma$

$2500\text{N} = (m)(3\text{m/s}^2)$

$m = 833$kg

- *acceleration*

What is the acceleration of a 50kg object, when a force of 1500N is applied?

$F = ma$

$1500\text{N} = (50\text{kg})(a)$

$= 30\text{m/s}^2$

C5 Describe force as a vector quantity

C6 Define gravitational field strength

The force applied as an object is pushed or pulled has both magnitude and direction and is described as a vector quantity.

Gravitational field strength is an attractive property that all objects with mass possess, increasing in strength as mass increases. The gravitational field strength attributed to small objects such as cars or houses is negligible. For celestial bodies such as the moon, Earth or the sun, the gravitational field strength is significant. As the distance from the centre of an object increases, the field strength diminishes at an inverse square rate.

C7 solve problems involving:

- *the force of gravity (weight)*

Example: What is the weight of a crate with a mass of 250kg resting on the floor?

$F_g = mg = (250\text{kg})(9.8\text{m/s}^2)$

$= 2450\text{N} = 2.45\text{kN}$

- *gravitational field strength*

Example: What is the gravitational field strength between a 50kg object and 75kg object that are 30cm apart?

$F = \frac{Gm_1m_2}{r^2}$, where $G = 6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2$,

$m_1 = 50$kg, $m_2 = 75$kg, and $r = 0.30$m

$$F = \frac{(6.67\times10^{-11})(50)(75)}{(0.30)^2}$$

$= 2.78\times10^{-6}$N This force is negligible.

- *mass*

What is the mass of an object that weighs 150N?

$F = mg$

$150\text{N} = m(9.8\text{m/s}^2)$

$m = 15.3$kg

C8 Solve problems involving:

- *force of friction*

Example: The coefficient of static friction, μ_s, for wood on wood situations is 0.4. Find the force of friction of a 50kg wood crate being pulled on a wooden platform in one direction so that it is almost moving (the force of static friction is at a maximum).

$F = mg$

$= (50\text{kg})(9.8\text{m/s}^2)$

$= 490N$

$F_f = \mu_s FN$

$= (0.4)(490N)$

$= 196N$

- *coefficient of friction*

Example: Find the coefficient of friction for an ice block sliding on an ice surface (kinetic friction). (Assume that the ice block has a normal force of 980N and the force of friction is measured to be 29.4N)

$F_f = \mu_k FN$

$29.4 = \mu_k(980N)$

$\mu_k = 0.03$

- *normal force*

Example: What is the normal force of a car of mass 800kg at rest in a garage?

$F_n = mg$

$= (800\text{kg})(9.8\text{m/s}^2)$

$= 7840$N

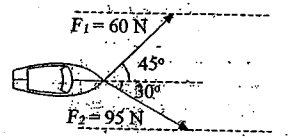
Vector Dynamics (Two-Dimensional Dynamics)

D1 Resolve a force into two orthogonal components

D2 Determine the magnitude and direction of a force given its two orthogonal components

D3 Determine the net force from two or more forces

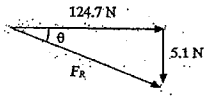
Example: Determine the net force acting on the boat in the following diagram.



F_1 F_2

Horizontal	$F_x = F_1 \cos 45°$	$F_x = F_2 \cos 30°$
	$= 60\cos 45°$	$= 95\cos 30°$
	$= 42.4$N	$= 82.3$N
Vertical	$Fy = F_1 \sin 45°$	$F_y = F_2 \sin 30°$
	$= 60\sin 45°$	$= 95\sin 30°$
	$= 42.4$N	$= 47.5$N
Sum	Horizontal $= 42.4 + 82.3 = 124.7$N	
	Vertical $= 42.4 - 47.5 = -5.1$N	

$F_R = \sqrt{124.7^2 + 5.1^2}$
$= 124.8$N



$\theta = \tan^{-1}(\frac{5.1}{124.7})$

$= 2.34°$ below horizontal

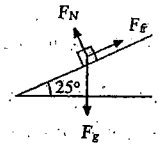
D4 Construct free-body diagrams for objects in various situations

D5 Use free-body diagrams to solve problems involving balanced or unbalanced forces

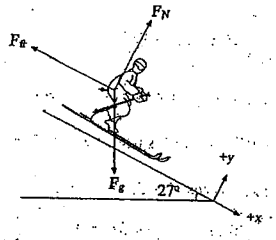
D6 Solve problems involving objects on inclines

Example: Create a free-body diagram for a crate on a ramp inclined at 25°, where the crate has a mass of 35kg and unknown friction μ_s.

$F_g = mg$
$= (35\text{kg})(9.8\text{m/s}^2)$
$= 343$N
$F_N = mg\cos 30°$
$= 297$N



Example: A 75kg skier skis down a 27° angle slope. If the coefficient of friction is 0.10, what is the skier's acceleration down the hill?



Horizontal:
$\Sigma F_x = ma$
$F_g \sin\theta - F_{fr} = ma$
$mg\sin 27° - \mu F_N = (75kg)a$
$333.68 - 0.1F_N = 75a$
Vertical:
$\Sigma F_y = ma$
$-F_g \cos 27° + F_N = 0$
$mg\cos 27° = F_N$

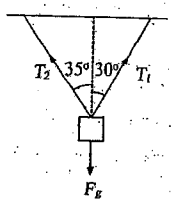
Substituting into Horizontal, we get

$333.68 - 0.1(654.89) = 75a$

$333.68 - 65.489 = 75a$

$a = 3.58\text{m/s}^2$

Example: Find the tension in each string supporting a 20kg mass.



$F_g = mg$
$= (20\text{kg})(9.8\text{m/s}^2)$
$= 196N$

$\Sigma F_x = ma$: $T_1 \sin 30° - T_2 \sin 35° = 0$

$\Sigma F_y = ma$: $T_1 \cos 30° + T_2 \cos 35° - F_g = 0$

Since $F_g = mg = 196$N, then

$T_1 \cos 30° + T_2 \cos 35° = 196$

$T_1 \cos 30° = 196 - T_2 \cos 35°$

$T_1 = \frac{1}{\cos 30°}(196 - T_2 \cos 35°)$

Substituting into $T_1 \sin 30° - T_2 \sin 35° = 0$, we get

$\frac{1}{\cos 30°}(196 - T_2 \cos 35)\sin 30° - T_2 \sin 35° = 0$

$\tan 30°(196 - T_2 \cos 35) - T_2 \sin 35° = 0$

$113.16 - T_2(0.5736) - T_2 \sin 35° = 0$

$T_2(0.5736 + \sin 35°) = 113.16$

$T_2 = 98.6N$

Substituting the value of T_2, we get

$T_1 \sin 30° - 98.6\sin 35° = 0$

$T_1 \sin 30° = 56.58$

$T_1 = 113.16\text{N} = 113\text{N}$

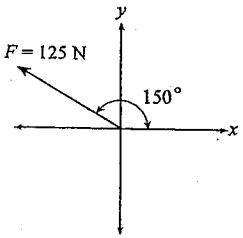
JANUARY 2000

VECTOR KINEMATICS AND DYNAMICS

1. Which of the following situations involves the use of kinematics?

   A. Solving a back emf problem
   B. Solving a projectile motion problem
   C. Determining the internal resistance of a cell
   D. Determining the sum of two momentum vectors

2. Consider the diagram below.



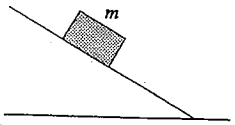
What are the components of the 125 N force?

	x–COMPONENT	y–COMPONENT
A.	−62.5 N	72.2 N
B.	−72.2 N	62.5 N
C.	−62.5 N	108 N
D.	−108 N	62.5 N

3. A projectile is launched at 35.0° above the horizontal with an initial velocity of 120 m/s. What is the projectile's speed 3.00 s later?

   A. 68.8 m/s
   B. 98.3 m/s
   C. 106 m/s
   D. 120 m/s

4. A block of mass m remains at rest on an incline as shown in the diagram.



The force acting up the ramp on this block is

   A. 0.
   B. mg.
   C. less than mg.
   D. more than mg.

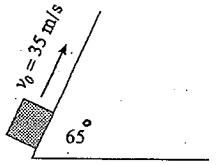
JUNE 2000

VECTOR KINEMATICS AND DYNAMICS

1. Which of the following contains scalar quantities only?

   A. speed, energy
   B. velocity, energy
   C. speed, displacement
   D. velocity, momentum

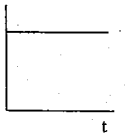
2. An object is fired up a frictionless ramp as shown in the diagram.

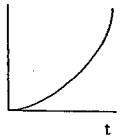


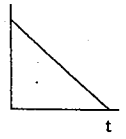
If the initial velocity is 35 m/s, how long does the object take to return to the starting point?

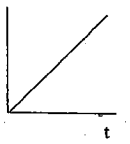
   A. 3.6 s
   B. 3.9 s
   C. 7.9 s
   D. 17 s

3. Which of the following graphs best illustrates the horizontal displacement of a projectile as a function of time? Ignore friction.

A. 

B. 

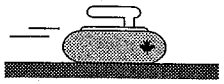
C. 

D. 

4. A constant net force acting on an object results in the object having a constant

   A. velocity.
   B. momentum.
   C. acceleration.
   D. kinetic energy.

5. A curling rock is travelling to the right across the ice as shown in the diagram.



Which of the following best represents the forces acting on the curling rock?

A. 

B. 

C. 

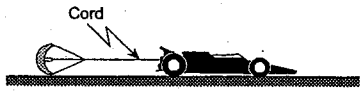
D. 

AUGUST 2000
VECTOR KINEMATICS AND DYNAMICS

1. A book is at rest on a desk. Which of the following statements concerning the book is correct?

   A. The desk exerts no force on the book.
   B. The book exerts no force on the desk.
   C. There are no forces acting on the book.
   D. The forces acting on the book are balanced.

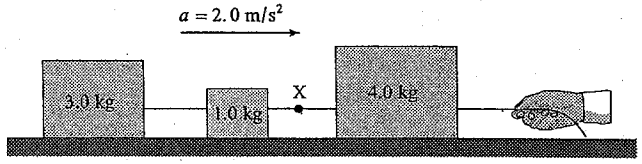
2. An 810 kg dragster is being decelerated by a parachute at 2.5 m/s^2 as shown in the diagram.



What is the tension in the cord at this moment?

   A. 0 N
   B. 2.0×10^3 N
   C. 5.9×10^3 N
   D. 7.9×10^3 N

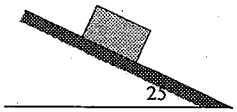
3. The system of blocks on a frictionless surface in the diagram below is accelerating at 2.0 m/s^2.



What is the tension in the cord at X?

   A. 2.0 N
   B. 6.0 N
   C. 8.0 N
   D. 16 N

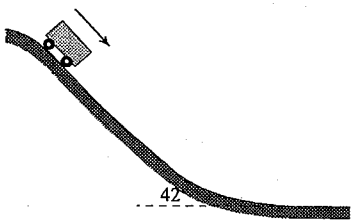
4. A 5.0 kg block remains stationary on an inclined surface.



What is the friction force acting on the block?

A. 21 N
B. 23 N
C. 44 N
D. 49 N

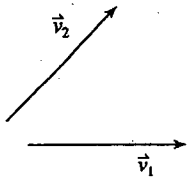
5. What is the acceleration of the roller coaster car in the diagram below? Ignore friction.



A. 6.6 m/s^2
B. 7.3 m/s^2
C. 8.8 m/s^2
D. Depends on car's mass.

JANUARY 2001
VECTOR KINEMATICS AND DYNAMICS

1. Two velocity vectors, v_1 and v_2 are shown.



Which of the following best represents the resultant of the addition of the two velocity vectors?

A.

B.

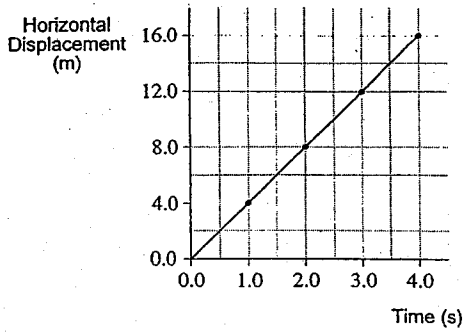
C.

D.

2. In landing, a jet plane decelerates uniformly and comes to a stop in 38 s, covering a distance of 1 500 m along the runway. What was the jet's landing speed when it first touched the runway?

A. 2.1 m/s
B. 39 m/s
C. 79 m/s
D. 170 m/s

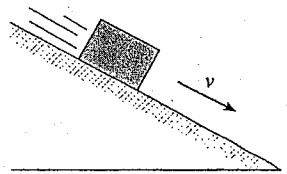
3. A projectile is fired into the air at some angle above the horizontal. The horizontal displacement of the projectile is measured against time in flight and the collected data is shown as a horizontal displacement versus time graph.



Based on this graph, the horizontal velocity of the projectile during this time interval is

A. constant.
B. increasing.
C. decreasing.
D. equal to zero.

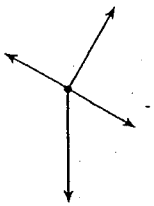
4. An object is sliding down an inclined plane at a constant speed.



Which of the following represents the free-body diagram for the object?

A. 

B. 

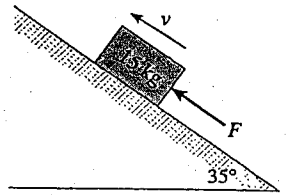
C. 

D. 

5. A 45 kg woman is standing in an elevator that is accelerating downwards at 2.0 m/s^2. What force (normal force) does the elevator floor exert on the woman's feet during this acceleration?

A. 90 N
B. 350 N
C. 440 N
D. 530 N

6. A 15 kg block is pushed up a 35° incline. A friction force of 110 N exists between the block and the incline.



What minimum force F, would be necessary to move the block up the incline at a constant speed?

A. 26 N
B. 84 N
C. 150 N
D. 190 N

JUNE 2001

VECTOR KINEMATICS AND DYNAMICS

1. Which one of the following contains only vector quantities?

   A. mass, time
   B. force, velocity
   C. time, momentum
   D. acceleration, speed

2. A 35 kg object released from rest near the surface of a planet falls 7.3 m in 1.5 s. What is the acceleration due to gravity on this planet?

   A. 4.9 m/s^2
   B. 6.5 m/s^2
   C. 9.7 m/s^2
   D. 170 m/s^2

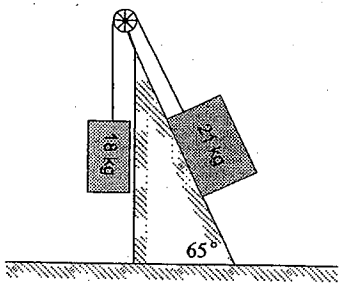
3. A projectile is fired with an initial velocity of 65 m/s at an angle of 23° above the horizontal. If air resistance is negligible, how much time elapses before the projectile reaches its maximum height?

   A. 2.6 s
   B. 2.8 s
   C. 6.1 s
   D. 6.6 s

4. A large mass, M, collides with a stationary small mass, m. During the collision, the forces exerted on each mass are measured. Which of the following is correct about the magnitude of the forces?

   A. No force is exerted during the collision.
   B. The large mass, M, exerts a greater force on the small mass, m.
   C. The small mass, m, exerts a greater force on the large mass, M.
   D. Both masses exert equal forces on each other during the collision.

5. Two masses are connected together by a rope and pulley on a frictionless inclined plane as shown.



When the system is released, what is the initial acceleration of the 21 kg mass?

	Magnitude of the Acceleration	Direction the Mass will Travel
A.	0.26 m/s^2	up the incline
B.	0.26 m/s^2	down the incline
C.	0.48 m/s^2	up the incline
D.	0.48 m/s^2	down the incline

AUGUST 2001

VECTOR KINEMATICS AND DYNAMICS

1. Newton's second law of motion is best shown by which of the following equations?

   A. $a = \frac{v}{t}$

   B. $a = \frac{F_{net}}{m}$

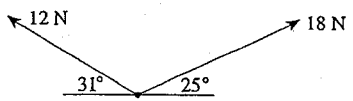
   C. $F_{net} = mv$

   D. $F_{net} = a\left(\frac{d}{t^2}\right)$

2. A 45 kg rock experiences a force of gravity of 168 N on the surface of Mars. What is the gravitational field strength on the surface of Mars?

   A. 1.6 N/kg
   B. 2.6 N/kg
   C. 3.7 N/kg
   D. 9.8 N/kg

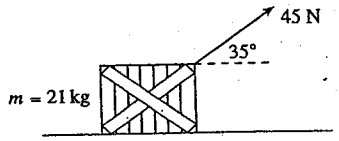
3. Two forces act at a single point as shown.



   What is the magnitude of the resulting force?

   A. 15 N
   B. 22 N
   C. 27 N
   D. 30 N

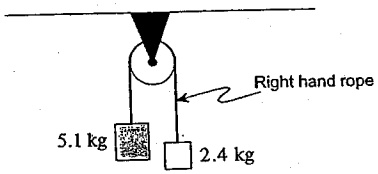
4. A force of 45 N is applied at an angle of 35° above the horizontal to pull a 21 kg crate across a floor as shown below.



   What is the normal force on the crate?

   A. 26 N
   B. 170 N
   C. 180 N
   D. 210 N

5. A frictionless pulley is set up with two hanging masses as shown below.



   What is the tension in the right hand rope while the masses move freely?

   A. 8.5 N
   B. 24 N
   C. 26 N
   D. 32 N

JANUARY 2002

VECTOR KINEMATICS AND DYNAMICS

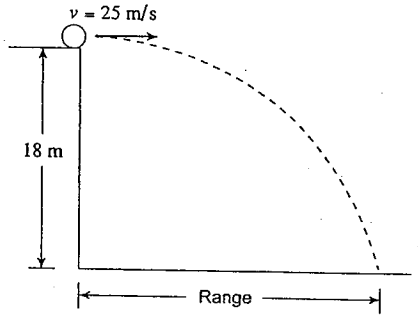
1. Which of the following contains only scalar quantities?

   A. mass, speed
   B. mass, velocity
   C. displacement, speed
   D. displacement, velocity

2. An airplane heads due north with an airspeed of 75 m/s. The wind is blowing due west at 18 m/s. What is the airplane's speed relative to the ground?

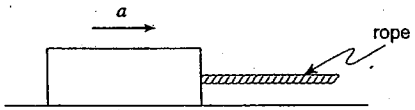
   A. 57 m/s
   B. 73 m/s
   C. 77 m/s
   D. 93 m/s

3. What is the range of the projectile launched horizontally at 25 m/s from the 18 m-high cliff edge as shown in the diagram below?



   A. 18 m
   B. 30 m
   C. 46 m
   D. 48 m

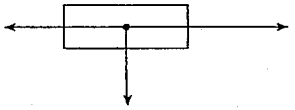
4. The block in the diagram below is being accelerated to the right across a rough surface by a force applied through the rope.



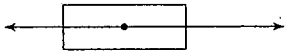
Which of the following best represents a free-body diagram for the block?

A.

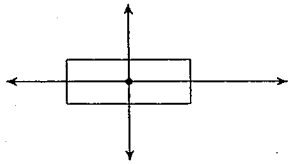
B.



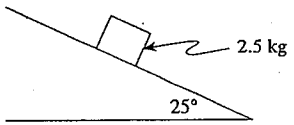
C.



D.



5. What is the normal force on the block in the diagram below?

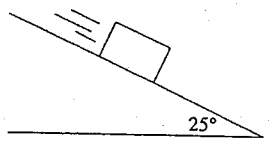


   A. 0.0 N
   B. 10 N
   C. 22 N
   D. 25 N

JUNE 2002

VECTOR KINEMATICS AND DYNAMICS

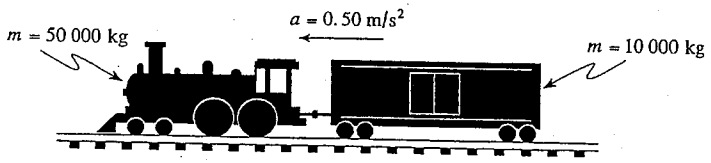
1. A 1.5 kg block slides down the incline at a constant speed.



What is the net force on this block?

A. 0 N
B. 6.2 N
C. 13 N
D. 15 N

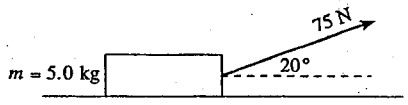
2. A locomotive pulling a freight car accelerates at 0.50 m/s^2 as shown in the diagram.



What is the tension in the coupling linking the locomotive and car? (Ignore friction.)

A. 5 000 N
B. 25 000 N
C. 30 000 N
D. 390 000 N

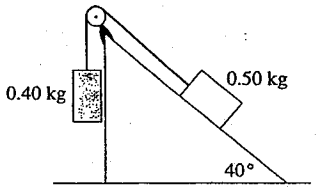
3. A 5.0 kg block is being pulled to the right by a 75 N force.



What is the normal force on this block?

A. 23 N
B. 26 N
C. 49 N
D. 75 N

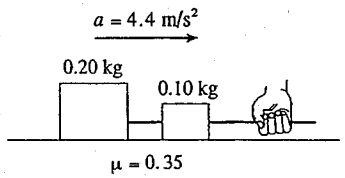
4. Two masses are connected by a string as shown in the diagram.



What is the magnitude of the acceleration of these masses? (Ignore friction.)

A. 0.11 m/s^2
B. 0.19 m/s^2
C. 0.86 m/s^2
D. 1.1 m/s^2

5. The system of blocks shown in the diagram below is being accelerated to the right at 4.4 m/s^2.

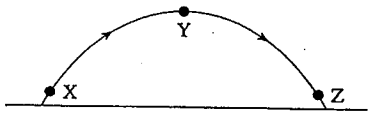


What pulling force is applied by the hand?

A. 0.3 N
B. 1.0 N
C. 1.3 N
D. 2.3 N

AUGUST 2002
VECTOR KINEMATICS AND DYNAMICS

1. Consider three points in the path of a certain projectile as shown in the diagram below.



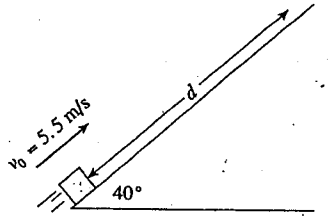
What is the acceleration of the projectile at each of these points?

	ACCELERATION (m/s^2)		
	At X	At Y	At Z
A.	+9.8	0	−9.8
B.	+9.8	0	+9.8
C.	−9.8	0	−9.8
D.	−9.8	−9.8	−9.8

2. A projectile is launched over level ground with an initial velocity of 65 m/s at 30° above the horizontal. What is the projectile's time of flight?

A. 3.6 s
B. 6.6 s
C. 11 s
D. 13 s

3. A block is launched up the frictionless incline in the diagram below with an initial speed of 5.5 m/s.



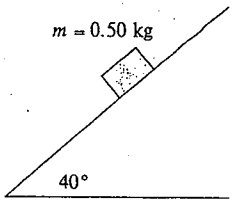
What is the maximum displacement, *d*, of the block up the incline?

A. 0.44 m
B. 0.87 m
C. 1.5 m
D. 2.4 m

4. Which of the following are units for gravitational field strength?

A. kg/m
B. $kg \cdot m/s^2$
C. N/kg
D. N/kg^2

5. The block shown in the diagram below remains at rest.



What is the friction force acting on the block?

A. 0 N
B. 3.1 N
C. 3.8 N
D. The friction force cannot be calculated.

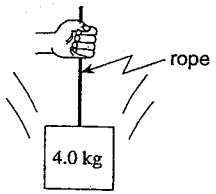
JANUARY 2003

VECTOR KINEMATICS AND DYNAMICS

1. Inertia is directly related to which of the following quantities?

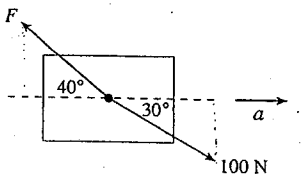
   A. mass
   B. charge
   C. velocity
   D. position

2. The 4.0 kg block shown below is accelerating downwards at 3.0 m/s^2 near the earth's surface. What is the tension in the rope attached to it?



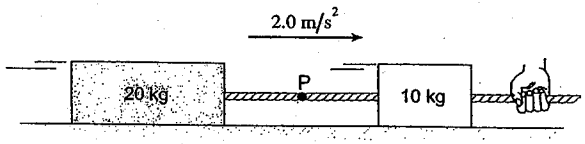
   A. 12 N
   B. 27 N
   C. 39 N
   D. 51 N

3. The mass shown below is accelerating to the right due to the two forces acting on it. What is the size of the force F ?



   A. 32 N
   B. 50 N
   C. 65 N
   D. 78 N

4. The system of masses shown below is accelerating to the right at 2.0 m/s^2. If the tension in the rope at point P is 70 N, what is the coefficient of friction between the masses and the surface?



   A. 0.15
   B. 0.20
   C. 0.43
   D. 0.57

5. A 6.0 kg penguin in a zoo exhibit starts from rest and slides 5.0 m along a very slippery rock slope (ignore friction) into the water in 1.4 s. What angle does the rock slope make with the horizontal?

   A. 21°
   B. 28°
   C. 31°
   D. 59°

JUNE 2003
VECTOR KINEMATICS AND DYNAMICS

1. Which of the following is constant for all projectiles?

   A. vertical velocity
   B. horizontal velocity
   C. vertical displacement
   D. horizontal displacement

2. A projectile is launched at 30 m/s over level ground at an angle of 37° to the horizontal. What maximum height does this projectile reach?

   A. 3.1 m
   B. 17 m
   C. 29 m
   D. 46 m

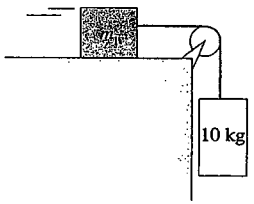
3. A few minutes after takeoff a jet is heading due east with an air speed of 300 km/h. If the wind is blowing at 60 km/h, towards 40° S of E, what is the jet's ground speed?

   A. 260 km/h
   B. 340 km/h
   C. 350 km/h
   D. 360 km/h

4. Which of the following statements is always correct about an object in motion?

   A. It has a tendency to accelerate.
   B. A net force must be acting on it.
   C. It has a tendency to keep moving.
   D. The net force acting on it must be zero.

5. If the tension in the line joining the two masses shown below is 12 N, what is the mass, m_1? (Ignore surface friction.)



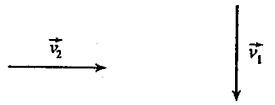
   A. 1.1 kg
   B. 1.4 kg
   C. 2.0 kg
   D. 10 kg

AUGUST 2003
VECTOR KINEMATICS AND DYNAMICS

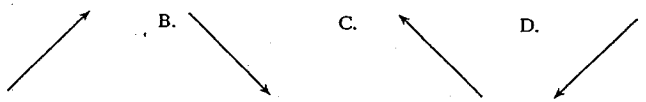
1. The velocity of a moving object as observed from another moving object is called its

   A. relative velocity.
   B. associated velocity.
   C. differential velocity.
   D. comparative velocity.

2. Consider the two vectors shown below.



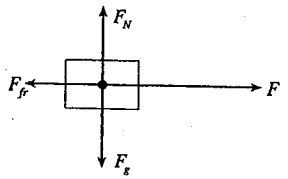
   Which of the choices given best represents $\vec{v}_2 - \vec{v}_1$?



3. A green ball rolls off of the end of a table at 2.5 m/s. The table top is 1.5 m above the floor. How much time passes before the ball hits the floor?

   A. 0.35 s
   B. 0.55 s
   C. 0.60 s
   D. 1.2 s

4. The free body diagram shown below is for a block being accelerated across a floor to the right by the force F. Which of the following represents the coefficient of friction for this situation?



   A. $\frac{F}{F_g}$
   B. $\frac{F_{fr}}{F}$
   C. $\frac{F_N}{F_g}$
   D. $\frac{F_{fr}}{F_N}$

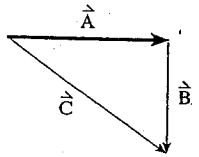
JANUARY 2004
VECTOR KINEMATICS AND DYNAMICS

1. Which of the following contains vector quantities only?

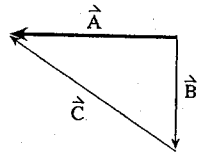
   A. mass, speed
   B. energy, velocity
   C. displacement, energy
   D. displacement, velocity

2. Which of the following vector diagrams shows $\vec{A}$ as the sum of $\vec{B}$ and $\vec{C}$ (i.e. $\vec{A} = \vec{B} + \vec{C}$)?

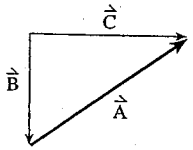
A.



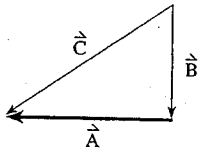
B.



C.



D.



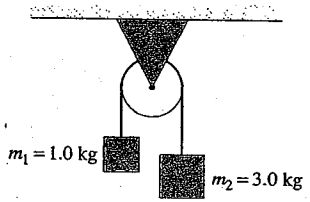
3. A projectile is launched with a velocity of 35 m/s at 55° above the horizontal. What is the maximum height reached by the projectile? Ignore friction.

   A. 5.3 m
   B. 42 m
   C. 54 m
   D. 63 m

4. If the net force on a falling object is zero, then the object has

   A. constant speed.
   B. constant altitude.
   C. no kinetic energy.
   D. no potential energy.

5. Two masses, one of 1.0 kg, the other of 3.0 kg, are suspended from the ends of a light string passing over a frictionless pulley.



   What is the magnitude of the acceleration of these masses?

   A. 2.5 m/s^2
   B. 4.9 m/s^2
   C. 7.4 m/s^2
   D. 9.8 m/s^2

6. A 2.0 kg mass is suspended by a spring scale from the ceiling of an elevator. If the spring scale reads 25 N, then the acceleration of the elevator is

   A. 2.7 m/s^2 upwards.
   B. 2.7 m/s^2 downwards.
   C. 13 m/s^2 upwards.
   D. 13 m/s^2 downwards.

JUNE 2004
VECTOR KINEMATICS AND DYNAMICS

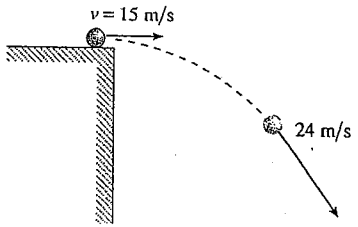
1. Which of the following is a scalar quantity?

   A. work
   B. force
   C. velocity
   D. momentum

2. An astronaut on the moon throws a 5.0 kg wrench vertically upwards with an initial speed of 15 m/s. The acceleration due to gravity on the surface of the moon is one-sixth that on the surface of the earth. What is the maximum height reached by the wrench?

   A. 25 m
   B. 46 m
   C. 69 m
   D. 75 m

3. A ball rolls off a horizontal roof at 15 m/s.



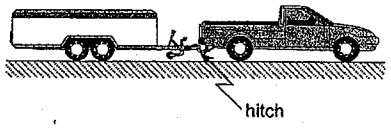
   How far will the ball have fallen vertically when it reaches a speed of 24 m/s?

   A. 4.1 m
   B. 18 m
   C. 29 m
   D. 37 m

4. The units N/kg are used for

   A. net force.
   B. gravitational force.
   C. electric field strength.
   D. gravitational field strength.

5. A 1200 kg trailer is accelerated from rest to 15 m/s in 5.0 s. The average force of friction acting on the trailer is 800 N.



   What is the pulling force applied to the trailer through the hitch?

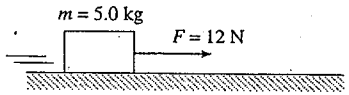
   A. 800 N
   B. 2800 N
   C. 3600 N
   D. 4400 N

AUGUST 2004
VECTOR KINEMATICS AND DYNAMICS

1. When an object is subjected to a constant positive net force it will experience a constant

   A. velocity.
   B. momentum.
   C. acceleration.
   D. displacement.

2. A 5.0 kg object is pulled at a constant speed by a horizontal 12 N force as shown in the diagram below.



   What is the coefficient of friction between the object and the surface?

   A. 0.24
   B. 0.42
   C. 1.0
   D. 2.4

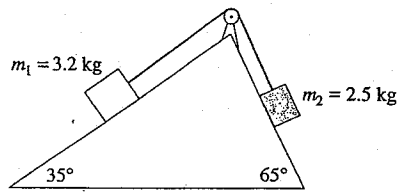
3. A falling 0.60 kg object experiences a frictional force due to air resistance of 1.5 N. What is the object's acceleration?

   A. 2.5 m/s^2
   B. 4.4 m/s^2
   C. 7.3 m/s^2
   D. 12 m/s^2

4. A 1200 kg vehicle is accelerated from rest to 15 m/s over a distance of 85 m. What is the net force on the car during this acceleration?

   A. 1 600 N
   B. 3 200 N
   C. 6 800 N
   D. 10 000 N

5. Two masses on frictionless surfaces are connected by a light string as shown.



   Determine the magnitude and direction of the acceleration of mass m_2.

	ACCELERATION (m/s^2)	DIRECTION OF m_2
A.	0.74	up incline
B.	0.74	down incline
C.	1.2	up incline
D.	1.2	down incline

WORK, ENERGY AND POWER AND MOMENTUM

Work, energy and power
One-dimensional momentum
Two-dimensional momentum

Outcomes	Questions
It is expected that students will demonstrate an ability to apply energy transformations and the concept of power to everyday situations.	
It is expected that students will:	
E1. define work	
E2. solve problems involving: • work • force • displacement	
E3. determine graphically the amount of work done on objects by constant or linearly varying forces	1, 2
E4. define energy	3
E5. state the work-energy theorem	4
E6. differentiate between kinetic energy and gravitational potential energy and give examples of each	
E7. solve problems involving: • kinetic energy • mass • gravitational potential energy • height • velocity	
E8. state the law of conservation of energy and apply it to real-life situations	5, 6
E9. define power	
E10. solve problems involving: • power • work • time • efficiency	7, 8, 9, 10
F1. define momentum and impulse	12
F2. state that momentum and impulse are vector quantities	
F3. identify and compare momenta of common objects	
F4. solve problems involving: • net force • time • impulse • velocity • mass • momentum	11, 13, 14
F5. state the law of conservation of momentum	
F6. determine whether a collision is elastic or inelastic	
F7. solve problems related to collisions or explosions involving: • mass • initial velocity • final velocity • momentum	
G1. analyse conservation of momentum in two dimensions	
G2. give examples of common situations involving momentum and impulse	
G3. solve problems for two objects involved in an oblique collision or for a stationary object exploding into no more than three fragments, involving: • mass • momentum • velocity • impulse	15

Work, Energy, Power, and Momentum

Work, Energy, and Power

E1 Define work

E2 Solve problems involving:

- *work*
- *force*
- *displacement*

E3 Determine graphically the amount of work done on objects by constant or linearly varying forces

E4 Define energy

E5 State the work-energy theorem

E6 Differentiate between kinetic energy and gravitational potential energy and give examples of each

E7 Solve problems involving:

- *kinetic energy*
- *mass*
- *gravitational potential energy*
- *height*
- *velocity*

E8 State the law of conservation of energy and apply it to real-life situations

E9 Define power

E10 Solve problems involving:

- *power*
- *work*
- *time*
- *efficiency*

Scalar quantities are quantities which have magnitude (size) but no direction. Energy and mass do not have direction, only size. Energy can be positive, meaning a system has gained energy, or negative, meaning it has lost energy. The actual energy of a system is neither negative nor positive, only the change in energy may have either negative or positive values.

Not only are mass and energy both conserved quantities, but they can be converted from one to the other and back again. The amount of energy created when an amount of mass is converted can be determined using Einstein's famous equation

$E = mc^2$. This equation can also be used to determine how much mass can be created from a certain amount of energy.

E = energy in joules

m = mass being converted in kg

c = the speed of light in a vacuum: 3.00×10^8 m/s

The mechanical energy of a system of objects is the sum of all the potential energy (due to gravity or a compressed spring) and all the kinetic energy of the objects in the system.

Example: A 2000 kg plane is flying at 500 m above the ground at a velocity of 30 m/s. What is the plane's total mechanical energy?

$E_{mechanical} = E_{potential} + E_{kinetic}$

$= mgh + \frac{1}{2}mv^2$

$= (2000\text{ kg})\times 9.8\text{ m/s}^2 \times 500\text{ m})$

$+(\frac{1}{2}\times 2000\text{ kg}\times(30\text{ m/s})^2)$

$= 9.8\text{ MJ} + 0.90\text{ MJ}$

$E_{mechanical} = 10.7\text{ MJ}$

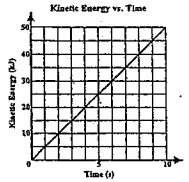
The first law of thermodynamics states that energy cannot be created or destroyed, simply transformed from one state to another. This can be tested using algebraic or graphical analysis of mechanical systems.

Algebraic analysis is based on mathematical relationships that exist between mass, time, distance, velocity, force, and energy such that

$\Sigma E_{initial} = \Sigma E_{final}$

Graphical analysis is most often used during experimentation to determine mathematical relationships.

Example: What is the significance of the slope of the graph below?



The graph shows kinetic energy with respect to time. The slope, m, of the graph is

$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{E_{K2} - E_{k1}}{t_2 - t_1}$

$m = \frac{\Delta E}{\Delta t}$

Since $W = \Delta E$, then the slope is the power of the system described.

Conservation of energy calculations consider friction, force and work as well as velocity and acceleration, in accordance with Newton's three laws of motion, such that

$\Sigma E_{initial} + W = \Sigma E_{final}$

where W is the work done on the system.

Momentum (One-Dimensional Momentum)

F1 Define momentum and impulse

Momentum is a quantity measured by an object's mass and velocity. $p = mv$

Momentum is the measure of an object's tendency to stay in motion. A fast-moving object will have more momentum than a slow-moving object of the same mass.

Impulse is the change in momentum over time. The total change in momentum is equal to the impulse.

$\Delta p = F\Delta t$

F2 State that momentum and impulse are vector quantities

Since momentum is the product of mass and velocity and only velocity is a vector, momentum must also be a vector. Since impulse is a measure of the change in momentum, impulse is a vector quantity also.

F3 Identify and compare momenta of common objects

Example: Find the momentum of a 680kg car, travelling at 120km/h.

First we must convert to m/s.

$(120km/h)(\frac{1h}{3600s})(\frac{1000m}{1km}) = 33.33\text{m/s}$

$p = mv$

$= (680\text{kg})(33.33\text{m/s})$

$= 22\,666.67\text{kg·m/s}$

$= 2.27\times10^4\text{ kg·m/s}$

Example: If the same car in the above example were travelling at 100km/h, how would the momenta compare?

100km/h = 27.78m/s

$p = mv$

$= (680\text{kg})(27.78\text{m/s})$

$= 18\,890.4\text{ kg·m/s}$

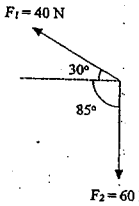
$= 1.89\times10^4\text{ kg·m/s}$

The difference in momentum is 3 809kg·m/s.

F4 Solve problems involving:

- *net force*

Example: Two forces are acting on a particle of negligible mass. What is the net force?

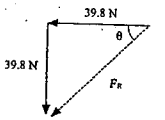


	F_1	F_2
Horizontal	$F_{x1} = 40\cos30°$	$F_{x2} = 60\cos85°$
	$= 34.6$ N	$= 5.2$ N
Vertical	$F_{y1} = 40\sin30°$	$F_{y2} = 60\sin85°$
	$= 20$ N	$= 59.8$ N

Net Force:

Horizontal $F_{x1} + F_{x2} = 34.6 + 5.2 = 39.8\text{N}$

Vertical $F_{y1} + F_{y2} = 20 - 59.8 = -39.8\text{N}$



$F_R = \sqrt{39.8^2 + 39.8^2} = 56.3\text{N}$ $\theta = 45°$

- *time*

Example: A 200g bullet is shot with an initial velocity of 630m/s from a gun with a barrel length of 80cm.

i. How long does the bullet take to travel the length of the barrel?

$v_{avg} = \frac{v_i + v_f}{2} = \frac{0 + 630m/s}{2} = 315\text{m/s}$

$t = \frac{d}{v} = \frac{0.8m}{315m/s} = 2.54\times10^{-3}s$

- *momentum*

ii. What is the momentum of the bullet as it leaves the barrel?

$p = mv = (0.200\text{kg})(630\text{m/s}) = 126\text{kg·m/s}$

- *impulse*

iii. What is the impulse given to the bullet while it is in the barrel?

Δp = *impulse*

$m_f v_f - m_i v_i$ = impulse

$= (0.200\text{kg})(630\text{m/s}) - (0.200\text{kg})(0) = 126\text{kg·m/s}$

• *velocity*

Example: The momentum of a 1100kg car is 27 000kg•m/s. What is its velocity?

$p = mv \qquad v = \frac{p}{m}$

$= \frac{27000\,\text{kg•m/s}}{1100\,\text{kg}}$

$= 24.5\,\text{m/s}$

• *mass*

Example: The momentum of a bullet leaving the barrel of a gun at 615m/s is 135kg•m/s. What is the weight of the bullet?

$p = mv \quad m = \frac{p}{v}$

$= \frac{135\,\text{kg•m/s}}{615\,\text{m/s}} = 0.2195\,\text{kg}$

$= 220\text{g}$

F5 State the law of conservation of momentum

When no outside forces are acting on a system of moving objects, the total momentum of the system remains constant.

F6 Determine whether a collision is elastic or inelastic

An elastic collision occurs when two objects collide and there is no permanent deformation of either object.

In contrast, an inelastic collision is one where there is permanent deformation or when the objects become tangled up with each other.

F7 Solve problems related to collisions or explosions involving:

• *mass*

A ball of mass 2.0kg travelling to the right at a velocity of 6.0m/s impacts a heavier ball that is at rest. The heavier ball moves to the right at a velocity of 1.5m/s and the lighter ball recoils at 2.0m/s. What is the mass of the heavier ball.

Initial Final

$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$

$(2.0\,\text{kg})(6.0\,\text{m/s}) + (m_2)(0\,\text{m/s})$

$= (2.0\,\text{kg})(-2.0\,\text{m/s}) + (m_2)(1.5\,\text{m/s})$

$12\text{kg•m/s} = -4\text{kg•m/s} + 1.5m_2\text{m/s}$

$16\text{kg•m/s} = 1.5\text{m/s•}m_2$

$m_2 = 10.7\,\text{kg}$

• *initial velocity*

Two particles travelling in opposite directions collide head on in an elastic collision. Find the initial velocity of particle 1 given that:

$m_1 = 1.01\mu \qquad m_2 = 4.00\mu$ (μ= Atomic mass units)

$v_1 = ? \qquad v_2 = 3.8\times10^4\,\text{m/s}$

$m_1' = 1.01\mu \qquad m_2' = 4.00\mu$

$v_1' = 1.6\times10^4\,\text{m/s} \quad v_2' = 3.0\times10^4\,\text{m/s}$

$m_1v_1 + m_2v_2 = m_1'v_1' + m_2'v_2'$

$(1.01)v_1 + (4)(3.8\times10^4\text{m/s})$

$= (1.01)(1.6\times10^4\text{m/s}) + (4)(3.0\times10^4\text{m/s})$

$1.01v_1 + 1.52\times10^5 = 1.616\times10^4 + 12.0\times10^4$

$1.01v_1 + 1.52\times10^5 = 1.36160\times10^5$

$1.01v_1 = -1.584\times10^4$

$v_1 = -1.5683\times10^4$

$= -1.57\times10^4\,\text{m/s}$

• *final velocity*

A cue ball in a game of pool hits the 8-ball directly in a completely elastic collision. What is the final velocity of the cue ball given:

Cue ball (m_1) = 0.200kg	8-ball(m_2) = 0.200kg
$v_1 = 2\text{m/s}$	$v_2 = 0\text{m/s}$
$m_1' = 0.200kg$	$m_2' = 0.200kg$
$v_1' = 0.2m/s$	$v_2' = ?$

$m_1v_1 + m_2v_2 = m_1'v_1' + m_2'v_2'$

$(\cancel{0.200\text{kg}})(2\text{m/s}) + (\cancel{0.200\text{kg}})(0\text{m/s})$

$= (\cancel{0.200\text{kg}})(0.2\text{m/s}) + (\cancel{0.200\text{kg}})(v_2')$

$(2\text{m/s}) = (0.2\text{m/s}) + (v_2')$

$1.8\text{m/s} = (v_2')$

• *momentum*

A block of unknown size at rest is hit by another block (m_1 = 2.0kg and v_1 = 3.0m/s) in a completely elastic collision. What momentum is imparted to the unknown block if v_1' = 0.5m/s?

$m_1v_1 + m_2v_2 = m_1'v_1' + m_2'v_2'$

$(2.0\text{kg})(3.0\text{m/s}) + 0 = (2.0\text{kg})(0.5\text{m/s}) + m'_1v'_1$

$6 = 1 + m'_1v'_1$

$5\text{kg•m/s} = m'_1v'_1$

G1 Analyse conservation of momentum in two dimensions

G2 Give examples of common situations involving momentum and impulse

G3 Solve problems for two objects involved in an oblique collision or for a stationary object exploding into no more than three fragments; involving:

- *mass*
- *momentum*
- *velocity*
- *impulse*

If we consider a stone ricocheting off a wall, we see that the stone's momentum is in fact a vector. The angle and speed at which the stone strikes the wall determine the angle and speed at which it leaves the wall. The magnitude of an object's momentum is determined by multiplying together its mass and velocity. Momentum has the same direction as the object's velocity.

$p = mv$, where p is the object's momentum (measured in kg • m/s or $N \cdot s$), m is its mass and v is its velocity.

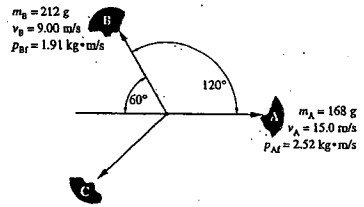
Example: What is the momentum of a 1500 kg mass traveling at 20 m/s to the West?

$p = mv$

$p = (1550\text{kg})(20\text{m/s})$

$p = 3.0\times10^4\,\text{kg•m/s}$ west.

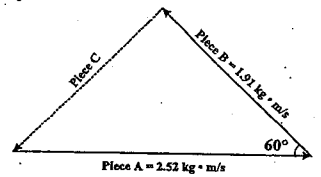
A glass ornament of mass 575 g sitting on a table is subjected to a resonant frequency of 440 Hz. The ornament breaks into three pieces that travel horizontally across the frictionless tabletop. Fragment A has a mass of 168 g and fragment B has a mass of 212 g. What is the magnitude of the momentum of the third piece of glass fragment C?



Since the ornament was stationary before it broke, its momentum was zero.

The momenta of three pieces after the break must add to zero also.

$\vec{p} = m\vec{v}$



Using the cosine law:

momentum of piece C = $\sqrt{A^2 + B^2 - 2AB\cos 60°}$

$= \sqrt{(2.52)^2 + (1.91)^2 - 2(2.52)(1.91)\cos 60°}$

$= 2.28\text{kg•m/s}$

Or, using vector components:

$[p_x = p\cos\theta,\ p_y = p\sin\theta]$

$p_{Af} = [2.52\text{kg•m/s}, 0]$

$p_{Bf} = [-0.955\text{kg•m/s}, 1.65\text{kg•m/s}]$

$p_{Cf} = [1.57\text{kg•m/s}, 1.65\text{kg•m/s}]$

momentum of piece C = $\sqrt{1.57^2 + 1.65^2}$

$= 2.28\ \text{kg•m/s}$

Momentum in a system is conserved as a vector quantity during any interactions between two or more objects.

JANUARY 2000

WORK, ENERGY, POWER AND MOMENTUM

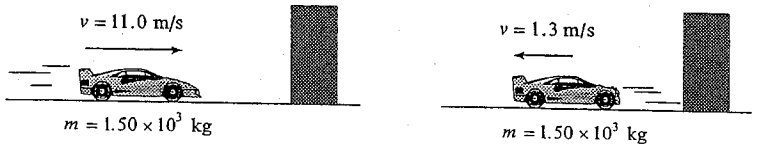
5. What is the minimum work done when a 65 kg student climbs an 8.0 m-high stairway in 12 s?

   A. 420 J
   B. 520 J
   C. 5 100 J
   D. 6 200 J

6. Which of the following is equal to impulse?

   A. Energy
   B. Momentum
   C. Change in energy
   D. Change in momentum

7. A 1.50×10^3 kg car travelling at 11.0 m/s collides with a wall as shown.



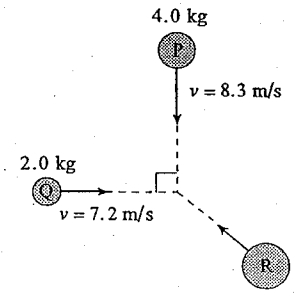
The car rebounds off the wall with a speed of 1.3 m/s. If the collision lasts for 1.7 s, what force does the wall apply to the car during the collision?

   A. 8.6×10^3 N
   B. 1.1×10^4 N
   C. 1.5×10^4 N
   D. 1.8×10^4 N

8. A 1 500 kg car travelling at 25 m/s collides with a 2 500 kg van stopped at a traffic light. As a result of the collision the two vehicles become entangled. With what initial speed will the entangled mass move off, and is the collision elastic or inelastic?

	Speed	Type of Collision
A.	9.4 m/s	Elastic
B.	9.4 m/s	Inelastic
C.	15 m/s	Elastic
D.	15 m/s	Inelastic

9. Three objects travel as shown.



What is the magnitude of the momentum of object R so that the combined masses remain stationary after they collide?

   A. 19 kg·m/s
   B. 30 kg·m/s
   C. 36 kg·m/s
   D. 48 kg·m/s

JUNE 2000
WORK, ENERGY, POWER AND MOMENTUM

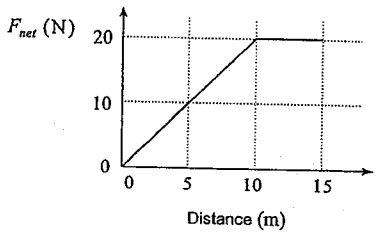
6. A change in kinetic energy is equivalent to

A. work.
B. power.
C. impulse.
D. momentum.

7. A 16 kg object is dropped from a height of 25 m and strikes the ground with a speed of 18 m/s. How much heat energy was produced during the fall?

A. 0 J
B. 1 300 J
C. 2 600 J
D. 3 900 J

8. A force is applied to an 8.0 kg object initially at rest. The magnitude of the net force varies with distance as shown.



What is the speed of the object after moving 15 m?

A. 5.0 m/s
B. 6.1 m/s
C. 7.1 m/s
D. 8.7 m/s

9. A machine rated at 1 500 W lifts a 100 kg object 36 m vertically in 45 s. What is the efficiency of this machine?

A. 0.053
B. 0.48
C. 0.52
D. 0.65

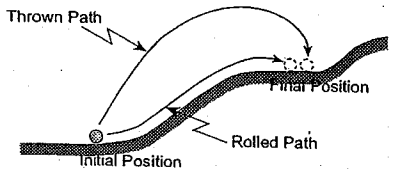
10. Two cars collide head-on and come to a complete stop immediately after the collision. Which of the following is correct?

	TOTAL MOMENTUM	TOTAL ENERGY
A.	is conserved	is conserved
B.	is conserved	is not conserved
C.	is not conserved	is conserved
D.	is not conserved	is not conserved

AUGUST 2000

WORK, ENERGY, POWER AND MOMENTUM

6. A child rolls a ball up a hill as shown. The same child then throws an identical ball up the hill.



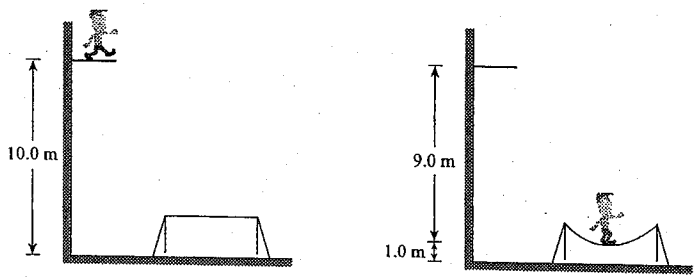
When both balls end up in the same location on the hill, which of the following correctly describes the potential energy change for each ball?

A. Both balls have the same potential energy change.
B. There is no potential energy change for either ball.
C. The thrown ball has a greater potential energy change than the rolled ball.
D. The thrown ball has a smaller potential energy change than the rolled ball.

7. A 950 kg elevator ascends a vertical height of 410 m with an average speed of 9.1 m/s. What average power must the lifting motor supply?

A. 8.6×10^3 W
B. 8.5×10^4 W
C. 4.2×10^5 W
D. 3.8×10^6 W

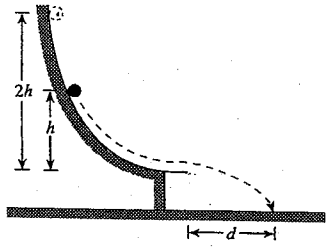
8. A 55.0 kg athlete steps off a 10.0 m high platform and drops onto a trampoline. As the trampoline stretches, it brings him to a stop 1.00 m above the ground.



How much energy must have been momentarily stored in the trampoline when he came to rest?

A. 0 J
B. 539 J
C. 4 850 J
D. 5 390 J

9. An object starts from rest and slides down a frictionless track as shown. It leaves the track horizontally, striking the ground at a distance d as shown.



The same object is now released from twice the height, $2h$. How far away will it land?

A. d
B. $\sqrt{2}\,d$
C. $2d$
D. $4d$

JANUARY 2001

WORK, ENERGY, POWER AND MOMENTUM

7. A crane lifts a 3 900 kg shipping container through a vertical height of 45 m in 8.0 s. What is the minimum average power that the crane motor must supply?

   A. 2.7×10^3 W
   B. 7.7×10^3 W
   C. 2.1×10^5 W
   D. 1.7×10^6 W

8. Identify momentum and kinetic energy as scalar or vector quantities.

	MOMENTUM	KINETIC ENERGY
A.	scalar	scalar
B.	scalar	vector
C.	vector	scalar
D.	vector	vector

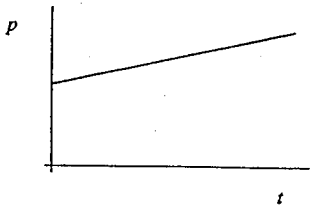
9. A 1.0 kg cart moves to the right at 6.0 m/s and strikes a stationary 2.0 kg cart. After the head-on collision, the 1.0 kg cart moves back to the left at 2.0 m/s and the 2.0 kg cart moves to the right at 4.0 m/s. In this collision

   A. only momentum is conserved.
   B. only kinetic energy is conserved.
   C. both momentum and kinetic energy are conserved.
   D. neither momentum nor kinetic energy is conserved.

10. A 12.0 kg shopping cart rolls due south at 1.50 m/s. After striking the bumper of a car, it travels at 0.80 m/s, 30° E of S. What is the magnitude of the change in momentum sustained by the shopping cart?

    A. 8.4 kg·m/s
    B. 9.7 kg·m/s
    C. 11 kg·m/s
    D. 27 kg·m/s

11. The graph below shows momentum, p, versus time, t, for a spacecraft while it is firing its rocket engines in space.



What does the slope of this graph represent?

   A. the mass of the spacecraft
   B. the velocity of the spacecraft
   C. the net force on the spacecraft
   D. the work done on the spacecraft

JUNE 2001
WORK, ENERGY, POWER AND MOMENTUM

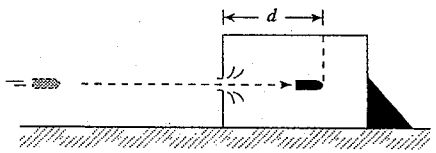
6. In order to use the joule as a unit of energy in an experiment, measurements must be converted to

   A. cm, g and s
   B. m, kg and s
   C. cm, N and s
   D. m, g and min

7. Which of the following best represents the work done by an adult in ascending a typical flight of stairs in a home?

   A. 10^0 J
   B. 10^1 J
   C. 10^2 J
   D. 10^3 J

8. A 0.055 kg bullet was fired at 250 m/s into a block of wood as shown in the diagram below.



   Assuming an average force of 9 500 N brings the bullet to rest in the wood, what distance d did the bullet penetrate the block?

   A. 1.4×10^{-3} m
   B. 1.4×10^{-2} m
   C. 1.8×10^{-1} m
   D. 3.6×10^{-1} m

9. An electric winch operates from a 120 V source at 3.5 A. The winch lifts a 360 kg object 2.5 m vertically in 45 s. What is the efficiency of the winch?

   A. 4.8%
   B. 17%
   C. 19%
   D. 47%

10. A 0.40 kg ball rolls at 8.5 m/s towards a player. The player kicks the ball so that it then travels at 15.2 m/s in the opposite direction. What is the magnitude of the impulse that the ball sustained?

    A. 1.3 N·s
    B. 2.7 N·s
    C. 4.7 N·s
    D. 9.5 N·s

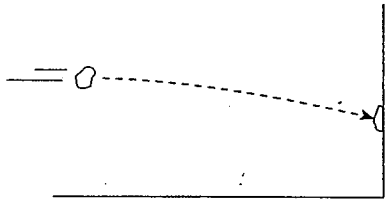
AUGUST 2001

WORK, ENERGY, POWER AND MOMENTUM

6. Which of the following best represents efficiency?

   A. Final time compared to initial time
   B. Work output compared to work input
   C. Final velocity compared to initial velocity
   D. Momentum after compared to momentum before

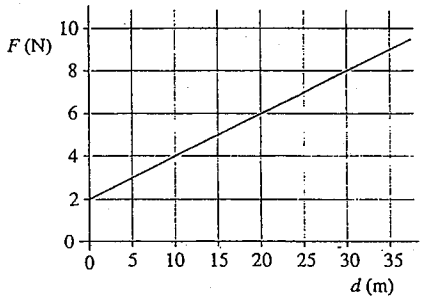
7. A wad of putty is thrown against a wall as shown. The wad of putty sticks against the wall.



Which of the following statements best applies the application of the law of conservation of energy to this collision?

   A. All energy has been lost.
   B. Kinetic energy is converted to heat.
   C. Kinetic energy is converted to momentum.
   D. Kinetic energy is converted to potential energy.

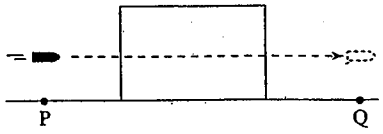
8. The graph below shows how the force applied to an object varies with distance.



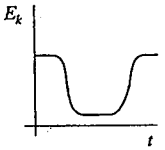
What is the work done to move the object from 10 m to 30 m?

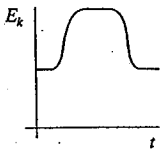
   A. 40 J
   B. 80 J
   C. 120 J
   D. 240 J

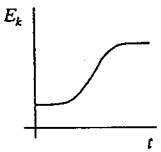
9. A projectile is fired through a fixed block of wood. The diagram shows the projectile above point P just before it enters the block and again above point Q just after leaving the block.

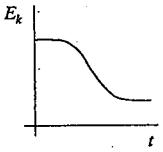


Which of the graphs best illustrates how the kinetic energy of the projectile varies over the time it takes to travel from P to Q?

A. 

B. 

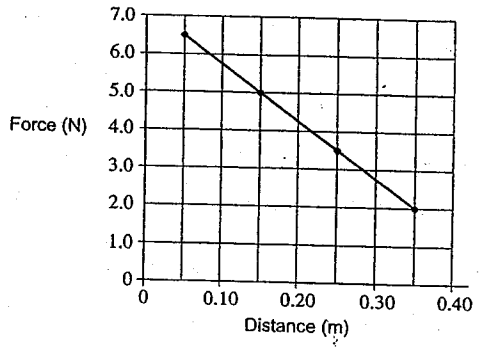
C. 

D. 

JANUARY 2002

WORK, ENERGY, POWER AND MOMENTUM

6. A student records the force used to move a block. The graph of his force and distance data is shown below.



What is the work done in moving the block from 0.050 m to 0.35 m?

A. 0.68 J
B. 0.98 J
C. 1.3 J
D. 2.0 J

7. Which are correct units for change in momentum?

A. $N \cdot m$

B. $N \cdot s$

C. $kg \cdot \frac{s}{m}$

D. $kg \cdot \frac{m}{s^2}$

8. A 2.3 kg object moving due north at 17 m/s made contact with a barrier for 0.75 s, resulting in a final velocity of 12 m/s due east. What was the impulse on the object?

	MAGNITUDE OF IMPULSE	DIRECTION OF IMPULSE
A.	12 N·s	35° E of N
B.	12 N·s	35° E of S
C.	48 N·s	35° E of N
D.	48 N·s	35° E of S

JUNE 2002

WORK, ENERGY, POWER AND MOMENTUM

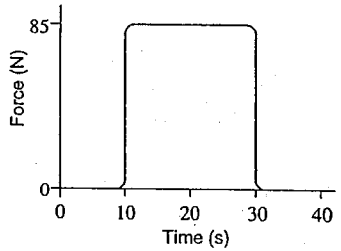
6. A 15 kg cement-filled bucket is raised to a vertical height of 5.0 m in 4.2 s by a motor drawing 373 W of power. What is the efficiency of this lifting system?

A. 4.8%
B. 47%
C. 51%
D. 84%

7. An object moving due east at 15 m/s collides with a wall. As a result, the object moves due west at 15 m/s. Which of the following best describes the collision?

A. elastic collision
B. inelastic collision
C. total momentum is increased
D. total momentum is decreased

8. A 5.0 kg model vehicle travelling at 14 m/s experiences a rocket boost of 85 N (in the direction of motion) for 20 s as shown on the graph.



What is the resulting speed?

A. 23 m/s
B. 30 m/s
C. 340 m/s
D. 350 m/s

9. A 4.0 kg object moving due east at 15 m/s collides with and sticks onto a 12 kg object moving due south at 5.0 m/s. What is the resulting speed of the combined objects?

A. 5.3 m/s
B. 10 m/s
C. 16 m/s
D. 20 m/s

AUGUST 2002
WORK, ENERGY, POWER AND MOMENTUM

6. Which of the following best represents the work-energy theorem?

A. $W = \Delta E$
B. $E_k = E_p$
C. $W = F_f \times d$
D. $E_p = P \times t$

7. A 1500 kg car moving at 8.0 m/s comes to a stop in 16 m when its brakes are applied. The speed of the car is now doubled to 16 m/s. Assuming the same braking force as before, how far will the car travel before coming to a stop?

A. 16 m
B. 32 m
C. 64 m
D. 130 m

8. The momentum of a male Olympic sprinter is about

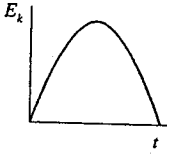
A. 10 kg · m/s
B. 100 kg · m/s
C. 1000 kg · m/s
D. 10 000 kg · m/s

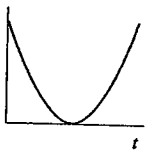
JANUARY 2003
WORK, ENERGY, POWER AND MOMENTUM

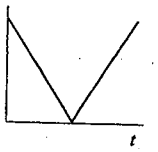
6. In which of the following would a person do the **least** amount of work?

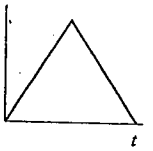
A. Lifting a 10 kg box a vertical height of 1.2 m.
B. Lifting a 10 kg box a vertical height of 1.2 m using a ramp.
C. Pushing a 10 kg box along a smooth floor a distance of 1.2 m.
D. Dragging a 10 kg box along a rough floor a distance of 1.2 m.

7. A rock is thrown straight up. Which of the following represents the kinetic energy versus time graph of the rock while it is in the air?

A. 

B. 

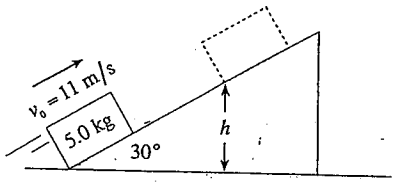
C. 

D. 

8. What minimum force applied over a distance of 35.0 m would be needed to accelerate a 925 kg car from rest to 13.9 m/s?

A. 367 N
B. 2550 N
C. 12 900 N
D. 89 400 N

9. A 5.0 kg block initially travelling at 11 m/s moves up a 30° incline as shown.



A frictional force of 9.4 N acts on the block as it moves up the incline. What maximum vertical height, h, will the block reach?

A. 4.5 m
B. 5.2 m
C. 6.2 m
D. 6.7 m

JUNE 2003
WORK, ENERGY, POWER AND MOMENTUM

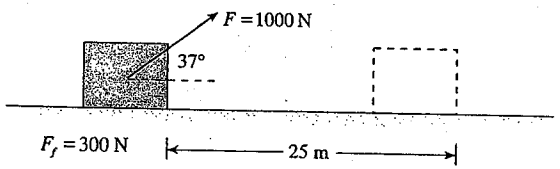
6. Power is

A. work done.
B. the change in energy.
C. the change in kinetic energy.
D. the rate of change in energy.

7. A motor using 1500 W takes 52 s to raise a 250 kg load vertically 24 m. What is the efficiency of this motor?

A. 7.7 %
B. 12 %
C. 25 %
D. 75 %

8. A 1000 N force is applied to a block as shown. There is 300 N of sliding friction as the block moves 25 m along the surface.



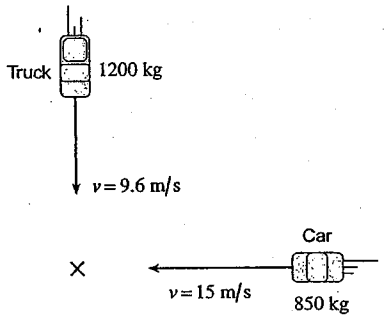
How much work was done by the applied force in moving this block?

A. 1.5×10^4 J
B. 1.8×10^4 J
C. 2.0×10^4 J
D. 2.7×10^4 J

9. What is the work done by the brakes of a 1500 kg car as they slow the car from 25 m/s to 15 m/s over a distance of 80 m ?

A. -2.6×10^4 J
B. -7.5×10^4 J
C. -3.0×10^5 J
D. -1.2×10^6 J

10. A 1200 kg truck travelling at 9.6 m/s due south runs into a 850 kg car travelling at 15 m/s due west. The two vehicles stick together after they collide.



With what speed does the combined mass move immediately after the collision?

A. 0.60 m/s
B. 2.7 m/s
C. 8.4 m/s
D. 12 m/s

AUGUST 2003
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5. A 6.0 kg object is projected directly upward with an initial speed of 15 m/s. This object experiences an average air resistance force of 24 N. What is the maximum height reached by this object?

A. 8.2 m
B. 11 m
C. 16 m
D. 19 m

6. Which of the following correctly identifies momentum and impulse as scalar or vector quantities?

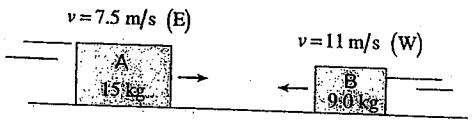
	MOMENTUM	IMPULSE
A.	scalar	scalar
B.	scalar	vector
C.	vector	scalar
D.	vector	vector

7. A 0.26 kg ball travelling due west at 22 m/s was hit by a bat and as a result the ball travelled due east at 18 m/s. If the bat remained in contact with the ball for 0.13 s, what average force did the bat exert on the ball?

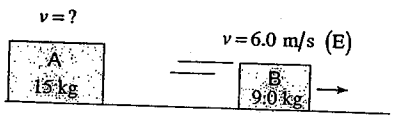
A. 8.0 N
B. 80 N
C. 116 N
D. 310 N

8. Block A of mass 15 kg is travelling at 7.5 m/s due east when it collides with block B of mass 9.0 kg travelling at 11 m/s due west. Block B bounces back at 6.0 m/s.

Before



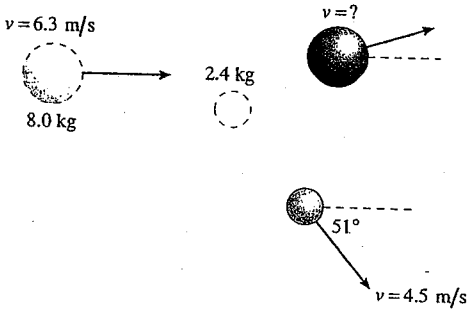
After



With what speed and in what direction will block A move?

	SPEED	DIRECTION
A.	2.7 m/s	East
B.	2.7 m/s	West
C.	4.5 m/s	East
D.	4.5 m/s	West

9. An 8.0 kg ball travelling at 6.3 m/s due east strikes a 2.4 kg ball initially at rest. The collision is oblique, causing the 2.4 kg ball to travel at 4.5 m/s at 51° south of east.



What speed will the 8.0 kg ball have after the collision?

A. 5.0 m/s
B. 5.6 m/s
C. 5.8 m/s
D. 7.7 m/s

JANUARY 2004
WORK, ENERGY, POWER AND MOMENTUM

7. A 10 kg block initially at rest is pulled 13 m across a floor by a 50 N force.

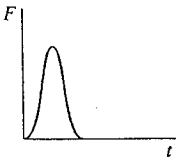
If friction does 380 J of work over this distance, what is the block's final velocity?

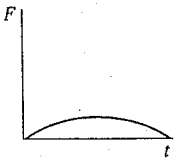
A. 7.3 m/s
B. 8.7 m/s
C. 11 m/s
D. 14 m/s

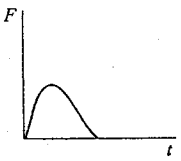
8. A small rubber ball moving at high speed strikes a stationary cart. As a result of the collision, the rubber ball rebounds and the cart rolls forward. Which object experienced the greater magnitude of impulse?

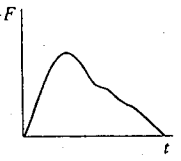
A. Cart
B. Rubber ball
C. Both experienced the same magnitude of impulse.
D. It depends on whether the collision was elastic or inelastic.

9. An object experiences a varying force as shown in the following *F*-*t* graphs. Which graph shows the largest change in momentum?

A. 

B. 

C. 

D. 

10. A 200 kg object moving at 15 m/s due east collides with a 100 kg block moving at 15 m/s due north. The objects stick together following the collision. What is the speed of the 200 kg object immediately after the collision?

A. 5.0 m/s
B. 11 m/s
C. 15 m/s
D. 21 m/s

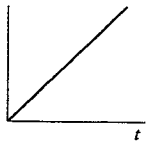
11. Outside the International Space Station, a 60 kg astronaut holding a 4.0 kg object (both initially at rest) throws the object at 10 m/s relative to the space station. A 50 kg astronaut, initially at rest, catches the object. What is the speed of separation of the two astronauts?

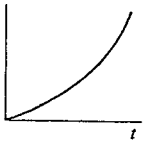
A. 0.67 m/s
B. 0.80 m/s
C. 1.4 m/s
D. 1.5 m/s

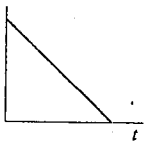
JUNE 2004

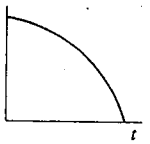
WORK, ENERGY, POWER AND MOMENTUM

7. Which of the following is a graph of E_k vs. time for a ball dropped off a roof? (Ignore air friction.)

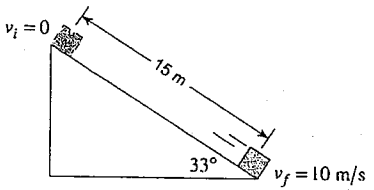
A. 

B. 

C. 

D. 

8. A 2.0 kg wood block slides down an incline from rest as shown below. Determine the force of friction on the block during the slide if its final velocity at the bottom is 10 m/s.



A. 4.0 N
B. 6.7 N
C. 11 N
D. 17 N

9. You are pushing a crate across a smooth wood floor with a constant pushing force. The crate is accelerating. Which of the following describes your power output?

A. increasing
B. decreasing
C. increasing then constant
D. decreasing then constant

10. A 25 kg object is moving due north at 33 m/s. If an impulse of 330 N·s is applied at 45° N of W to this object, what is the final velocity of this object?

	SPEED	DIRECTION
A.	33 m/s	45° N of W
B.	33 m/s	78° N of W
C.	43 m/s	45° N of W
D.	43 m/s	78° N of W

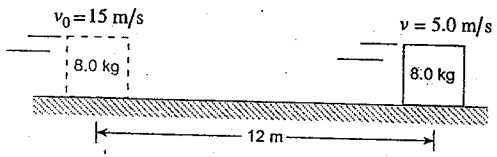
AUGUST 2004

WORK, ENERGY, POWER AND MOMENTUM

6. You drop an orange ball near the surface of the moon. Which of the following is true for the ball as it falls? (The moon has no atmosphere.)

   A. $E_p = constant$
   B. $E_k = constant$
   C. $E_p + E_k = constant$
   D. $E_p - E_k = constant$

7. An 8.0 kg wood block is sliding along on a concrete floor at 15 m/s as shown below.



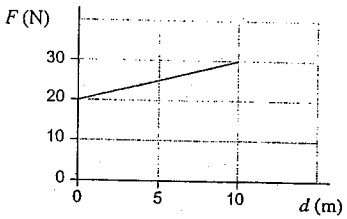
   After 12 m its speed has been reduced to 5.0 m/s by friction. How much work was done by friction over the 12 m distance?

   A. 100 J
   B. 800 J
   C. 900 J
   D. 1000 J

8. An electric motor outputs 1500 W of power in pulling a 70 kg crate of fish up a very slippery loading ramp at a constant speed. The ramp is inclined 31° to the horizontal. Determine the speed of the crate. (Ignore friction.)

   A. 1.9 m/s
   B. 2.1 m/s
   C. 2.6 m/s
   D. 4.2 m/s

9. The graph below shows the force exerted by a rope in lifting a 2.0 kg mass a vertical distance of 10 m from the ground.



   What is the final speed of the box at 10 m?

   A. 7.3 m/s
   B. 10 m/s
   C. 16 m/s
   D. 21 m/s

EQUILIBRIUM

Equilibrium

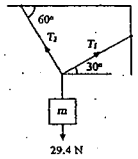
Equilibrium

H1 Define translational equilibrium

H2 Use free-body diagrams and vector analyses to determine the sum of the forces acting at a single point on an object

H3 Solve problems for common objects in translational equilibrium

An object of mass m is suspended from a ceiling and the wall. What is the tension in each rope?



$\Sigma F_x = -T_2 \sin 30° + T_1 \cos 30° = 0$

$\Sigma F_y = T_2 \cos 30° + T_1 \sin 30° - 294\text{N} = 0$

$\Rightarrow T_2 \sin 30° = T_1 \cos 30°$

$T_1 = T_2 \tan 30°$

$\Rightarrow T_2 \cos 30° + T_2 \tan 30° = 294$

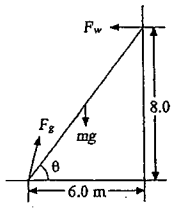
$T_2 = (\frac{1}{\cos 30° + \tan 30°})294$

$T_2 = 203.69\text{N}$

$\Rightarrow T_1 = (203.69\text{N})(\tan 30°)$

$= 117.67\text{N}$

A 10.0m ladder leans against a wall 8.0m above the ground. The ladder is uniform and has a mass of 12.0kg. Find the forces acting on the ladder by the ground and the wall. (Assume the wall is frictionless but the ground is not.)



$mg = (12.0)(9.8\text{m/s}^2)$
$= 117.6\text{N}$

$\theta = \sin^{-1}(\frac{8}{10}) = 53.1°$

$\tan 53.1° = \frac{8}{x}$

$x = 6.0\text{m}$

$\Sigma F_x = 0: \quad F_{gx} - F_w = 0$

$\Sigma F_y = 0: \quad F_{gy} - mg = 0$

$F_{gy} = (12.0\text{kg})(9.8\text{m/s}^2) = 117.6\text{N}$

$F_w(8.0\text{m}) - mg(3.0\text{m}) = 0$

$F_w(8.0\text{m}) - 117.6(3.0\text{m}) = 0$

$F_w(8.0\text{m}) = 352.8\text{N•m}$

$F_w = 44.1\text{N}$

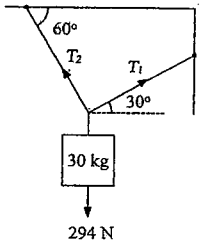
$\Rightarrow F_{gx} = 44.1\text{N}$

$F_{gy} - 117.6\text{N}$

$F_g = \sqrt{44.1^2 + 117.6^2}$

$= 1.26 \times 10^3\text{N}$

An object of mass 30 kg is suspended from a ceiling and the wall. What is the tension in each rope?



$m = 30\text{ kg}$

$F_g = (30\text{ kg})(9.8\text{ m/s}^2) = 294\text{ N}$

$\Sigma F_x = T_1 \cos 30° - T_2 \sin 30° = 0$

Therefore, $T_2 \sin 30° = T_1 \cos 30°$

$T_1 = \frac{T_2 \sin 30°}{\cos 30°}$

$T_1 = T_2 \tan 30°$

$\Sigma F_y = T_2 \cos 30° + T_1 \sin 30° - 294\text{N} = 0$

Therefore, substituting for T_1,
$T_2 \cos 30° + T_2 \tan 30° \sin 30° = 294\text{ N}$

$T_2 = \frac{294}{\cos 30° + \tan 30° \sin 30°}$

$T_2 = 254.61\text{ N}$

Recall that $T_1 = T_2 \tan 30°$

$T_1 = (254.61\text{N})(\tan 30°)$

$T_1 = 147\text{ N}$

H4 Define torque and identify situations involving the application of torque

H5 Solve problems involving:

- *torque*
- *force*
- *lever arm*

H6 Define centre of gravity and determine its location for objects of uniform shape and density

H7 Define rotational equilibrium

H8 Determine the sum of the forces and the torques on an object

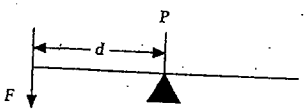
H9 Define static equilibrium

H10 Demonstrate that in static equilibrium, any location can be chosen as the pivot point

H11 Solve problems for common objects in static equilibrium

If the sum of all forces acting on an object is zero ($\Sigma \vec{F} = 0$), then an object experiences translational equilibrium. Newton's first law of motion states that such an object will maintain a constant velocity. If this object is initially at rest, we can also state that its centre of gravity will not move (an object at rest tends to remain at rest). However, an object may still rotate.

Consider the following:

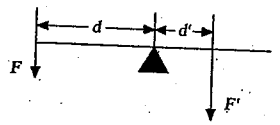


Fulcrum (Pivot)

In the diagram, a rod is resting on a pivot or fulcrum (P) placed at its centre of gravity. The centre of gravity for any uniform extended object like this rod will always be its midpoint. This point can be thought of as the place where all of the rod's weight seems to be concentrated. The force exerted on the rod in this diagram will tend to make the rod rotate. The degree to which this rod will rotate is dependent on both the force (F) and the distance (d) from the pivot point (sometimes called the lever arm). The rotational effect of this force (which in this case would produce a counter-clockwise rotation) is referred to as torque and is represented by the Greek letter τ (Tau). In equation form:

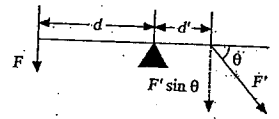
$\tau = Fd$ (the units for force are thus N · m)

To bring the rod in the diagram into rotational equilibrium, a clockwise torque is needed. This can be produced as follows:



Note that even though $F \neq F'$, the actual condition for equilibrium is that the two torques involved are equal in magnitude. In other words $Fd = F'd'$.

It should also be noted that if the force F' is not applied perpendicularly to the rod, then we must use the perpendicular component of F' to calculate the torque.



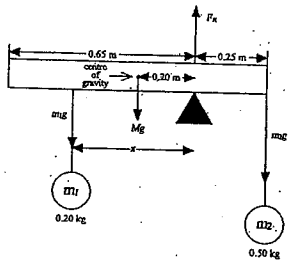
In this case, we need $Fd = (F' \sin\theta)d'$ to establish rotational equilibrium where angle θ is the angle between the force F' and the rod.
To establish rotational equilibrium, we need the following: Sum of clockwise torques = sum of counter-clockwise torques.

For an object to be in static equilibrium, both of the following conditions must be met:

1) $\Sigma \vec{F} = 0 \rightarrow$ translational equilibrium

2) $\Sigma \vec{\tau} = 0 \rightarrow$ rotational equilibrium

Example:



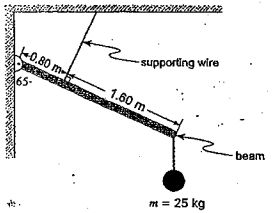
For translational equilibrium,

F_R = combined weights of the rod and the two balls.
Or, $F_R = m_1 g + Mg + m_2 g$

(F_R is the reaction force of the fulcrum on the rod)

Note that the weight of the rod can be thought of as concentrated at the centre of gravity. This condition is met automatically when the rod is resting on the fulcrum and not accelerating up or down.

The following situation is slightly more complex:



To find the parallel and perpendicular components of the wall's force on the beam ($F_{R\|}$ and $F_{R\perp}$), we would need to equate all the perpendicular components and all the parallel components of all the forces on the beam (translational equilibrium). However, if all we need is the tension (T) in the supporting wire, we need only look at the rotational equilibrium condition (using the wall as the pivot point): Sum of clockwise torques = sum of counter-clockwise torques.

What then is distance x such that rotational equilibrium is achieved?

For this to occur, we need:

Sum of clockwise torques = sum of counter-clockwise torques.

Note that the pivot point for rotation can be any point on the beam. In this case though, it is most convenient to select the fulcrum as the pivot point since we will **not** need to calculate F_R (any force at the selected pivot point will produce a zero torque because $d = 0$)

Once we select the pivot point, the above equation becomes:

$m_2 g(0.25\text{m}) = Mg(0.20\text{m}) + m_1 g(x)$

Solving for x, we get $x = 0.50\text{m}$

Which becomes:

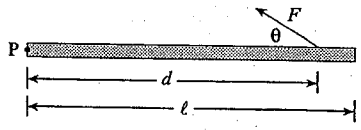
$= Mg(\sin 65°)(1.2\text{m}) + m_1 g(\sin 65°)(2.4\text{m}) = T(0.80\text{m})$

Solving for T we get:

T = 870N

JANUARY 2000
EQUILIBRIUM

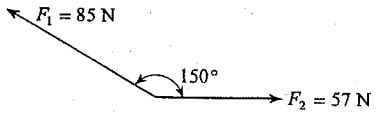
10. A force F is applied to a uniform horizontal beam as shown in the diagram below.



Which of the following is a correct expression for the torque on the beam about pivot point P due to this force?

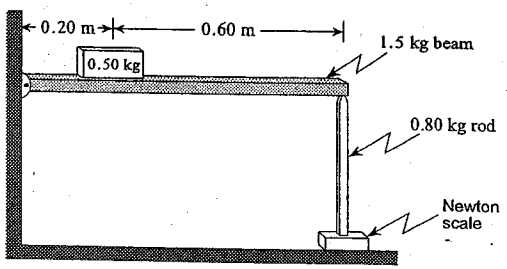
A. $F\sin\theta \cdot d$
B. $F\sin\theta \cdot d/\ell$
C. $F\cos\theta \cdot d$
D. $F\cos\theta \cdot d/\ell$

11. What is the magnitude of the sum of the two forces shown in the diagram below?



A. 46 N
B. 102 N
C. 137 N
D. 142 N

12. A uniform 1.5 kg beam hinged at one end supports a 0.50 kg block. The beam is held level by a vertical 0.80 kg rod resting on a Newton scale at the other end.

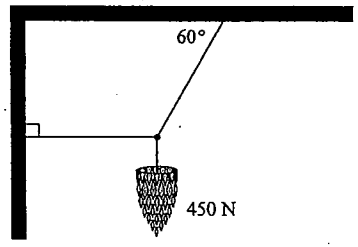


What is the reading on the scale?

A. 8.6 N
B. 9.1 N
C. 16 N
D. 27 N

JUNE 2000
EQUILIBRIUM

11. A 450 N chandelier is supported by three cables as shown in the diagram.

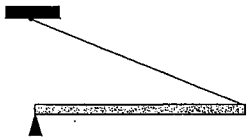


What is the tension in the horizontal cable?

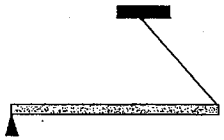
A. 46 N
B. 260 N
C. 450 N
D. 520 N

12. A beam is to be kept horizontal by a cord. In which of the four situations shown below will the tension in the cord be least?

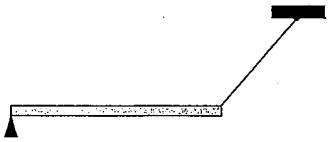
A.



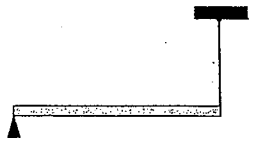
B.



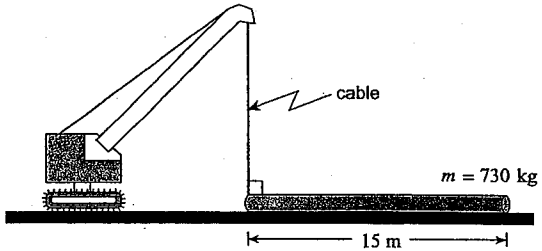
C.



D.



13. A crane is used to lift one end of a uniform 15 m long pipe with a mass of 730 kg as shown in the diagram below.



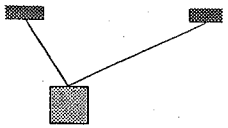
What is the minimum force of tension in the crane cable to just lift the end of the pipe off the ground?

A. 3.7×10^2 N
B. 4.8×10^2 N
C. 3.6×10^3 N
D. 7.2×10^3 N

AUGUST 2000
EQUILIBRIUM

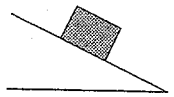
10. Which of the four problems shown requires the application of torque?

A.



What is the tension in the supporting cables?

B.

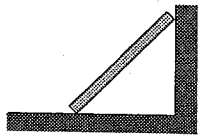


What is the friction force acting on the block?

C.

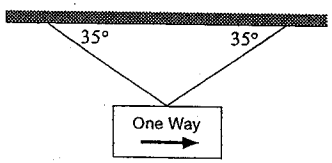
What is the acceleration of the puck?

D.



What force does the wall exert on the board?

11. A traffic sign hangs from two cables as shown.



If the tension in each cable is 220 N, what is the weight of the sign?

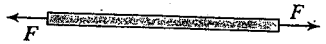
A. 130 N
B. 250 N
C. 360 N
D. 440 N

JANUARY 2001
EQUILIBRIUM

12. A metre stick, as seen from above, is sitting on a table and is then subjected to two forces of equal magnitude as shown. In which case would the metre stick be in rotational equilibrium?

A.

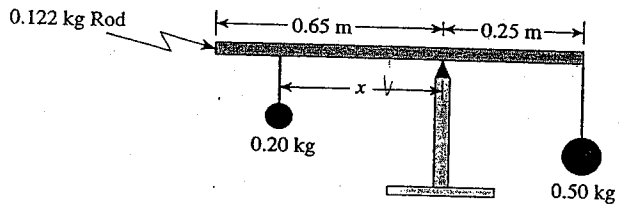
B.



C.

D.

13. A uniform 0.122 kg rod of 0.90 m length is used to suspend two masses as shown below.

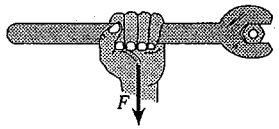


At what distance x should the 0.20 kg mass be placed to achieve static equilibrium?

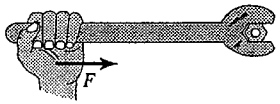
A. 0.30 m
B. 0.50 m
C. 0.63 m
D. 0.75 m

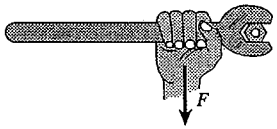
JUNE 2001
EQUILIBRIUM

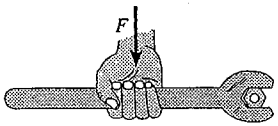
11. A student uses a wrench to loosen a very tight nut in the position shown.

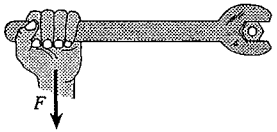


In which of the following would the student have more success at loosening the nut?

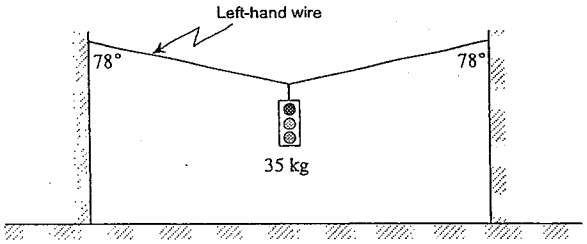
A.


B.


C.


D.


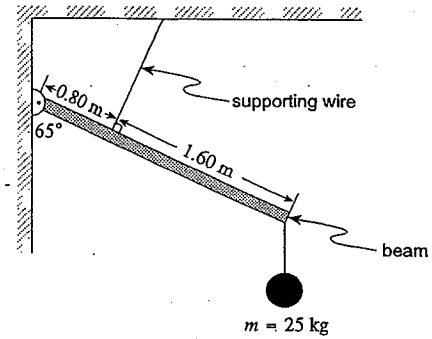
12. A 35 kg traffic light is suspended by two wires as shown.



What is the tension in the left-hand wire?

A. 84 N
B. 410 N
C. 820 N
D. 1 600 N

13. A 15 kg uniform beam 2.40 m long is suspended from a wall and a ceiling as shown.

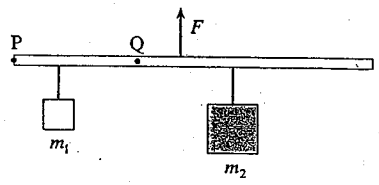


What is the tension in the supporting wire?

A. 670 N
B. 740 N
C. 870 N
D. 960 N

AUGUST 2001
EQUILIBRIUM

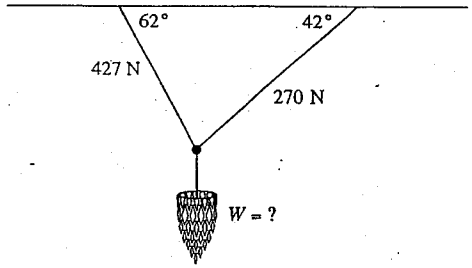
10. A beam holding two masses is in static equilibrium.



Compare the sum of the torques about point P to the sum of the torques about point Q.

A. The sum of the torques is the same about both point P and point Q.
B. You need to know the mass of the beam to compare the sum of the torques.
C. The sum of the torques about point P is less than the sum of the torques about point Q.
D. The sum of the torques about point P is greater than the sum of the torques about point Q.

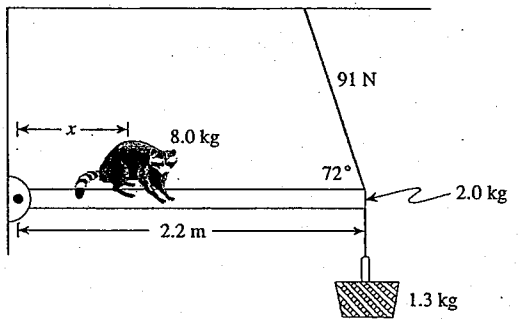
11. In the diagram below, the tension in each wire is shown.



What is the weight of the chandelier supported by these wires?

A. 300 N
B. 510 N
C. 560 N
D. 620 N

12. A hungry 8.0 kg raccoon walks out on a 2.0 kg, 2.2 m long uniform beam in an attempt to reach a 1.3 kg food basket hanging at the end. A cord that can withstand 91 N is used to support the beam at the end as shown.

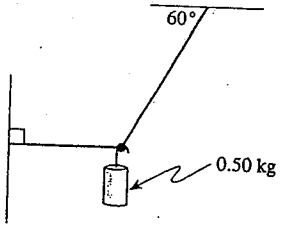


What is the maximum distance, x, the raccoon can walk out onto the beam before the cord breaks?

A. 1.8 m
B. 1.9 m
C. 2.0 m
D. 2.2 m

JANUARY 2002
EQUILIBRIUM

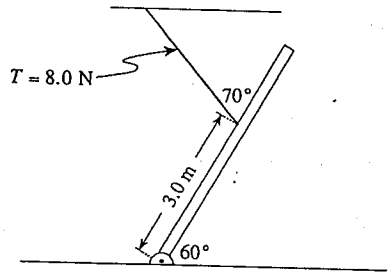
9. A 0.50 kg mass is suspended as shown in the diagram.



What is the tension in the horizontal string?

A. 2.5 N
B. 2.8 N
C. 4.2 N
D. 4.9 N

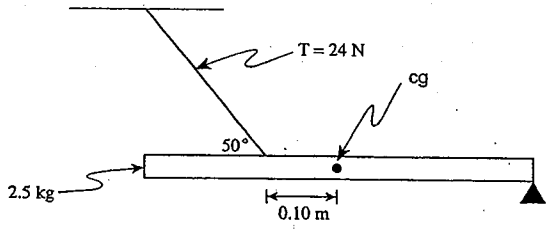
10. A 5.0 m-long uniform beam is held in position by a cord as shown in the diagram.



If the tension in the cord is 8.0 N, what is the weight of the beam?

A. 4.8 N
B. 8.0 N
C. 9.6 N
D. 18 N

11. A uniform 2.5 kg beam, pivoted at its right end, is held in a horizontal position by a cable as shown in the diagram.

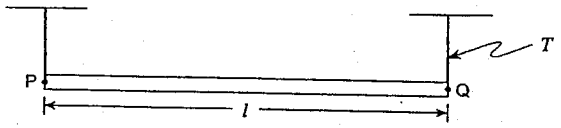


If the cable is attached 0.10 m to the left of the beam's centre of gravity, how long is the beam?

A. 0.34 m
B. 0.60 m
C. 1.2 m
D. 9.6 m

JUNE 2002
EQUILIBRIUM

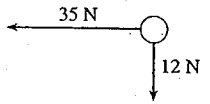
10. A beam is suspended by cords from its ends as shown.



If the tension in the right hand cord is T, what is the sum of the torques about point P?

A. 0 N·m
B. $T \cdot l$
C. $T \cdot l/2$
D. $\frac{T}{l}$

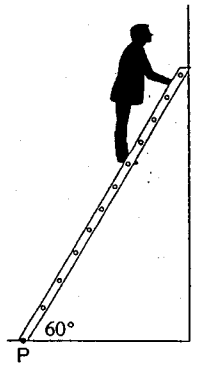
11. Two forces act on an object as shown in the diagram below.



What are the magnitude and direction of a third force needed to keep the object in equilibrium?

	MAGNITUDE OF FORCE	DIRECTION OF FORCE
A.	37 N	19° below the horizontal
B.	37 N	19° above the horizontal
C.	47 N	19° below the horizontal
D.	47 N	19° above the horizontal

12. A 65 kg person is $\frac{3}{4}$ of the way up the 4.0 m ladder as shown in the diagram below.



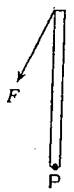
What are the magnitude and direction of the torque about the base of the ladder at P produced by the person?

	MAGNITUDE OF TORQUE	DIRECTION OF TORQUE
A.	9.6×10^2 N·m	clockwise
B.	9.6×10^2 N·m	counter-clockwise
C.	1.9×10^3 N·m	clockwise
D.	1.9×10^3 N·m	counter-clockwise

AUGUST 2002
EQUILIBRIUM

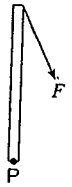
9. In which of the following situations does force F produce a counter-clockwise torque about point P?

A.



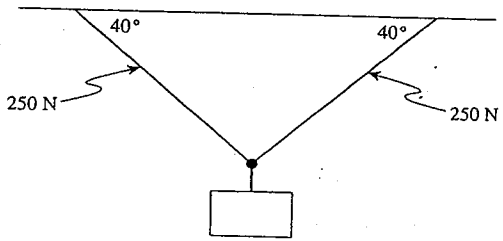
B.

C.



D.

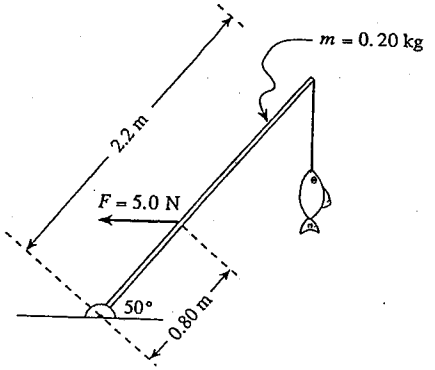
10. An object is suspended by cords as shown in the diagram below.



If the tension in two of the cords is 250 N, what is the weight of the object?

A. 160 N
B. 320 N
C. 380 N
D. 500 N

11. As shown in the diagram below, a horizontally applied force of 5.0 N is required to hold a fish at the end of a uniform 0.20 kg fishing rod.



What is the weight of the fish?

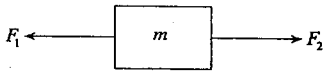
A. 0.84 N
B. 1.2 N
C. 2.2 N
D. 3.2 N

JANUARY 2003
EQUILIBRIUM

10. Which of the following are correct units for torque?

A. N/m
B. N/kg
C. N·s
D. N·m

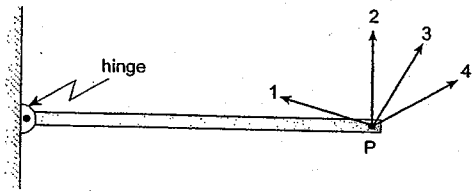
11. If the only forces acting on the object shown below are equal in magnitude, which of the following is **not possible**?



A. The object is at rest.
B. The object is accelerating to the left.
C. The object is moving with constant velocity to the right.
D. The object is moving with constant velocity towards the top of the page.

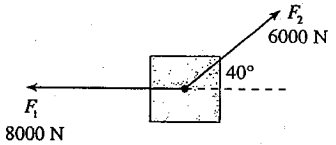
JUNE 2003
EQUILIBRIUM

11. The diagram below shows a force F applied in several different directions at the point P on a hinged beam. In which direction will the force produce the **smallest** torque about the hinge?



A. 1
B. 2
C. 3
D. 4

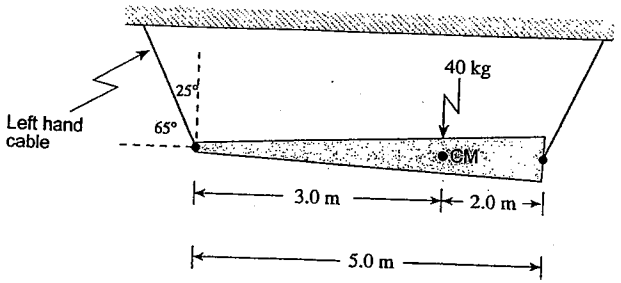
12. Two forces are acting at a single point on an object. Force 1 has a magnitude of 8000 N and is directed due W. Force 2 has a magnitude of 6000 N and is directed at 40° N of E.



Determine the magnitude of the third force which must act at the same point so that the object will be in translational equilibrium.

A. 2000 N
B. 3400 N
C. 5100 N
D. 6200 N

13. A 40 kg non-uniform beam (centre of mass CM) is supported by two cables.



(Diagram not to scale.)

What is the tension in the left hand cable?

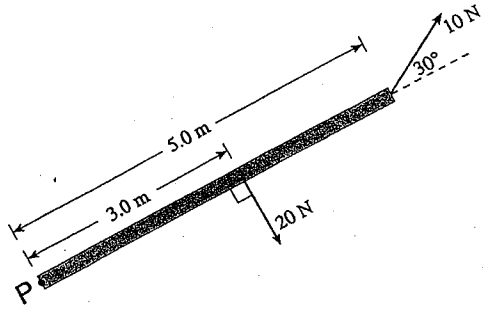
A. 170 N
B. 260 N
C. 370 N
D. 560 N

AUGUST 2003
EQUILIBRIUM

10. A physics exam booklet lying on a table in front of you is in translational equilibrium because

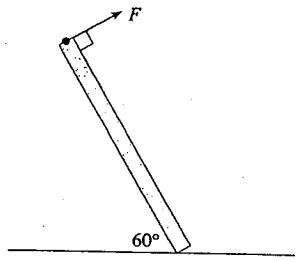
A. there are no forces acting on it.
B. the forces acting on it are balanced.
C. the force due to gravity is holding it down.
D. surface friction is preventing it from sliding.

11. Determine the sum of the torques about the point P for the two forces shown below acting on a very light wooden beam. (Ignore its weight.)



A. 10 N · m
B. 17 N · m
C. 35 N · m
D. 85 N · m

12. The 0.10 kg metre stick shown below is held up by the perpendicular force F. The bottom of the metre stick is on the verge of sliding to the right.



Determine the size of the friction force being provided by the floor.

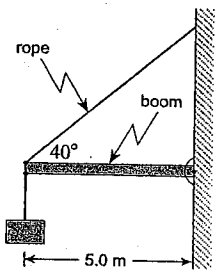
A. 0.12 N
B. 0.21 N
C. 0.25 N
D. 0.49 N

JANUARY 2004
EQUILIBRIUM

12. Which of these is an acceptable definition of rotational equilibrium?

A. $\Sigma\tau = 0$
B. $\Sigma v = 0$
C. $\Sigma F = \Sigma\tau$
D. $\Sigma F_x = \Sigma F_y$

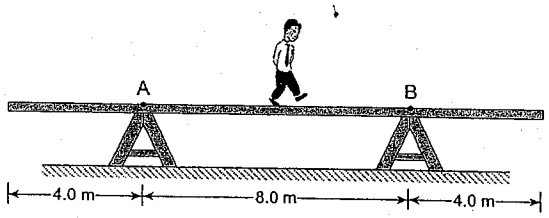
13. A 25 kg mass is suspended from the end of a 5.0 m long uniform boom.



If the mass of the boom is 12 kg, what is the tension in the supporting rope?

A. 300 N
B. 380 N
C. 470 N
D. 560 N

14. A uniform 16 m long plank weighing 350 N rests on supports 8.0 m apart. An 850 N man walks along the plank to the right.

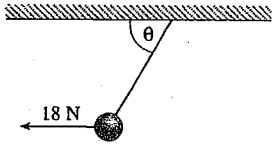


How far past point B can the man walk before the plank tips?

A. 0.82 m
B. 1.6 m
C. 2.5 m
D. 3.3 m

JUNE 2004
EQUILIBRIUM

12. A 5.0 kg mass suspended by a rope is pulled to the left by a horizontal force of 18 N.

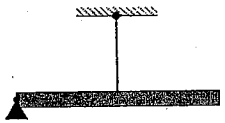


What is angle θ ?

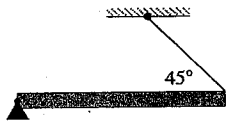
A. 16°
B. 20°
C. 70°
D. 74°

13. A uniform 2.0 m long beam is to be kept horizontal by a cord. In which of the four situations shown below will the tension in the cord be one-half of the beam's weight?

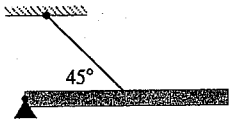
A.



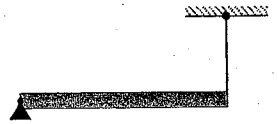
B.



C.



D.



AUGUST 2004
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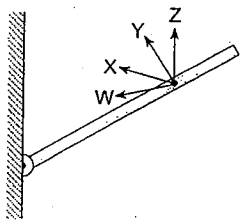
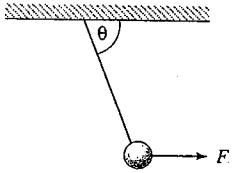
10. In which direction should a force act on the boom so that it creates a **minimum** torque about the hinge?



A. W
B. X
C. Y
D. Z

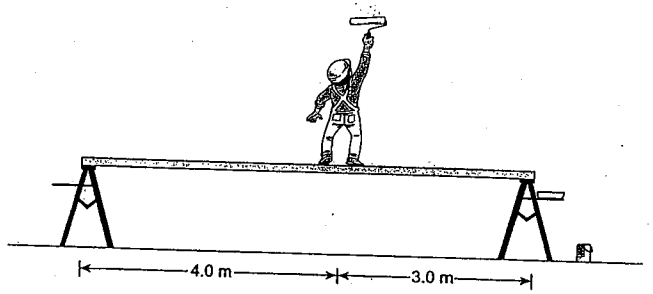
11. A 5.0 kg mass is suspended by a rope. A horizontally directed force F is applied to the mass.



What magnitude of force is needed to produce an angle of $\theta = 65°$?

A. 21 N
B. 23 N
C. 44 N
D. 110 N

12. An 840 N painter stands on a 7.0 m board of negligible weight. The board is supported by two step-ladders as shown.



What is the force exerted on the board by the left step-ladder?

A. 360 N
B. 420 N
C. 630 N
D. 840 N

CIRCULAR MOTION

AND

GRAVITATION

Circular motion

Gravitation

Circular Motion and Gravitation	
Outcomes	**Questions**
It is expected that students will demonstrate an ability to describe and apply the concepts of uniform circular motion to real-world situations.	
It is expected that students will:	
I1. describe the velocity of an object moving in uniform circular motion at any point in that motion	1
I2. demonstrate that the acceleration of an object may result in a change in direction with no change in speed	
I3. define centripetal acceleration and centripetal force	2, 3, 4
I4. solve problems involving:	5, 6, 7, 8, 9, 10
• centripetal force	
• speed	
• radius of revolution	
• period of revolution	
• object's mass	
I5. analyse and describe the forces acting on common objects in circular motion	11
J1. state Newton's law of universal gravitation	12, 13, 14, 15
J2. apply Newton's law of universal gravitation to solve problems involving:	
• force	
• mass	
• distance of separation	
J3. describe the gravitational field of a body in terms of an inverse square relationship	
J4. indicate that the work required to move an object in a gravitational field is given by the area below a graph of gravitational force versus distance of separation	16
J5. define gravitational potential energy	17
J6. solve problems involving:	18
• gravitational potential energy relative to zero at infinity	
• mass	
• distance of separation	
J7. calculate the work required to change the separation distance between objects	19
J8. analyse and describe orbiting systems in terms of universal gravitational and centripetal forces	
J9. olve problems involving orbiting systems	20, 21
J10. calculate the total energy of an orbiting object	22

Circular Motion and Gravitation

Circular Motion

I1 Describe the velocity of an object moving in uniform circular motion at any point in that motion.

Newton's First Law, an object in motion stays in motion unless acted upon by an outside force, demonstrates an object's tendency to continue moving in a defined way. In circular motion, the direction is continuously changing. Therefore, acceleration must continuously be pulling the object toward the centre. We can describe the velocity of an object at any point in its rotation by:

$$a_c = \frac{v^2}{r}$$

I2 Demonstrate that the acceleration of an object may result in a change in direction with no change in speed.

Since an object tends to stay at the same speed and direction unless acted upon by an outside force, any deviation in these two properties results from acceleration. Since $F = ma$, where mass is constant, for an object moving in a circular path, the direction must constantly be changing toward the centre. Even if the velocity magnitude is constant, the direction is not. We therefore have a constant acceleration to maintain a circular path.

I3 Define centripetal acceleration and centripetal force.

I4 Solve problems involving:

- *centripetal force*
- *speed*
- *radius of revolution*
- *period of revolution*
- *object's mass*

I5 Analyse and describe the forces acting on common objects in circular motion

The formula $F = m\frac{v^2}{r}$, where F is force, m is mass, v is velocity and r is radius, can be used to solve for any of the above unknowns except period of revolution. The time that it takes for an object to complete one complete circular revolution is called the period. Centripetal force pulls an object toward the centre of a uniform circular path. The path of an object in circular motion is thus changing at a continuous rate which results from a continuous force. This continuous acceleration is called centripetal acceleration.

Example: Find the centripetal force required to keep a 1000kg car moving in a uniform circle of radius 50m at a speed of 50km/h.

Converting km/h to m/s we get:

$$50\text{km/h} = \left(\frac{50\,\text{km}}{1\,\text{h}}\right)\left(\frac{1000\text{m}}{1\,\text{km}}\right)\left(\frac{1\,\text{h}}{3600\text{s}}\right)$$

$$F = m\frac{v^2}{r}$$

$$= (1000\text{kg})\frac{(13.9\text{m/s})^2}{50\text{m}}$$

$$= 3.86\times10^3\text{N}$$

Example: The centripetal force required to keep a 400kg motorbike moving in a uniform circular path of radius 75m is 4000N. What is the speed of the motorbike in km/h?

$$F = m\frac{v^2}{r}$$

$$4000\text{N} = (400\text{kg})\left(\frac{v^2}{75\text{m}}\right)$$

$$v^2 = 750\text{m}^2/\text{s}^2$$

$$v = 27.4\text{m/s}$$

$$= \left(\frac{27.4\,\text{m}}{1\,\text{s}}\right)\left(\frac{3600\,\text{s}}{1\,\text{h}}\right)\left(\frac{1\,\text{km}}{1000\,\text{m}}\right)$$

$$= 98.6\text{km/h}$$

Example: Find the period of revolution of a motorbike moving in a circular path of radius 75m at 98.6 km/h.

$$v = \frac{2\pi r}{T} \text{ or } T = \frac{2\pi r}{v}$$

$$= \frac{(2\pi)(75\text{m})}{27.4\text{m/s}}$$

$$= 17.2\text{s for one revolution.}$$

An object in motion will tend toward a straight line motion. In order for the object to change direction, an outside force must be applied. The outside force applied to pull the object toward the centre of a circular path causes the object to accelerate. We must not assume that there is a force pulling the object away from this circular path. Rather, the object's momentum is the quantity over which centripetal force must act in order to maintain the circular path.

Gravitation

J1 State Newton's law of universal gravitation.

J2 Apply Newton's law of universal gravitation to solve problems involving:

- *force*
- *mass*
- *distance of separation*

J3 Describe the gravitational field of a body in terms of an inverse square relationship.

Every particle in the universe attracts every other particle with a force proportional to the product of their masses and inversely proportional to the square of the distance between them. This force acts along the line that connects the two particles.

A gravitational field exists for every body that has mass. An object attracts another by means of the gravitational field responsible for the gravitational force on the object. The gravitational field strength is force per unit mass. It varies according to the inverse square of the distance away from the body.

$F \propto \frac{1}{r^2}$, where r = distance.

Given two objects, $m_1 = 50\text{kg}$ and $m_2 = 75\text{kg}$, at a distance 50cm apart, find the gravitational force between them.

$$F_g = \frac{Gm_1m_2}{r^2},\ G = 6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2$$

$$= \frac{(6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2)(50\text{kg})(75\text{kg})}{(0.5\text{m})^2}$$

$$= 1.0\times10^{-6}\text{N}$$

What is the apparent weight of a 80kg astronaut orbiting at a constant velocity, 4700km above Earth's surface?

(Earth's mass, M_E, is 5.98×10^{24}kg, gravity G is $6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2$, and Earths radius r_E is 6380km.)

$$F_g = \frac{Gm_1m_2}{r^2}$$

$$\frac{(6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2)(80\text{kg})(5.98\times10^{24}\text{kg})}{(6380\times10^3\text{m}+4700\times10^3\text{m})^2}$$

$$= \frac{3.1909\times10^{16}}{2.8494\times10^{13}}$$

Two objects are separated by a distance d and the attractive force between them is $1.0\times10^{-5}N$. If $m_1 = 100\text{kg}$ and $m_2 = 50\text{kg}$, what is d?

$$F_g = \frac{Gm_1m_2}{r^2}$$

$$1.0\times10^{-5}\text{N} = \frac{(6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2)(100\text{kg})(50\text{kg})}{d^2}$$

$$d = \sqrt{\frac{(6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2)(100\text{kg})(50\text{kg})}{(1.0\times10^{-5}\text{N})^2}}$$

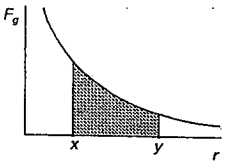
$$= 1.83\times10^{-1}\text{m}$$

$$= 18.3\text{cm}$$

J4 Indicate that the work required to move an object in a gravitational field is given by the area below a graph of gravitational force versus distance of separation.

J5 Define gravitational potential energy.

The following graph shows the relationship between force and distance in Newton's Law of Universal Gravitation:



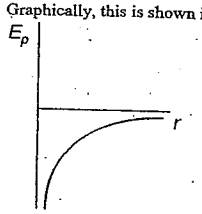
Since the area under a "force vs distance" graph always gives us the work done, the area of the shaded region in such a graph will equal the amount of work needed to move two masses m_1 and m_2 that are distance x apart to distance y apart. The work needed to move these masses an infinite distance apart can be calculated by summing the entire area under the curve in this graph. Advanced mathematical techniques (not part of this course) show us that the work done to move two masses from a distance $r \to \infty$ is given by:

$$W = \frac{Gm_1m_2}{r}$$

When two masses are essentially infinitely apart, their gravitational potential energy with respect to each other is zero. Since it takes positive work to move them apart, they must start out at a distance r apart with negative energy. Thus the gravitational potential energy of two masses m_1 and m_2 that are a distance r apart is:

$$E_p = -\frac{Gm_1m_2}{r}$$

Graphically, this is shown in the following:



J6 Solve problems involving:

- *gravitational potential energy relative to zero at infinity*
- *mass*
- *distance of separation*

J7 Calculate the work required to change the separation distance between objects.

The total mechanical energy ($E_p + E_k$) of a satellite orbiting Earth can be calculated with:

$$E_T = \underbrace{-\frac{Gm_em_s}{r}}_{E_p} + \underbrace{\frac{1}{2}m_sv_s^2}_{E_k}$$

where r is the distance from the satellite to the centre of the Earth. It should be noted that this potential energy formula does not work if the orbiting object penetrates the surface of earth.

J8 Analyse and describe orbiting systems in terms of universal gravitational and centripetal forces.

J9 Solve problems involving orbiting systems.

J10 Calculate the total energy of an orbiting object.

The speed of a satellite in stable orbit is given by:

$v_s = \sqrt{\frac{Gm_e}{r}}$ (obtained by equating $F_g = F_c$)

The total energy of the satellite becomes:

$$E_T = -\frac{Gm_em_s}{r} + \frac{1}{2}m_s\left(\frac{Gm_e}{r}\right)$$

or $E_T = -\frac{Gm_em_s}{2r}$

Note that this energy is always negative. The kinetic energy obtained by a satellite falling straight to earth from a high altitude (ignoring air resistance) can be calculated using energy principles.

$$\Sigma E_i = \Sigma E_f$$

$$-\frac{Gm_em_s}{r_i} = \frac{1}{2}m_sv_f^2 + \frac{(-Gm_em_s)}{r_f}$$

where r_i is the initial distance from the centre of the earth and r_f is the final distance from the centre of the earth. This can be rewritten as:

$$\Delta E_k = Gm_em_s\left(\frac{1}{r_f} - \frac{1}{r_i}\right)$$

To calculate the work required to push the satellite back to its original altitude, we can use:

$$W = \Delta E_p = E_{pf} - E_{pi}$$

which gives us the same result as above since it involves the same energy difference.

Escape velocity is defined as the speed required to take a rocket or satellite away from an object such as Earth so that it does not get pulled back by gravity. Once an object escapes Earth's gravitational pull, it will find itself eventually an infinite distance away from Earth with zero energy left.

$$E_p + E_k = 0$$

$$\text{or } -\frac{Gm_em_s}{r} + \frac{1}{2}m_sv_{esc}^2 = 0$$

Solving, we get

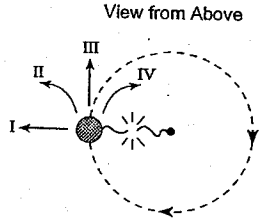
$$v_{esc} = \sqrt{\frac{2Gm_e}{r}}$$

where r is the original distance from the centre of the earth.

JANUARY 2000

CIRCULAR MOTION AND GRAVITATION

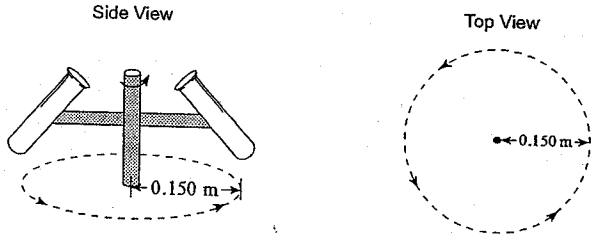
13. A ball attached to a string is swung in a horizontal circle.



Which path will the ball follow at the instant the string breaks?

A. I
B. II
C. III
D. IV

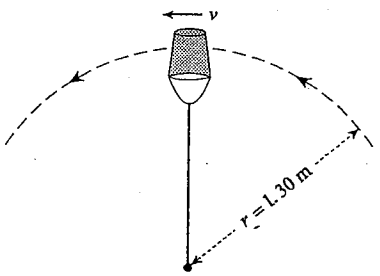
14. A test tube rotates in a centrifuge with a period of 1.20×10^{-3} s. The bottom of the test tube travels in a circular path of radius 0.150 m.



What is the centripetal force exerted on a 2.00×10^{-8} kg amoeba at the bottom of the tube?

A. 9.86×10^{-5} N
B. 2.08×10^{-3} N
C. 8.22×10^{-2} N
D. 4.11×10^{6} N

15. A physics student swings a 5.0 kg pail of water in a vertical circle of radius 1.3 m.

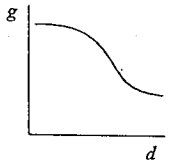


What is the minimum speed, v, at the top of the circle if the water is not to spill from the pail?

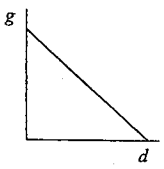
A. 3.6 m/s
B. 6.1 m/s
C. 8.0 m/s
D. 9.8 m/s

16. Which of the following is a correct graph for gravitational field strength, g, versus the distance, d?

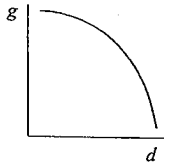
A.



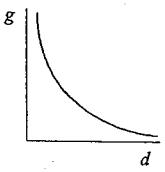
B.



C.



D.



17. *Sputnik I*, Earth's first artificial satellite, had an orbital period of 5 760 s. What was the average orbital radius of *Sputnik's* orbit?

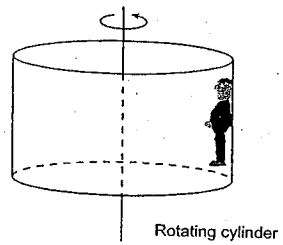
A. 6.38×10^{6} m
B. 6.95×10^{6} m
C. 8.24×10^{6} m
D. 3.84×10^{8} m

18. A 620 kg satellite orbits the earth where the acceleration due to gravity is $0.233\ m/s^2$. What is the kinetic energy of this orbiting satellite?

A. -5.98×10^{9} J
B. -2.99×10^{9} J
C. 2.99×10^{9} J
D. 5.98×10^{9} J

JUNE 2000
CIRCULAR MOTION AND GRAVITATION

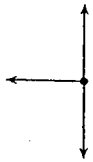
14. In a popular amusement park ride, a large cylinder is set in rotation. The floor then drops away leaving the riders suspended against the wall in a vertical position as shown.



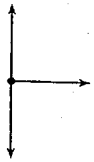
Rotating cylinder

Which of the following is the correct free-body diagram for the person at the position shown?

A.

B. 

C. 

D. 

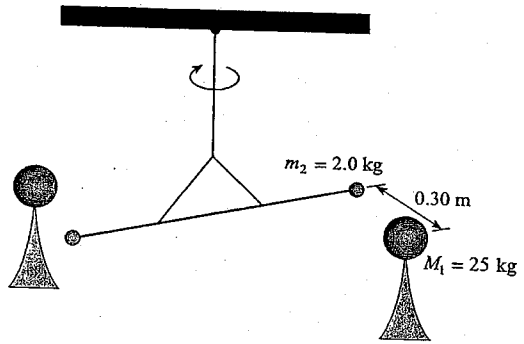
15. A 0.500 kg ball is swung in a horizontal circle of radius 1.20 m with a period of 1.25 s. What is the centripetal force on the ball?

A. 0.384 N
B. 15.2 N
C. 18.9 N
D. 30.3 N

16. A rock drops from a very high altitude towards the surface of the moon. Which of the following is correct about the changes that occur in the rock's mass and weight?

	MASS	WEIGHT
A.	decreases	decreases
B.	decreases	increases
C.	remains constant	decreases
D.	remains constant	increases

17. Cavendish's historic experiment is set up as shown to determine the force between two identical sets of masses. What would be the net force of attraction between **one** set of masses?



A. 1.1×10^{-8} N
B. 1.9×10^{-8} N
C. 2.2×10^{-8} N
D. 3.7×10^{-8} N

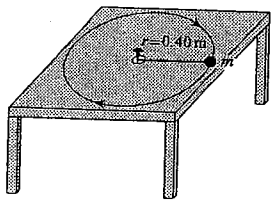
AUGUST 2000

CIRCULAR MOTION AND GRAVITATION

12. A car travels at a uniform speed through a level circular curve in the road. Which of the following correctly describes the magnitude of the acceleration, velocity and force acting on the car?

	MAGNITUDE OF ACCELERATION	MAGNITUDE OF VELOCITY	MAGNITUDE OF FORCE
A.	constant	constant	constant
B.	constant	changing	changing
C.	constant	changing	constant
D.	changing	changing	changing

13. An object is attached to a string that can withstand a maximum tension force of 6.3 N. The object travels in a circular path of radius 0.40 m with a period of 2.1 s.



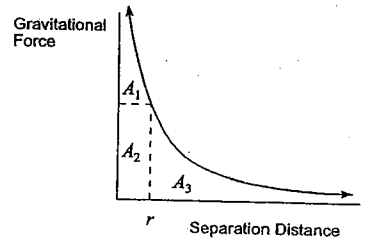
What is the maximum mass of the object?

A. 0.57 kg
B. 0.64 kg
C. 1.8 kg
D. 3.6 kg

14. A 65 kg pilot in a stunt plane performs a vertical loop with a 700 m radius. The plane reaches a speed of 210 m/s at the bottom of the loop. What is the upward force on the pilot at the bottom of the loop?

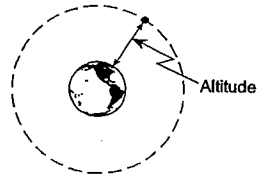
A. 640 N
B. 3 500 N
C. 4 100 N
D. 4 700 N

15. Which of the indicated areas of the graph represent the work needed to send an object from separation distance r to infinity?



A. $A_1 + A_2$
B. A_2
C. $A_2 + A_3$
D. A_3

16. A satellite experiences a gravitational force of 228 N at an altitude of 4.0×10^7 m above Earth.



What is the mass of this satellite?

A. 23 kg
B. 650 kg
C. 910 kg
D. 1 200 kg

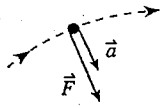
17. A 1 570 kg satellite orbits a planet in a circle of radius 5.94×10^6 m. Relative to zero at infinity the gravitational potential energy of this satellite is -9.32×10^{11} J. What is the mass of the planet?

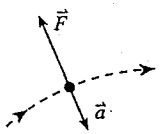
A. 5.29×10^{25} kg
B. 8.31×10^{28} kg
C. 3.14×10^{31} kg
D. 4.93×10^{34} kg

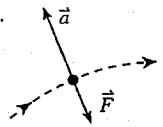
JANUARY 2001

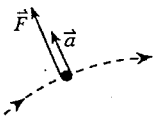
CIRCULAR MOTION AND GRAVITATION

15. Which vector diagram best represents the acceleration, $\vec{a}$, and force, $\vec{F}$, for an object travelling along a circular path?

A. 

B. 

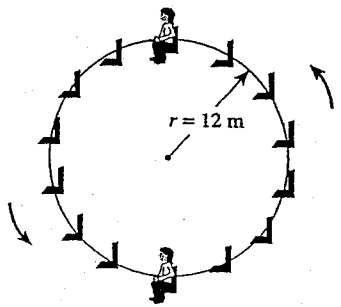
C. 

D. 

16. An object travels along a circular path with a constant speed v when a force F acts on it. How large a force is required for this object to travel along the same path at twice the speed ($2v$)?

A. $\frac{1}{2}F$
B. F
C. $2F$
D. $4F$

17. The diagram shows a 52 kg child riding on a Ferris wheel of radius 12 m and period 18 s. What force (normal force) does the seat exert on the child at the top and bottom of the ride?

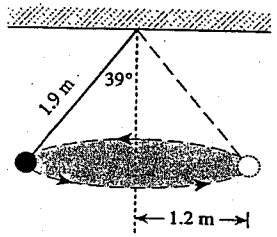


	TOP	BOTTOM
A.	76 N	76 N
B.	430 N	590 N
C.	510 N	510 N
D.	590 N	430 N

18. The equation $E_p = mgh$, in which g is 9.8 m/s^2, can not be used for calculating the gravitational potential energy of an orbiting Earth satellite because

A. the Earth is rotating.
B. of the influence of other astronomical bodies.
C. the Earth's gravity disappears above the atmosphere.
D. the Earth's gravitational field strength varies with distance.

19. The diagram shows an object of mass 3.0 kg travelling in a circular path of radius 1.2 m while suspended by a piece of string of length 1.9 m. What is the centripetal force on the mass?



A. 19 N
B. 23 N
C. 24 N
D. 29 N

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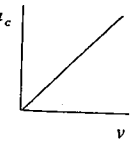
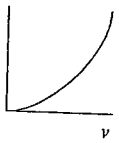
CIRCULAR MOTION AND GRAVITATION

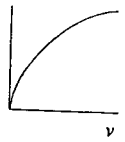
14. A car travels at 25 m/s along a horizontal curve of radius 450 m. What minimum coefficient of friction is necessary between its tires and the road in order for the car not to skid?

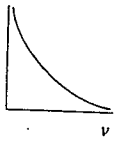
A. 0.14
B. 0.54
C. 0.72
D. 1.4

15. In a series of test runs, a car travels around the same circular track at different velocities. Which graph best shows the relationship between its centripetal acceleration, a_c, and its velocity, v?

A. 

B. 

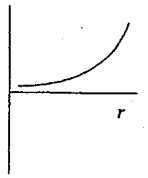
C. 

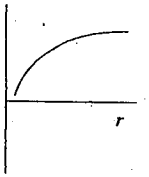
D. 

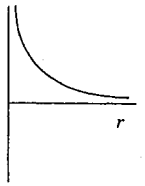
16. Tarzan, of mass 85 kg, holds on to a horizontal vine of length 8.0 m and jumps off a cliff. What is the tension force in the vine as Tarzan passes the lowest point of his circular path?

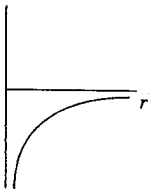
A. 830 N
B. 1 700 N
C. 2 500 N
D. 6 700 N

17. Which graph shows gravitational potential energy plotted as a function of distance r from the centre of the earth?

A. 

B. 

C. 

D. 

18. How much work must be done to lift a 4.00×10^4 kg object from Earth's surface to a height of 3.00×10^5 m?

A. 1.12×10^{11} J
B. 1.18×10^{11} J
C. 2.39×10^{12} J
D. 5.32×10^{13} J

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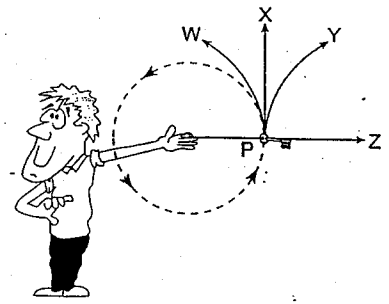
CIRCULAR MOTION AND GRAVITATION

13. The diagram shows a student "twirling" a car key in a circular path on the end of a string.



If the string snaps at P, which path will the keys follow?

A. W
B. X
C. Y
D. Z

14. An athlete runs, at a constant speed, around a circle of radius 5.0 m in 12 s. What are the athlete's speed and acceleration?

	SPEED	MAGNITUDE OF ACCELERATION
A.	0.42 m/s	0.22 m/s^2
B.	0.42 m/s	1.4 m/s^2
C.	2.6 m/s	0.22 m/s^2
D.	2.6 m/s	1.4 m/s^2

15. A frictionless 3.0 kg cart rolls down an incline, and then "loops the loop."

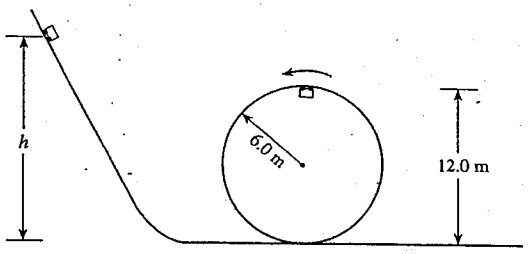


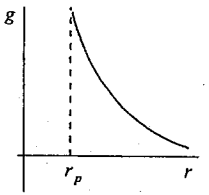
Diagram not to scale.

From what minimum height, h, should the cart be released so that it does not fall off the circular track?

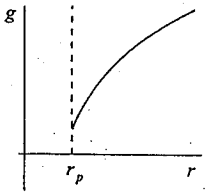
A. 12.0 m
B. 15.0 m
C. 18.0 m
D. 24.0 m

16. Which graph best shows how the gravitational field strength, g, varies with the distance, r, from the centre of a planet? (r_p is the radius of the planet.)

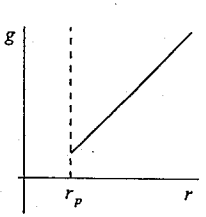
A.



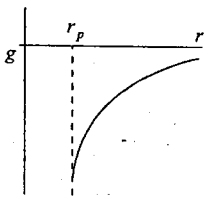
B.



C.



D.



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CIRCULAR MOTION AND GRAVITATION

17. A satellite is in a stable circular orbit around the earth. Another satellite in a stable circular orbit at a greater altitude must have

A. a smaller speed and a shorter period.
B. a smaller speed and a longer period.
C. a greater speed and a shorter period.
D. a greater speed and a longer period.

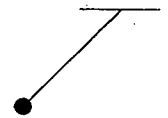
18. Which of the following could represent the kinetic energy, the gravitational potential energy and the total energy for an orbiting satellite in a stable circular orbit?

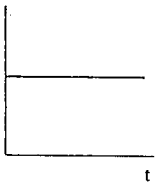
	KINETIC ENERGY	GRAVITATIONAL POTENTIAL ENERGY	TOTAL ENERGY
A.	40 000 J	−80 000 J	−40 000 J
B.	40 000 J	40 000 J	80 000 J
C.	80 000 J	40 000 J	120 000 J
D.	80 000 J	−40 000 J	40 000 J

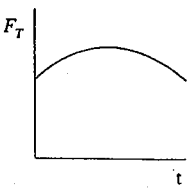
12. Which of the following best describes uniform circular motion?

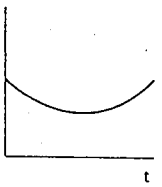
	SPEED	VELOCITY	ACCELERATION
A.	constant	constant	constant
B.	constant	constant	changing
C.	constant	changing	changing
D.	changing	changing	changing

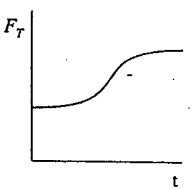
13. As a simple pendulum swings from one side to the other, the tension in the supporting thread is best represented by which graph?



A. 

B. 

C. 

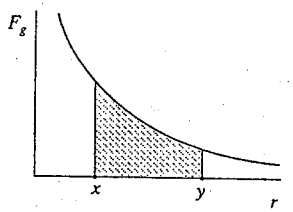
D. 

14. An aircraft flies in a vertical circular path of radius 2000 m. At the top of this path the 71 kg pilot feels lighter and experiences a 200 N upward force from the seat.

What is the speed of the aircraft?

A. 75 m/s
B. 120 m/s
C. 140 m/s
D. 160 m/s

15. As an object moves from x to y, the shaded area below the graph of gravitational force versus distance of separation represents



A. the gain in kinetic energy.
B. the energy released into space.
C. the work required to move the object.
D. the average force required to move the object.

16. A 75 kg astronaut stands on the surface of a planetoid with a mass of 5.8×10^{21} kg and a radius of 7.3×10^{5} m. What is the gravitational field strength at the surface?

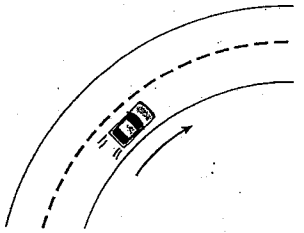
A. 0.73 N/kg
B. 1.6 N/kg
C. 9.8 N/kg
D. 54 N/kg

17. What minimum energy is required to raise a 1.7×10^{3} kg vehicle from the surface of the Moon to a height of 5.22×10^{6} m?

A. 1.6×10^{9} J
B. 3.6×10^{9} J
C. 4.8×10^{9} J
D. 1.4×10^{10} J

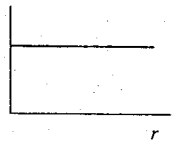
JUNE 2002
CIRCULAR MOTION AND GRAVITATION

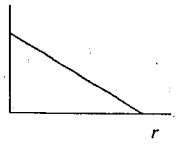
13. A car is moving at a constant speed around a circular curve. Which of the following best describes this situation?

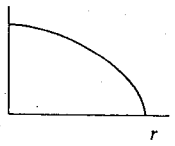


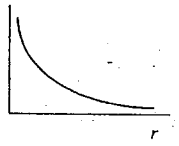
	VELOCITY OF CAR	ACCELERATION OF CAR	NET FORCE ON CAR
A.	↗	↗	↖
B.	↗	↘	↖
C.	↗	↘	↘
D.	↘	↘	↘

14. Which of the following best illustrates how the gravitational field strength of a body varies with distance r from the body's centre?

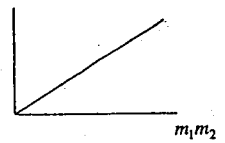
A. 

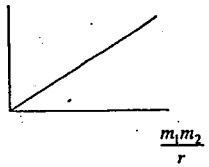
B. 

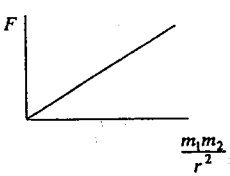
C. 

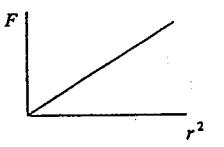
D. 

15. Which of the following graphs has a slope equal to the gravitational constant, G?

A. 

B. 

C. 

D. 

16. What is the gravitational force exerted on a 63 kg student by her 1400 kg car when their centres are 7.0 m apart?

A. 8.6×10^{-11} N
B. 1.9×10^{-9} N
C. 1.2×10^{-7} N
D. 1.8×10^{3} N

17. A satellite orbits the earth with a speed of 7.3×10^{3} m/s. What is the distance from the centre of the earth to this satellite?

A. 2.3×10^{5} m
B. 3.8×10^{6} m
C. 7.5×10^{6} m
D. 1.3×10^{7} m

18. At an altitude of 1.3×10^{7} m above the surface of the earth an incoming meteor of mass 1.0×10^{6} kg has a speed of 6.5×10^{3} m/s. What would be the speed just before impact with the surface of the earth? Ignore air resistance.

A. 9.1×10^{3} m/s
B. 1.0×10^{4} m/s
C. 1.1×10^{4} m/s
D. 1.7×10^{4} m/s

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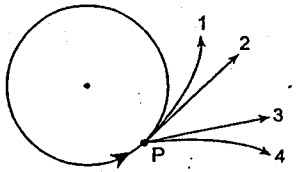
CIRCULAR MOTION AND GRAVITATION

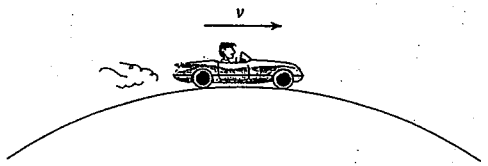
12. When an object moving in a horizontal circle breaks free at point P, it will follow which path?



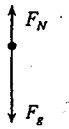
Viewed from above

A. 1
B. 2
C. 3
D. 4

13. A vehicle and driver travel at constant speed over the hill as shown.



Which of the following free body diagrams best describes the vehicle at this position?

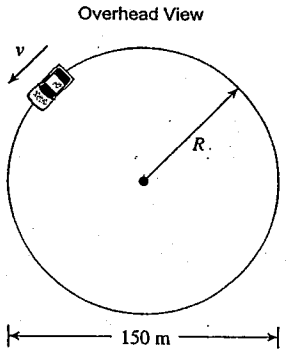
A. 

B. 

C. 

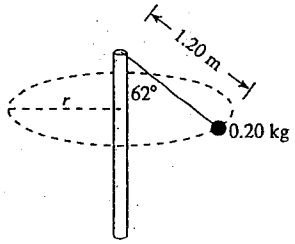
D. 

14. What is the maximum speed a car can travel along a level circular path (as shown below) if the coefficient of friction is 0.86?



A. 4.1 m/s
B. 8.0 m/s
C. 25 m/s
D. Depends on the mass of the car

15. A 0.20 kg object moves at a constant speed in a horizontal circular path as shown.



What is the speed of this object?

A. 2.3 m/s
B. 3.2 m/s
C. 3.4 m/s
D. 4.4 m/s

16. A 2.0×10^{3} kg satellite is in a circular orbit around the earth. The satellite has a speed of 3.6×10^{3} m/s at an orbital radius of 3.1×10^{7} m. What is the total energy of this orbiting satellite?

A. -2.6×10^{10} J
B. -1.3×10^{10} J
C. 1.3×10^{10} J
D. 3.9×10^{10} J

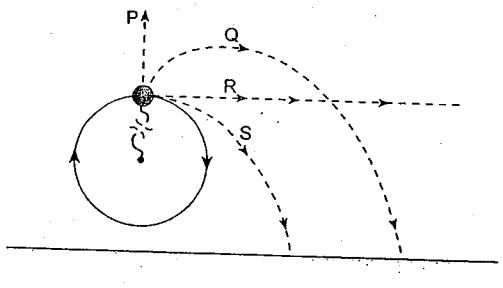
17. What is the change in gravitational potential energy as a 3500 kg object is raised vertically from the surface of the earth to a height of 8.2×10^{5} m?

A. 5.5×10^{7} J
B. 2.5×10^{10} J
C. 2.8×10^{10} J
D. 1.9×10^{11} J

JANUARY 2003

CIRCULAR MOTION AND GRAVITATION

12. A ball moves at a constant speed in a **vertical** circle when the string breaks at the position shown.



The ball would then move along which of the indicated paths?

A. P
B. Q
C. R
D. S

13. A 0.090 m **diameter** computer floppy disk spins at a constant speed of 1.40 m/s measured at its rim. What is the centripetal acceleration at the rim of this floppy disk?

A. $16\ m/s^2$
B. $22\ m/s^2$
C. $31\ m/s^2$
D. $44\ m/s^2$

14. A 960 kg car is travelling on a 65 m radius horizontal circular track. The coefficient of friction between the tires and the track surface is 0.57. What is the minimum time for the car to complete one lap of the track?

A. 0.69 s
B. 12 s
C. 21 s
D. 67 s

15. A satellite is brought from a higher circular orbit to a lower circular orbit around the earth. Which of the following describes what has happened to the satellite's period?

A. The satellite's period decreased.
B. The satellite's period increased.
C. The satellite's period did not change.
D. You cannot determine this without more information.

16. A 2500 kg satellite is placed into a circular orbit at an altitude of 1.2×10^5 m above the earth's surface. What is the period of this satellite?

A. 13 s
B. 700 s
C. 5100 s
D. 5200 s

17. A 3500 kg piece of space debris is brought from an altitude of 2.1×10^5 m back to the earth's surface. What is the change in potential energy of this space debris?

A. -7.0×10^9 J
B. -7.2×10^9 J
C. -2.1×10^{11} J
D. -2.2×10^{11} J

JUNE 2003
CIRCULAR MOTION AND GRAVITATION

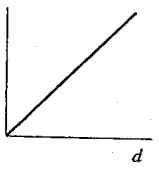
14. A car is travelling in uniform circular motion. Which of the following correctly describes the speed, velocity and acceleration of the car?

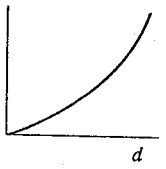
	SPEED	VELOCITY	ACCELERATION
A.	Constant	Constant	Constant
B.	Constant	Changing	Changing
C.	Changing	Constant	Constant
D.	Changing	Changing	Changing

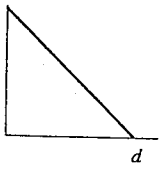
15. A 45 kg child stands on the rim of a merry-go-round of radius 2.3 m. The child completes 5 rotations in 72 s. What is the centripetal force acting on the child?

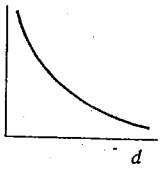
A. 0.44 N
B. 0.79 N
C. 20 N
D. 280 N

16. Which of the following represents the graph of gravitational field strength g as a function of the distance d from the centre of a planet?

A. 

B. 

C. 

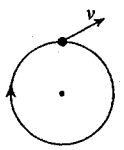
D. 

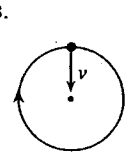
17. Which of the following best represents the gravitational force of attraction between two people one metre apart?

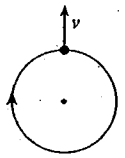
A. 10^{-17} N
B. 10^{-12} N
C. 10^{-7} N
D. 10^{-2} N

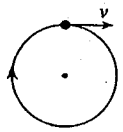
AUGUST 2003
CIRCULAR MOTION AND GRAVITATION

13. Which of the following correctly shows the velocity vector, v, for an object in uniform circular motion?

A. 

B. 

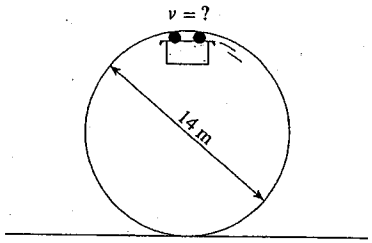
C. 

D. 

14. An airplane is flying in a horizontal circle at a speed of 86 m/s. The 72 kg pilot does not want his centripetal acceleration to exceed 68.6 m/s^2. What is the minimum radius of the circular path?

A. 90 m
B. 110 m
C. 750 m
D. 7700 m

15. A roller coaster car is moving past the top of a loop of diameter 14 m as shown below. The normal force (directed downwards) provided by the track at the top of the loop is equal to one-half the weight of the car.



What is the speed of the coaster car at this point?

A. 5.9 m/s
B. 8.3 m/s
C. 10 m/s
D. 14 m/s

16. The earth pulls an apple towards its centre with a force of 4.9 N. Which of the following is correct?

A. The apple attracts the earth with a force of 4.9 N.
B. The apple does not exert an attractive force on the earth.
C. The apple attracts the earth with a force that is less than 4.9 N.
D. The apple attracts the earth with a force that is more than 4.9 N.

17. A 2500 kg space probe is sitting on the surface of an asteroid of mass 4.8×10^{14} kg. The asteroid has a radius of 3.5×10^{4} m. What is the force of attraction between the space probe and the asteroid?

A. 2.6×10^{-5} N
B. 6.5×10^{-2} N
C. 9.1×10^{-1} N
D. 2.3×10^{3} N

18. A satellite circling the earth completes each orbit in 5.10×10^{3} s. What is the gravitational field strength at the location of the satellite's orbit?

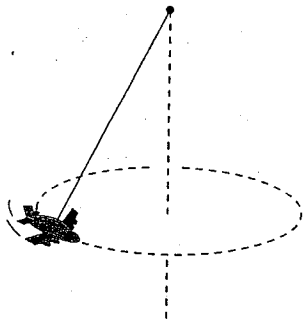
A. 3.08 m/s^2
B. 9.68 m/s^2
C. 9.72 m/s^2
D. 9.80 m/s^2

JANUARY 2004
CIRCULAR MOTION AND GRAVITATION

15. When an object is in uniform circular motion,

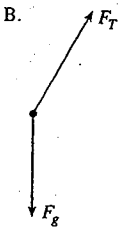
A. its speed is constant.
B. its velocity is constant.
C. its acceleration is constant.
D. the net force on the object is constant.

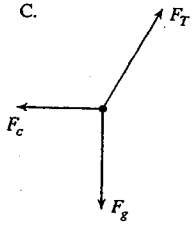
16. A toy airplane, suspended by a light thread, is moving in a circular path at a constant speed as shown.

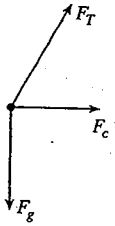


Which of the following is the correct free body diagram for the toy airplane?

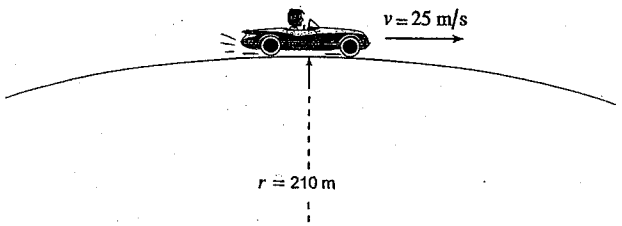
A.

B.


C.


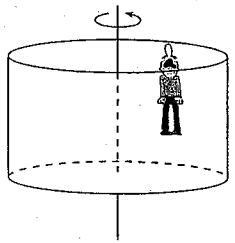
D.


17. A 1400 kg car is travelling at 25 m/s on a circular hill of radius 210 m. What is the normal force on this car at the top of the hill?



A. 4.2×10^{2} N
B. 9.6×10^{3} N
C. 1.4×10^{4} N
D. 2.3×10^{4} N

18. In an amusement park, a 2.8 m radius "drum" rotates such that a person does not fall when the "floor" drops away.



If the coefficient of friction between the person and the wall is 0.35, what is the maximum period of the rotation so that a person will not fall?

A. 2.0 s
B. 3.4 s
C. 5.7 s
D. 18 s

19. Which of the following is a correct statement about gravitational force?

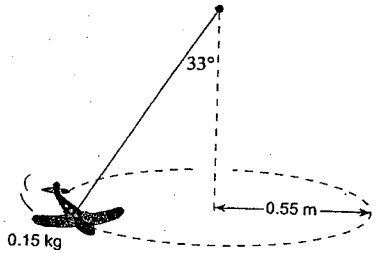
A. It is applicable only to our solar system.
B. It is both an attractive and repulsive force.
C. It is directly proportional to the product of the masses involved.
D. It is directly proportional to both the mass and radius of the earth.

JUNE 2004
CIRCULAR MOTION AND GRAVITATION

14. A 5.0×10^{4} kg moonlet travels in a circular path around a planet. The moonlet's orbital radius is 2.5×10^{7} m and the orbital period is 3.7×10^{5} s. What is the mass of the planet?

A. 1.1×10^{8} kg
B. 6.8×10^{22} kg
C. 3.4×10^{27} kg
D. 2.5×10^{28} kg

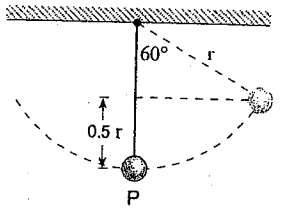
15. A 0.15 kg toy airplane is suspended as shown. It travels in a horizontal circle at a constant speed.



What is the period of the motion of this airplane?

A. 0.84 s
B. 1.6 s
C. 1.8 s
D. 2.0 s

16. A small object of mass m is suspended from a fixed point by a light cord.

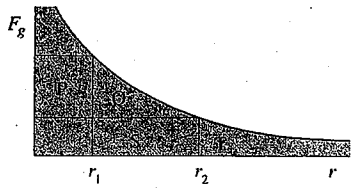


The object is raised to an angle of 60° and released from rest. The object moves in an arc of a circle as shown. When the object passes through its lowest position at point P, what is the tension in the cord in terms of the object's weight (mg)?

A. 0.5 mg
B. 1.0 mg
C. 1.5 mg
D. 2.0 mg

AUGUST 2004
CIRCULAR MOTION AND GRAVITATION

17. The graph shows the gravitational force between the earth and an object as a function of the distance of separation, r, from the centre of the earth.



As the object is moved from r_1 to r_2, what is the work done?

A. Q
B. Q+S
C. P+Q
D. Q+S+T

18. A 200 kg object is released from rest at an altitude of 1.0×10^7 m. What is its impact speed with the earth? Assume no air resistance.

A. 7.0×10^3 m/s
B. 8.7×10^3 m/s
C. 1.1×10^4 m/s
D. 1.4×10^4 m/s

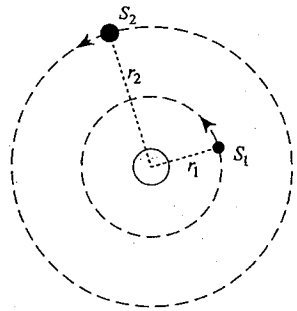
13. The net force acting on a body in uniform circular motion is constant in

A. direction only.
B. magnitude only.
C. both magnitude and direction.
D. neither magnitude nor direction.

14. A 1200 kg car travels with a maximum speed of 24 m/s in a circular path on a dry level road surface where $\mu = 0.90$ between the car tires and the road. What is the radius of this circular path?

A. 27 m
B. 59 m
C. 65 m
D. 640 m

15. Two satellites, S_1 and S_2, are in circular orbits around a planet. Satellite S_2 has twice the mass and twice the orbital radius of satellite S_1.



What is the ratio of the centripetal force on S_2 to that of S_1 $(S_2 : S_1)$?

A. 1:1
B. 1:2
C. 1:4
D. 1:8

16. Which of the following is a correct statement about gravity?

A. An object falling freely has no gravitational force on it.
B. The acceleration due to gravity, g, is a universal constant.
C. The gravitational field of a body follows an inverse square law.
D. The gravitational potential energy varies with the square of distance of separation.

17. The mass of planet Neptune is 17 times more than that of the earth. It has a radius 3.8 times that of the earth. Which of the following is the best approximation of the acceleration due to gravity on the surface of Neptune?

A. $8.3\ m/s^2$
B. $12\ m/s^2$
C. $44\ m/s^2$
D. $170\ m/s^2$

18. How much work is required to raise a 4.0×10^3 kg object to an altitude of 5.0×10^6 m above the earth's surface?

A. 1.1×10^{11} J
B. 1.4×10^{11} J
C. 2.0×10^{11} J
D. 2.5×10^{11} J

ELECTROSTATICS

Electric force and Electric field

Electric potential energy
And
Electric potential

Outcomes	Questions
It is expected that students will apply Coulomb's law to situations involving point charges and demonstrate an understanding of electric fields and their effects on charged objects. *It is expected that students will:* **K1.** state Coulomb's law **K2.** solve problems using Coulomb's law for two point charges, involving: • electric force • charge • distance of separation • Coulomb's constant **K3.** calculate the net electric force on a point charge due to two other point charges **K4.** define electric field **K5.** calculate the net electric field at any point on a line containing two point charges **K6.** describe the electric field lines for simple charge distributions **K7.** describe situations that produce uniform or non-uniform electric fields **K8.** solve problems for a charge in an electric field, involving: • force • charge • electric field	1 2 3 4, 5, 6, 7
L1. define the following: • electric potential energy • electric potential • electric potential difference **L2.** solve problems for a charge in an electric field, involving: • electric potential difference • electric potential energy • charge **L3.** solve problems for a uniform electric field, involving: • electric potential difference • electric field • distance between two locations in a field **L4.** solve problems for two point charges, involving: • electric potential energy • charge • distance of separation • Coulomb's constant **L5.** calculate the work required to move a charge between two locations in an electric field **L6.** solve problems using the law of conservation of energy for a charge in an electric field, involving: • speed • mass • charge • distance • work • electric field • electric potential difference **L7.** apply the principles of electrostatics to qualitatively explain the operation of a cathode-ray tube (CRT) **L8.** solve problems for no more than two point charges, involving: • electric potential relative to zero at infinity • charge • distance	8 9 10

Electrostatics

It is expected that students will apply Coulomb's law to situations involving point charges and demonstrate an understanding of electric fields and their effects on charged objects.
It is expected that students will:

K1 State Coulomb's law

K2 Solve problems using Coulomb's law for two point charges, involving:

- *electric force*
- *charge*
- *distance of separation*
- *Coulomb's constant*

K3 Calculate the net electric force on a point charge due to two other point charges

K4 Define electric field

K5 Calculate the net electric field at any point on a line containing two point charges

K6 Describe the electric field lines for simple charge distributions

K7 Describe situations that produce uniform or non-uniform electric fields

K8 Solve problems for a charge in an electric field, involving:

- *force*
- *charge*
- *electric field*

Unlike charges (e.g. negative and positive) attract each other. Charging by conduction means that a once neutral object becomes charged through contact with a charged object (the two objects will now have the same charge). Charging by induction means that a once neutral object becomes charged by grounding the object in proximity to a charged object. This new charge is opposite to the original charged object. Both methods are caused by the repulsion of like charges.

In conduction, charges on the first object repel each other and some charges are pushed onto the second object. This continues until both objects carry equal charges.

In induction, charges on the first object repel like charges on the second object. When the second object is grounded the charges leave it. The object is left with a net charge opposite that of the first object.

Coulomb applied a charge, Q_1, to one end of a torsion balance. He then placed a second charge, Q_2, near Q_1. The repulsion or attraction between the charges caused the balance to twist. By measuring the angle of twist, Coulomb was able to determine the force of repulsion/attraction and relate this force to the distance between, and magnitudes of both charges.

Through his torsion balance experiments Coulomb was able to determine the following relationship:

Coulomb's Law: $F_e = \frac{kQ_1Q_2}{r^2}$

where F = force on a charged object in newtons, k = Coulomb's Law Constant ($8.99\times10^9\ N\cdot m^2/C^2$), r = distance between the charged objects centers, and and Q_2, and Q_1 = charges on the two objects.

Coulomb's law: $F_e = \frac{kQ_1Q_2}{r^2}$

Newton's universal law: $F_g = \frac{Gm_1m_2}{r^2}$

While the causes of both forces differ, there is an obvious similarity in the relationships between the magnitudes of the forces and the distance separating the objects causing the forces. In both cases the force diminishes as the distance between the objects increases, such that

$$F \propto \frac{1}{r^2}$$

Electric fields have both magnitude and direction. They are therefore vector fields. An electric field is the region around a charge in which a force is exerted upon other charges. A force cannot exist within an electric field unless another charge is present for that force to act upon.

The direction of an electric field is defined as the direction in which a small positive test charge will move when released within the field.

The magnitude of the field emanating from a charged object can be determined by

$$|\vec{E}| = \frac{kQ}{r^2}$$

where E is the electric field in N/C, k is Coulomb's Law Constant , r is the distance from the charged object's center, and Q is the magnitude of the charge on the object.

Electric fields can be added to and subtracted from one another according to their vector nature. In this manner two electric fields of equal strength and opposite direction may be used to cancel out each other.

Similar to a force acting on a mass due to a gravity field, electric fields exert forces on charged objects such that

$$\vec{F}_e = \vec{E}Q$$

where F is the force on the charged object in newtons (N), E is the strength of the electric field in newtons/coulomb (N/C), and Q is the magnitude of the charge on the object in the electric field in coulombs(C).

Uniform electric fields are typically created between two charged plates. The strength of such an electric field can be determined by the formula

$$\left|\vec{E}\right| = \frac{V}{d}$$

where E is the strength of the electric field newtons/coulomb (N/C), V is the voltage potential between the plates, and d is the distance between the two plates.

Using this in combination with Newton's laws of motion and an understanding of accelerating systems, we can determine the path a charged object will take in a uniform electric field.

The potential energy of a charged object in a uniform electrical field can be determined by the formula

$$\Delta E = VQ$$

where ΔE is the potential energy of the charged object in joules (J), V is the potential difference between the charged plates in volts (V), and Q is the charge on the object in coulombs (C).

If the potential energy is released it will become the kinetic energy of the object.

L1 Define the following:

- *electric potential energy*
- *electric potential*
- *electric potential difference*

L2 Solve problems for a charge in an electric field.

L3 Solve problems for a uniform electric field

L4 Solve problems for two point charges

L5 Calculate the work required to move a charge between two locations in an electric field

L6 Solve problems using the law of conservation of energy for a charge in an electric

L7 Apply the principles of electrostatics to qualitatively explain the operation of a cathode-ray tube (CRT)

L8 Solve problems for no more than two point charges

Similar to gravitational potential energy, the area under the curve of a "F_e vs r" graph tells us the work done to move two charges Q_1 and Q_2 closer together or further apart. This similarity is attributable to Newton's Law of Universal Gravitation being similar to Coulombs Law. The area under the curve is given by:

$$W = \frac{kQ_1Q_2}{r}$$

where k = Coulomb's constant ($9.00\times10^9\ \mathrm{N\cdot m^2/C^2}$) and r = the distance between two charges. We take the potential energy of the charges to be zero when they are infinitely apart. The electric potential energy at a certain point is defined as the work done to bring a one Coulomb positive charge from infinity to that point. Thus , we can modify our earlier equation to the following:

$V = \frac{kQ}{r}$, where V is electric potential and r is the distance from charge Q.

Since we have two types of charges, positive and negative (a problem that we did not have with mass), the positive charge is selected to be the standard. Thus the electric potential in the above equation is positive for positive charges but negative for negative charges.

Since $\Delta E_p = (\Delta V)Q$ (by definition),

then $E_p = \frac{kQ_1Q_2}{r}$.

If Q_1 and Q_2 are opposite charges, then E_p is negative. If they are like charges, then E_p is positive. Both electric potential (measured in volts) and electric potential energy (measured in joules) are scalar quantities even though both can be either negative or positive.

To calculate the total electric potential at a certain point due to two separate charges, use the following:

$$V_T = V_1 + V_2$$

or $V_T = \frac{kQ_1}{r_1} + \frac{kQ_2}{r_2}$

It is important to keep track of whether the charges are negative or positive.

To measure the work required to move a certain charge in the vicinity of other charges, we use

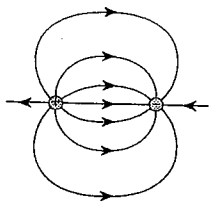
$$W = \Delta E_p = (\Delta V)Q$$

We must first calculate the change in electric potential (ΔV) between the two points in question and then multiply by the magnitude of the charge that is being moved. Since all these quantities are scalars, the actual path taken during the move is not important. All that matters is the initial point and the final destination. It is important to note that the electric field strength around point charges is non-uniform (it changes with distance). By comparison, the electric field between two charged plates is uniform and thus may be easier to manage.

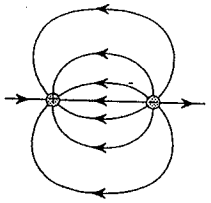
JANUARY 2000
ELECTROSTATICS

19. Which of the following diagrams shows the electric field between two equal but opposite charges?

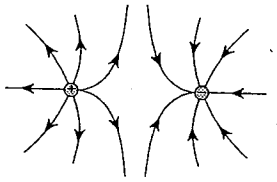
A.



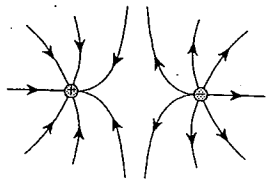
B.



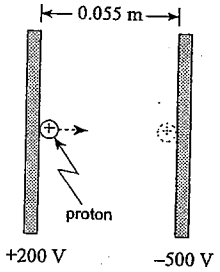
C.



D.



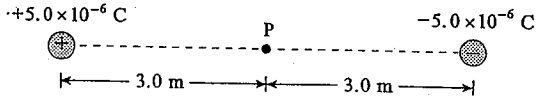
20. A proton initially at rest is accelerated between parallel plates through a potential difference of 700 V.



What is the maximum speed reached by the proton?

A. 8.6×10^{4} m/s
B. 3.1×10^{5} m/s
C. 3.7×10^{5} m/s
D. 1.6×10^{6} m/s

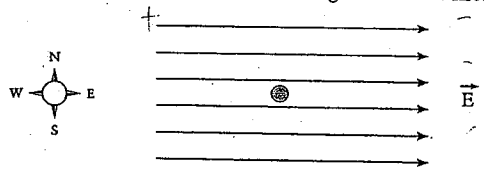
21. What are the magnitudes of the electric field and the electric potential at point P midway between the two fixed charges?



	Magnitude of Electric Field	Electric Potential
A.	0 N/C	0 V
B.	0 N/C	30 000 V
C.	10 000 N/C	0 V
D.	10 000 N/C	30 000 V

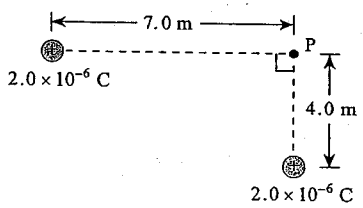
JUNE 2000
ELECTROSTATICS

18. An electron in the electric field has an electric force acting on it in what direction?



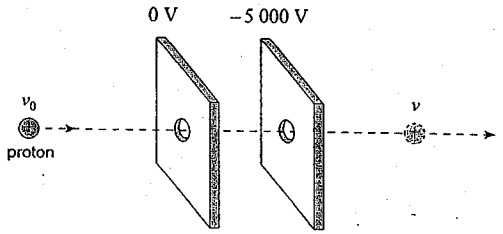
A. North
B. South
C. East
D. West

19. What is the electric potential at point P due to the two fixed charges as shown?



A. 1 200 V
B. 1 500 V
C. 5 200 V
D. 7 100 V

20. A moving proton has 6.4×10^{-16} J of kinetic energy. The proton is accelerated by a potential difference of 5 000 V between parallel plates.



The proton emerges from the parallel plates with what speed?

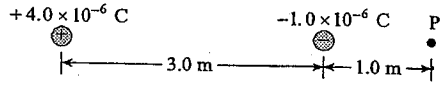
A. 8.8×10^{5} m/s
B. 9.8×10^{5} m/s
C. 1.3×10^{6} m/s
D. 1.8×10^{6} m/s

AUGUST 2000
ELECTROSTATICS

18. The electric field is uniform between

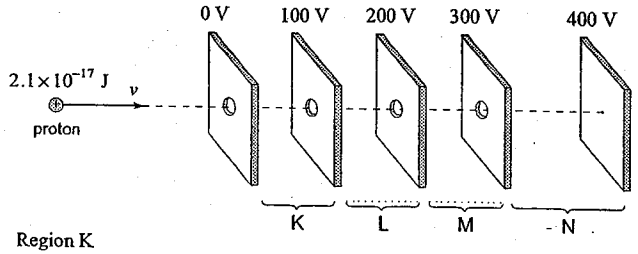
A. two positive point charges.
B. two negative point charges.
C. two opposite point charges.
D. two oppositely charged parallel plates.

19. What is the magnitude and direction of the electric field at point P due to the two fixed charges?



	Electric Field at Point P	
	Magnitude	Direction
A.	6 800 N/C	Right
B.	6 800 N/C	Left
C.	11 000 N/C	Right
D.	11 000 N/C	Left

20. A proton with kinetic energy of 2.1×10^{-17} J is moving into a region of charged parallel plates. The proton will be stopped momentarily in what region?



A. Region K
B. Region L
C. Region M
D. Region N

JANUARY 2001

ELECTROSTATICS

20. Which of the following best describes how electric potential varies with distance in the region around a point charge?

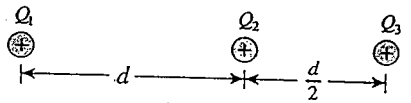
A. $V \propto r$

B. $V \propto \frac{1}{r}$

C. $V \propto r^2$

D. $V \propto \frac{1}{r^2}$

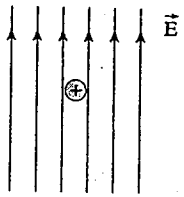
21. Three **identical** positive electric charges are fixed as shown in the diagram below.



What is the direction of the net electric force on Q_2 due to Q_1 and Q_3?

A. to the left
B. to the right
C. the net force is zero
D. cannot be determined

22. In an experiment, a positively charged oil droplet weighing 6.5×10^{-15} N is held stationary by a vertical electric field as shown in the diagram.



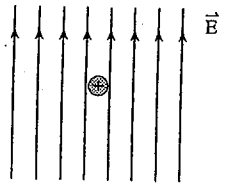
If the electric field strength is 5.3×10^{3} N/C, what is the charge on the oil droplet?

A. 1.2×10^{-18} C
B. 3.4×10^{-11} C
C. 4.1×10^{4} C
D. 8.2×10^{17} C

JUNE 2001

ELECTROSTATICS

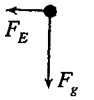
19. A positively charged oil droplet is in a vertical electric field.



Which of the following is a correctly labelled free-body diagram showing the forces acting on the oil droplet?

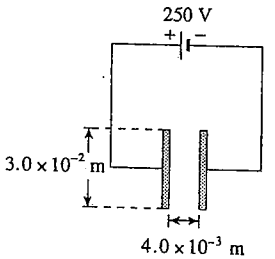
A. 

B. 

C. 

D. 

20. What are the magnitude and direction of the electric field between the plates in the situation shown below?

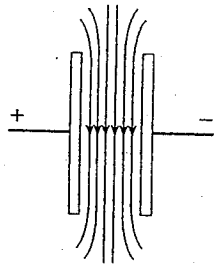


	DIRECTION OF FIELD	MAGNITUDE OF FIELD (V/m)
A.	left	8.3×10^{3}
B.	right	8.3×10^{3}
C.	left	6.3×10^{4}
D.	right	6.3×10^{4}

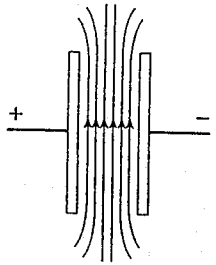
AUGUST 2001
ELECTROSTATICS

19. Which of the following best illustrates the electric field between parallel plates with opposite electric charges?

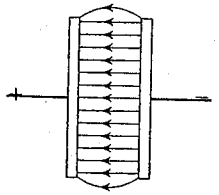
A.



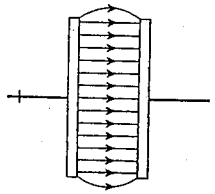
B.



C.



D.



20. The atomic nucleus of uranium contains 92 protons. What is the direction and magnitude of the electric field 2.5×10^{-10} m from this nucleus?

	DIRECTION OF ELECTRIC FIELD	MAGNITUDE OF ELECTRIC FIELD
A.	towards nucleus	5.3×10^{2} N/C
B.	away from nucleus	5.3×10^{2} N/C
C.	towards nucleus	2.1×10^{12} N/C
D.	away from nucleus	2.1×10^{12} N/C

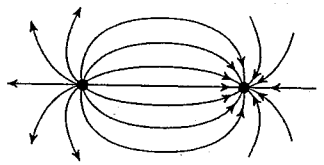
21. A 0.16 C charge is moved in an electric field from a point with a potential of 25 V to another point with a potential of 95 V. How much work was done to move this charge?

A. 4.0 J
B. 11 J
C. 15 J
D. 19 J

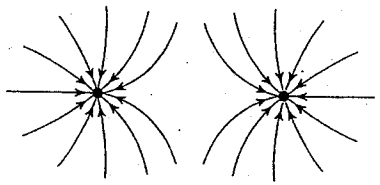
JANUARY 2002
ELECTROSTATICS

18. Which of the following shows the electric field for two opposite unequal point charges?

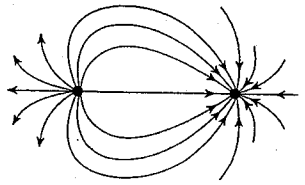
A.



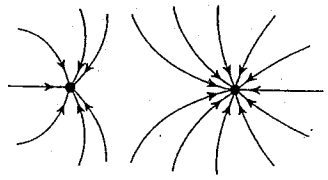
B.



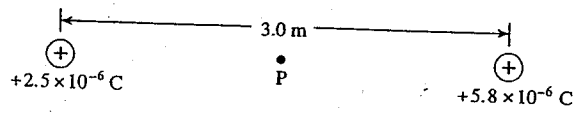
C.



D.



19. Two positive point charges are placed 3.0 m apart as shown.



What is the magnitude of the electric field at point P midway between the two charges?

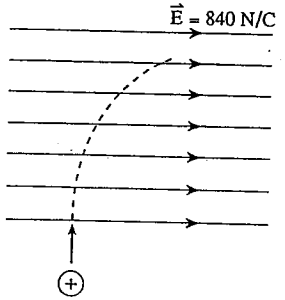
A. 0 N/C
B. 3 300 N/C
C. 13 000 N/C
D. 33 000 N/C

JUNE 2002.
ELECTROSTATICS

19. Which of the following are correct units for electric potential?

A. J/s
B. J/C
C. N/m
D. N/C

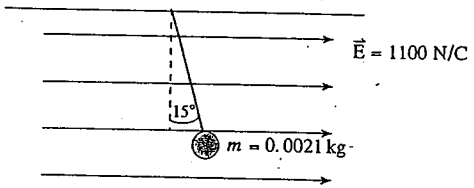
20. A proton beam is fired into a uniform electric field. The protons follow a parabolic path as shown.



What is the acceleration of these protons?

A. 1.3×10^{-16} m/s^2
B. 8.0×10^{10} m/s^2
C. 1.5×10^{14} m/s^2
D. 5.0×10^{29} m/s^2

21. A small 0.0021 kg plastic ball is suspended by a string in a uniform electric field as shown.

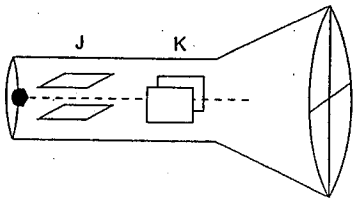


If the string makes an angle of 15° with the vertical, as indicated, what is the charge on the ball?

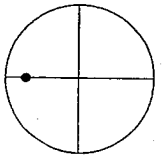
A. 4.8×10^{-6} C
B. 5.0×10^{-6} C
C. 1.9×10^{-5} C
D. 5.5×10^{-3} C

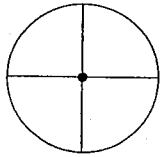
AUGUST 2002
ELECTROSTATICS

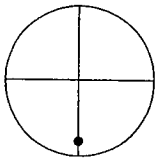
18. In the CRT shown below, a potential difference is only applied to the set of plates at J.

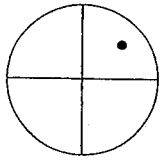


Which of the following could show the position of the electron beam on the screen?

A.


B.


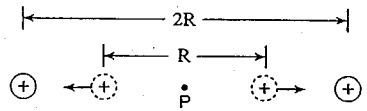
C.


D.


19. In one model of the hydrogen atom, the electron orbits the proton at a distance of 5.1×10^{-11} m. What is the electrostatic force between these two particles?

A. 3.9×10^{-47} N
B. 5.3×10^{-27} N
C. 4.5×10^{-18} N
D. 8.9×10^{-8} N

20. Two equal positive point charges are placed at distance R from each other. They are then moved to a distance of 2R away from each other. The electric potential and electric field at point P midway between the charges are measured before and after the move.



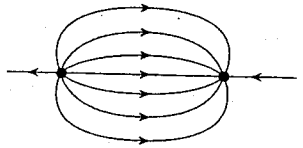
Which of the following is correct?

	NEW ELECTRIC POTENTIAL	NEW ELECTRIC FIELD
A.	half the original electric potential	half the original electric field
B.	same as the original electric potential	half the original electric field
C.	half the original electric potential	same as the original electric field
D.	same as the original electric potential	same as the original electric field

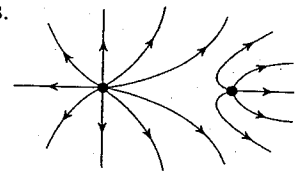
JANUARY 2003
ELECTROSTATICS

18. Which of the following represents the electric field between two opposite point charges of different magnitudes?

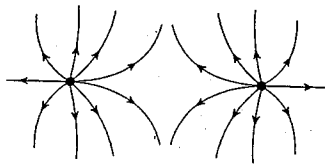
A.



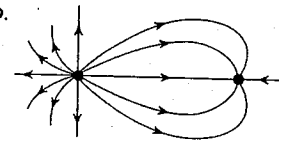
B.



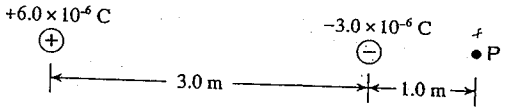
C.



D.

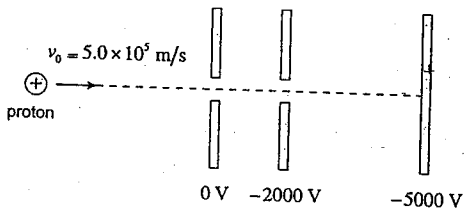


19. What are the magnitude and direction of the electric field at point P?



	MAGNITUDE OF ELECTRIC FIELD AT P	DIRECTION OF ELECTRIC FIELD AT P
A.	2.4×10^4 N/C	left
B.	2.4×10^4 N/C	right
C.	3.0×10^4 N/C	left
D.	3.0×10^4 N/C	right

20. A proton moving at 5.0×10^5 m/s enters a series of charged parallel plates. What is the impact speed on the last plate?

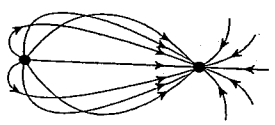


A. 9.1×10^5 m/s
B. 9.8×10^5 m/s
C. 1.1×10^6 m/s
D. 1.3×10^6 m/s

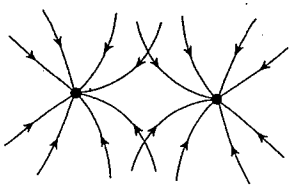
JUNE 2003
ELECTROSTATICS

18. Which of the following is a possible electric field configuration?

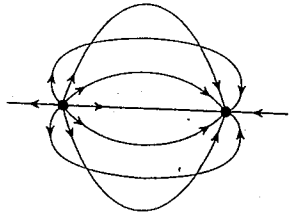
A.



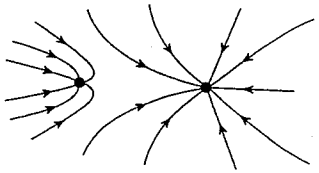
B.



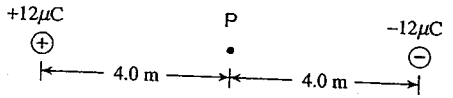
C.



D.



19. What is the electric potential at point P midway between the two point charges shown below? $(1\,\mu C = 1.0\times10^{-6}\ C)$



A. 0 V
B. 6.8×10^{3} V
C. 1.4×10^{4} V
D. 5.4×10^{4} V

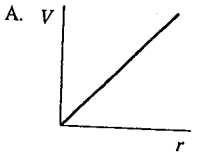
20. A proton is moving at 5.0×10^{6} m/s when it is 8.0 m from a fixed 1.5×10^{-5} C charge Q. What is the speed of the proton when it is 2.0 m from the fixed charge Q ?

A. 2.5×10^{6} m/s
B. 3.6×10^{6} m/s
C. 3.9×10^{6} m/s
D. 4.5×10^{6} m/s

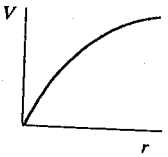
AUGUST 2003
ELECTROSTATICS

19. Which of the following shows how electric potential varies with distance from a positive point charge?

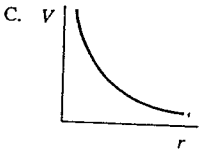
A.



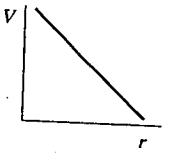
B.



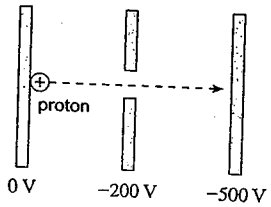
C.



D.



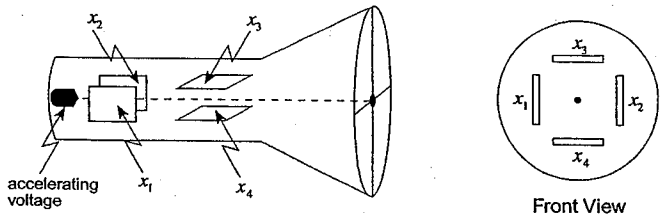
20. At what speed will a proton, accelerated from rest, hit the plate at the right?



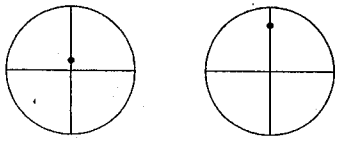
A. 2.2×10^{5} m/s
B. 2.4×10^{5} m/s
C. 3.1×10^{5} m/s
D. 4.4×10^{5} m/s

JANUARY 2004
ELECTROSTATICS

21. Two views of a cathode ray tube are shown below.



The beam is then adjusted to Position 1 as shown below.



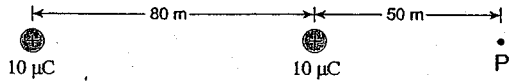
In order to change the electron beam from Position 1 to Position 2, a student can

A. make plate x_2 more positive.
B. make plate x_4 more positive.
C. increase the accelerating voltage.
D. decrease the accelerating voltage.

20. What does an electric field line indicate?

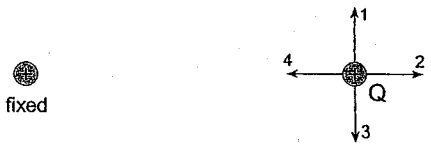
A. The direction of the electrostatic force on a positive charge.
B. The direction of the electrostatic force on a negative charge.
C. The magnitude of the electrostatic force on a positive charge.
D. The magnitude of the electrostatic force on a negative charge.

21. What is the magnitude of the electric field at point P in the diagram below? $\left(1\ \mu C = 1\times10^{-6}\ C\right)$



A. 22 N/C
B. 31 N/C
C. 41 N/C
D. 50 N/C

22. A positive charge Q is located several metres from a fixed positive charge as shown in the diagram below.



You are told to move charge Q a distance of 1.0 m so as to cause the greatest increase in its electrical potential energy. In which direction do you move it?

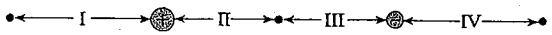
A. 1
B. 2
C. 3
D. 4

JUNE 2004
ELECTROSTATICS

19. Which of the following is equal to the work required per coulomb to move a positive charge from one position to another in an electric field?

A. E_p, electric potential energy
B. ΔE_p, change in electric potential energy
C. V, electric potential
D. ΔV, electric potential difference

20. The diagram below shows a positive charge located near a smaller (in magnitude) negative charge. In which region is there a point where the electric field due to the two charges is equal to zero?



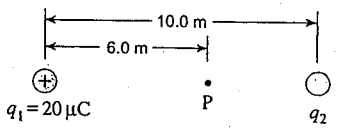
A. I
B. II
C. III
D. IV

AUGUST 2004
ELECTROSTATICS

19. The magnitude of the force experienced by any charged object, q, when placed in an electric field is equal to which of the following?

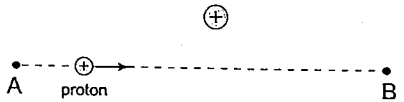
A. $\frac{V}{q}$
B. $\frac{E_p}{q}$
C. $\Delta V \cdot q$
D. $E \cdot q$

20. The electric field at point P in the diagram below is 8500 N/C directed to the right. What is the size and polarity of charge q_2? ($1\mu C = 1\times10^{-6}$ C)



	Polarity	Size
A.	+	6.2 μC
B.	–	6.2 μC
C.	+	14 μC
D.	–	14 μC

21. A proton is made to travel in a straight line near a fixed positively charged object as shown in the diagram below. What is happening to the proton's electric potential energy as it travels from A to B?



A. It is increasing.
B. It is decreasing.
C. It is increasing then decreasing.
D. It is decreasing then increasing.

ELECTRIC CIRCUITS

Ohm's Law
And
Kirschoff's Laws

Power and Energy

Outcomes	Questions
It is expected that students will demonstrate an ability to use Ohm's law and Kirchhoff's laws and apply them to direct current circuits in everyday situations.	
It is expected that students will:	
M1. define electric current	1
M2. solve problems involving: • current • time • charge	
M3. relate conventional current direction to the direction of electron flow in a conductor	2
M4. define resistance in terms of Ohm's law	
M5. solve problems involving: • electric potential difference • current • resistance	
M6. calculate the total (equivalent) resistance for resistors connected in parallel, series, or a combination	3
M7. state Kirchhoff's laws and apply them to circuits containing one source of electric potential difference	4, 5
M8. demonstrate the ability to construct circuits from schematic diagrams	
M9. demonstrate the correct placement and use of an ammeter and voltmeter in a circuit	6, 7
M10. define electromotive force (emf), terminal voltage, and internal resistance	
M11. solve problems using: • terminal voltage • electromotive force (emf) • internal resistance • current • electric potential difference	8, 9
N1. define electric power	
N2. solve problems involving: • electric power • electric potential difference • current • resistance • efficiency	10, 11
N3. compare energy consumption of various household electrical appliances	
N4. explain why electric energy is transmitted through transmission lines at high potential	

Electric Circuits

Ohm's Law and Kirchoff's Law

M1 Define electric current

M2 Solve problems involving:

- *current*
- *time*
- *charge*

M3 Relate conventional current direction to the direction of electron flow in a conductor

M4 Define resistance in terms of Ohm's law

M5 Solve problems involving:

- *electric potential difference*
- *current*
- *resistance*

M6 Calculate the total (equivalent) resistance for resistors connected in parallel, series, or a combination

M7 State Kirchhoff's laws and apply them to circuits containing one source of electric potential difference

M8 Demonstrate the ability to construct circuits from schematic diagrams

M9 Demonstrate the correct placement and use of an ammeter and voltmeter in a circuit

Electrical current is the flow of electrical charge in conductors, given in amperes(A or C/s). Potential difference or voltage is the energy per unit charge (V or J/C).

Resistance is the ratio of the voltage applied across a material to the current running through it (Ω).

Electrical Power is the rate at which work is done (W or J/s).

Electrical current, I, is the rate at which electrical charge flows through any given point in a conductor.

i.e., current is a measure of the change in charge per time unit.

$$I = \frac{\Delta Q}{\Delta t}$$

One ampere (A) is equal to a flow of one coulomb through a given point in one second.

1A=1C/s

Electron flow is the flow of electrical energy from the negative terminal to the positive terminal of a battery. As the name suggests, it follows the motion of electrons through the conductor.

Conventional current is the flow of positive charges from the positive terminal to the negative terminal of a battery. Conventional flow is still used in some electrical engineering applications where it is more practical.

According to Ohm's law, an object's resistance is affected by its dimensions, its resistivity, and its temperature. Resistance can also be explained if we compare electron flow through a wire to water flow through a pipe.

If the pipe is wide, less pressure is required to move the water. Similarly a wire with a larger cross-sectional surface area presents less resistance. Also it is more difficult to push water through a longer pipe than through a shorter pipe. Increasing the length of a wire will increase resistance in the same manner.

Resistivity is in the nature of the material from which the wire is made. If we change the substance in a pipe from water to a more viscous substance, like molasses, it will flow more slowly. If we use a more resistive metal for the wire we increase its resistance.

Unfortunately our water analogy fails when it comes to temperature. As water cools it becomes more viscous and it encounters more resistance. Conversely, as we cool a wire we allow electrons to flow more freely through it, thus resistance decreases. In fact if we cool some conductors to near absolute zero, they will lose all their resistance and become a super-conductor. Scientists in the field are experimenting with ceramics that become super-conductors at "warmer" temperatures (around -100°C).

Ohm's law states that the potential difference or "voltage drop" across a resistor is equal to the product of the current through it and its resistance.

$V=IR$

The power dissipated across a resistor is equal to the product of the voltage drop across it and the current through it

$P=IV$

Thus a drop of 1 V across a resistor through which 1A flows dissipates 1VA of power.

$$1VA=1\frac{J}{C}\times\frac{C}{s}=1\frac{J}{s}=1W$$

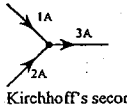
Electrical power is lost mostly in the form of heat.

Also, if we combine the two formulae we have two new formulae which can be used to describe power loss across a resistor

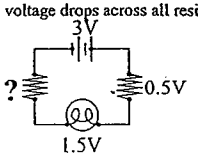
(i) $P=IV$ $V=IR$ $P=I^2R$

(ii) $P=IV$ $I=\frac{V}{R}$ $P=\frac{V^2}{R}$

Kirchhoff's first rule, the junction theorem, relates to conservation of charge and states: "the sum of currents into a given junction is equal to the sum of the currents out of that junction."



Kirchhoff's second rule, the loop equation, relates to conservation of energy and states: "the potential difference across a circuit is equal to the sum of the voltage drops across all resistances on that circuit."



The order in which Kirchhoff's rules are applied depends on the variable for which we are solving. If we are given currents and resistances for all branches of a parallel circuit, and we are asked to find the voltage of the power supply, we first apply Ohm's Law and then the loop equation. If the current is unknown, then we apply the junction theorem last, assuming other rules are needed for intermediate steps.

M10 Define electromotive force (emf), terminal voltage, and internal resistance

M11 Solve problems using:

- *terminal voltage*
- *electromotive force (emf)*
- *internal resistance*
- *current*
- *electric potential difference*

N1 Define electric power

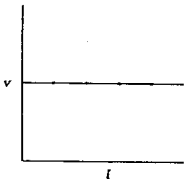
N2 Solve problems involving:

- *electric power*
- *electric potential difference*
- *current*
- *resistance*
- *efficiency*

N3 Compare energy consumption of various household electrical appliances

N4 Explain why electric energy is transmitted through transmission lines at high potential

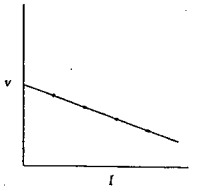
We often treat the power supply in a circuit as ideal. The potential difference supplied to the circuit will not change if we vary the resistance (and consequently the current) in the circuit. This is demonstrated in the following plot



In reality, all power supplies or sources of emf have some internal resistance which changes the potential difference supplied to the circuit as the resistance and current varies.

$V_{terminal} = \varepsilon - Ir$

The formula shows how the terminal voltage ($V_{terminal}$) goes down as the current (I) through a battery's internal resistance (r) goes up.

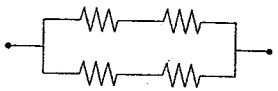


In the above plot, the y-intercept is the battery's rated emf (ε) and the slope is its internal resistance (r). As a battery "dies" its internal resistance increases to the point that the terminal voltage drops to zero.

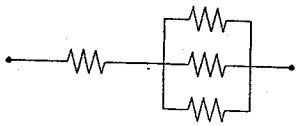
JANUARY 2000
ELECTRIC CIRCUITS

22. Which of the following arrangements would draw the largest current when connected to the same potential difference? All resistors have the same value.

A.

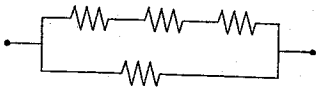


B.

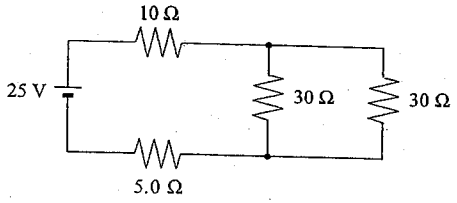


C.

D.



23. What is the power dissipated by the 5.0 Ω resistor in the following circuit?

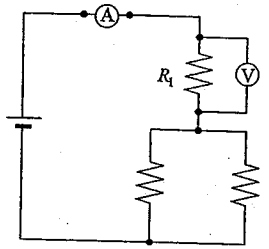


A. 0.56 W
B. 3.5 W
C. 6.2 W
D. 130 W

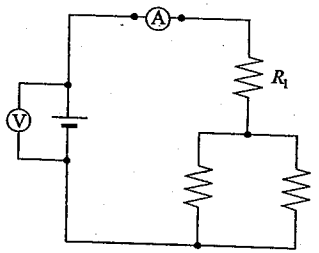
JUNE 2000
ELECTRIC CIRCUITS

21. Which one of the following shows the correct placement of an ammeter and a voltmeter to determine the power output of resistor R_1?

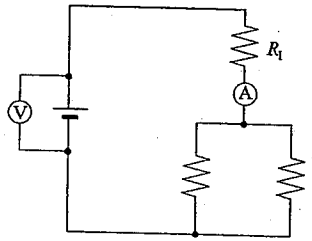
A.



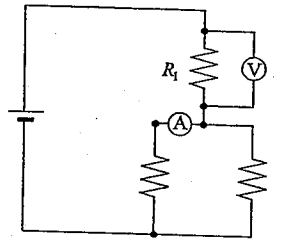
B.



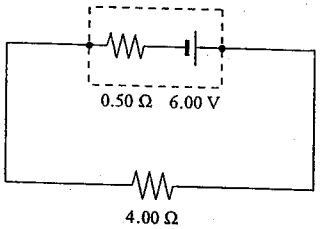
C.



D.



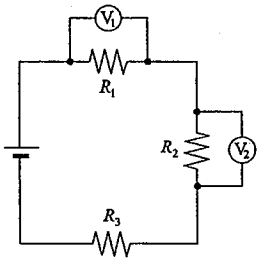
22. What is the terminal voltage of the battery in the circuit shown below?



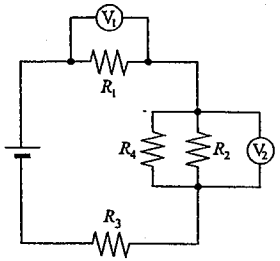
A. 5.25 V
B. 5.33 V
C. 6.00 V
D. 6.67 V

23. In circuit one, resistors and voltmeters are connected as shown. In circuit two, an additional resistor R_4 is placed in parallel with resistor R_2.

Circuit One



Circuit Two



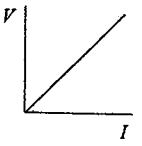
How have the values of V_1 and V_2 in circuit two changed compared to those in circuit one?

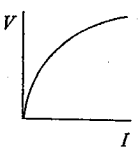
	V_1	V_2
A.	no change	decreased
B.	decreased	increased
C.	increased	decreased
D.	increased	no change

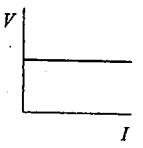
AUGUST 2000

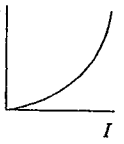
ELECTRIC CIRCUITS

21. Which of the following graphs illustrates Ohm's law?

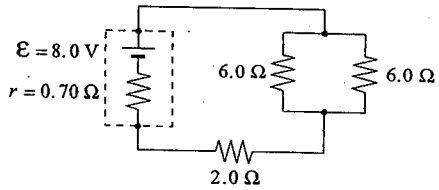
A.


B.


C.


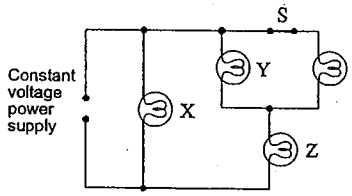
D.


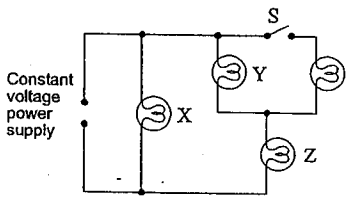
22. In the following circuit, what is the terminal voltage of the battery?



A. 6.9 V
B. 7.0 V
C. 8.0 V
D. 9.0 V

23. If switch S is opened, how does the brightness of each bulb (X, Y, and Z) compare to the situation when the switch was closed?



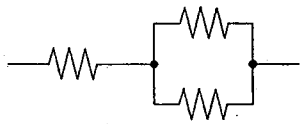


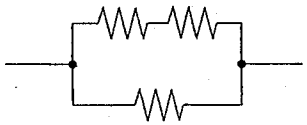
	BULB X	BULB Y	BULB Z
A.	same	same	same
B.	same	dimmer	brighter
C.	same	brighter	dimmer
D.	dimmer	dimmer	dimmer

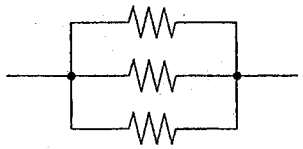
JANUARY 2001
ELECTRIC CIRCUITS

23. Which of the following combinations of three identical resistors has the least equivalent resistance?

A. 

B. 

C. 

D. 

24. An electrical device with a constant resistance draws 0.75 A when connected to a 4.8 V source. What are the current and power for this device when it is connected to a 6.0 V source?

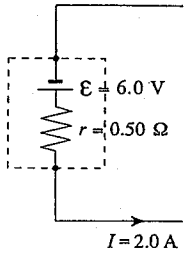
	CURRENT (A)	POWER (W)
A.	0.75	3.6
B.	0.75	5.6
C.	0.94	3.6
D.	0.94	5.6

JUNE 2001
ELECTRIC CIRCUITS

21. Current is a measure of

A. the number of charges stored in a cell.
B. the amount of energy given to a charged object.
C. the charge passing a point in a circuit in a given time.
D. the resistance to the flow of charged particles in a circuit.

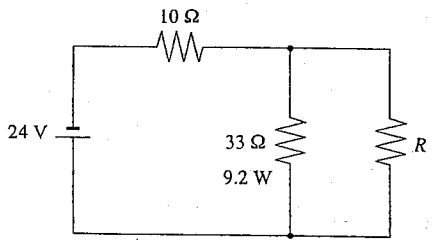
22. The battery in the diagram below is delivering a current of 2.0 A.



What will be the reading on a voltmeter connected to the battery terminals?

A. 1.0 V
B. 5.0 V
C. 6.0 V
D. 7.0 V

23. What is the total power dissipated by the three resistors in the circuit shown below?



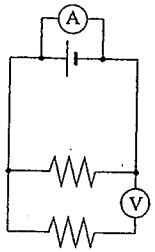
A. 12 W
B. 16 W
C. 23 W
D. 30 W

AUGUST 2001

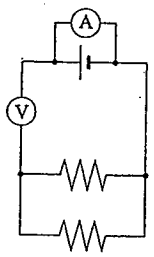
ELECTRIC CIRCUITS

22. Which of the following diagrams shows an ammeter correctly placed to measure the circuit current and a voltmeter correctly placed to measure the potential difference across the battery?

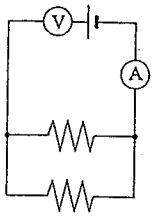
A.



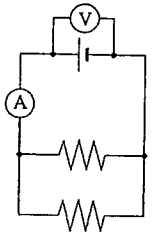
B.



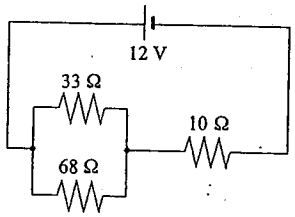
C.



D.



23. What is the current through the 10 Ω resistor in the circuit shown below?

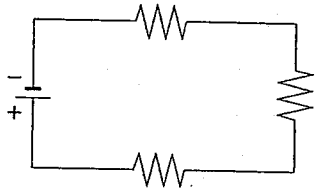


A. 0.11 A
B. 0.37 A
C. 1.2 A
D. 1.7 A

JANUARY 2002

ELECTRIC CIRCUITS

20. Examine the electric circuit below.



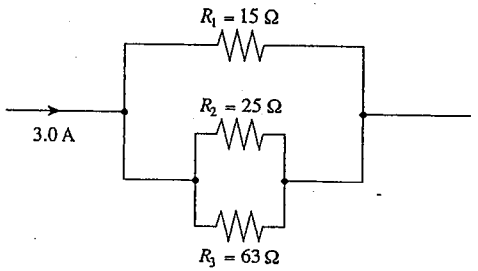
What is the direction of conventional current and electron flow in this circuit?

	CONVENTIONAL CURRENT	ELECTRON FLOW
A.	clockwise	clockwise
B.	clockwise	counter-clockwise
C.	counter-clockwise	clockwise
D.	counter-clockwise	counter-clockwise

21. A potential difference of 12 V causes 0.35 C of electric charge to pass through a resistor in 2.6 s. What power does the resistor dissipate?

A. 1.6 W
B. 4.2 W
C. 11 W
D. 89 W

22. The diagram below shows part of an electric circuit.

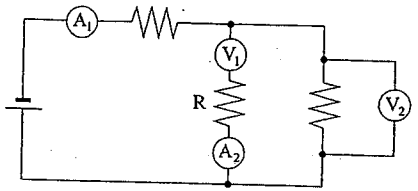


What is the current through resistor R_1?

A. 1.0 A
B. 1.4 A
C. 1.6 A
D. 3.0 A

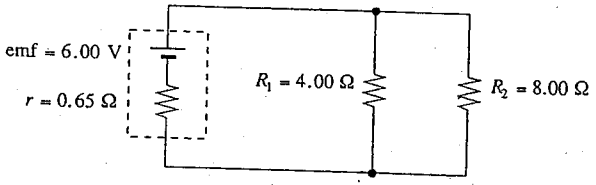
JUNE 2002
ELECTRIC CIRCUITS

22. Which of the following meter placements would allow you to measure the current through and electric potential difference across resistor, *R*?



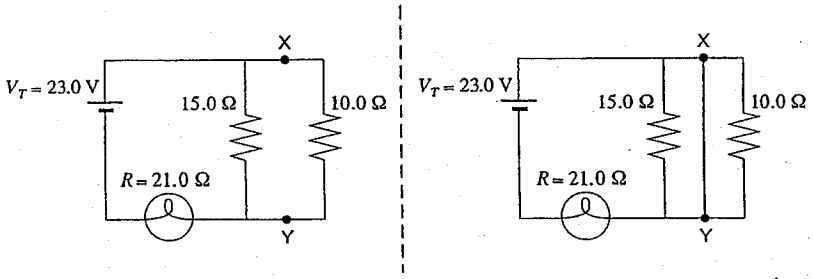
	AMMETER	VOLTMETER
A.	A_1	V_1
B.	A_2	V_1
C.	A_1	V_2
D.	A_2	V_2

23. What current flows through the 4.00 Ω resistor in the following circuit?



A. 0.47 A
B. 1.2 A
C. 1.3 A
D. 1.5 A

24. A circuit is made from two resistors and a light bulb as shown on the left. A short time later a copper wire is connected across points X and Y as shown on the right diagram.



What is the current through the light bulb and what happens to the brightness of the bulb when the wire is connected?

	CURRENT	BRIGHTNESS OF BULB
A.	0.64 A	dimmer
B.	0.64 A	brighter
C.	1.10 A	dimmer
D.	1.10 A	brighter

AUGUST 2002
ELECTRIC CIRCUITS

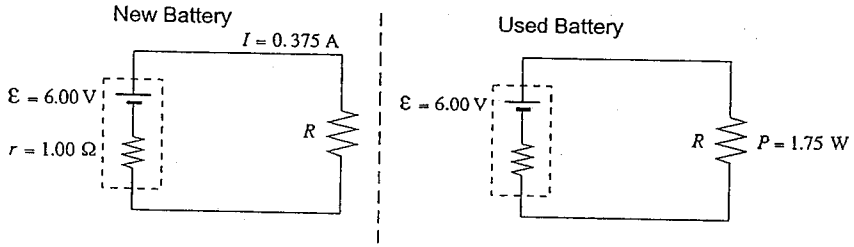
21. What happens to the total resistance of a circuit as one more resistor is added in parallel?

A. The total resistance decreases.
B. The total resistance increases.
C. The total resistance becomes zero.
D. The total resistance does not change.

22. The headlights in a car use 95 W of power. A driver parks her car but leaves the lights on. The 12 V battery has 3.4×10^5 C of stored charge. How long does it take for the battery to lose its charge?

A. 1.1×10^3 s
B. 3.6×10^3 s
C. 4.3×10^4 s
D. 2.7×10^6 s

23. A circuit using a new battery which has an emf of 6.00 V and an internal resistance of 1.00 Ω is shown on the left. The battery is then replaced with a used one that has the same emf of 6.00 V but a different internal resistance.



If resistor R now dissipates 1.75 W, what is the internal resistance of the used battery?

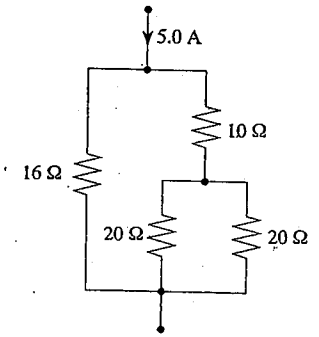
A. 1.00 Ω
B. 2.57 Ω
C. 3.55 Ω
D. 5.60 Ω

JANUARY 2003
ELECTRIC CIRCUITS

21. Which of the following is a correct statement?

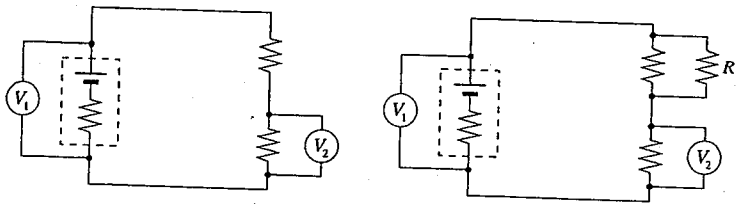
A. The current in a typical resistor is directly proportional to the applied voltage.
B. The current in a typical resistor is inversely proportional to the applied voltage.
C. The total current into a junction is less than the total current out of the junction.
D. The total current into a junction is greater than the total current out of the junction.

22. The following diagram shows part of a complete circuit. What is the power dissipated in one of the 20 Ω resistors?



A. 16 W
B. 25 W
C. 33 W
D. 99 W

23. Circuit 1 is shown below. Resistor R is added to form circuit 2.



Circuit 1 Circuit 2

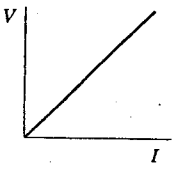
When resistor R is added, how do the voltmeter readings change?

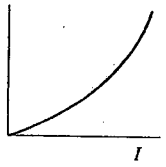
	V_1	V_2
A.	decrease	decrease
B.	decrease	increase
C.	increase	decrease
D.	increase	increase

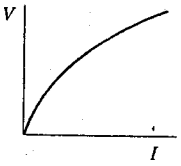
8

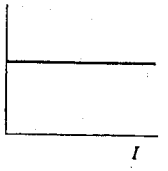
JUNE 2003
ELECTRIC CIRCUITS

21. Which of the following illustrates Ohm's Law?

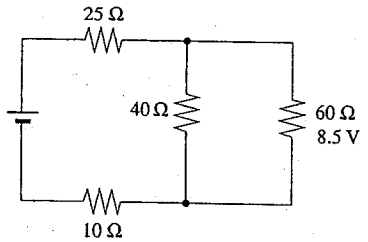
A. 

B. 

C. 

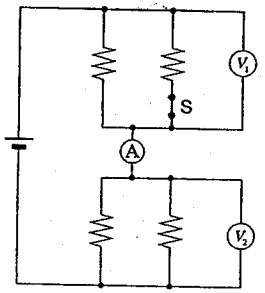
D. 

22. What is the total power dissipated by the four resistors in the diagram below?



A. 1.7 W
B. 2.7 W
C. 4.7 W
D. 7.4 W

23. The circuit and meters are connected as shown with the switch S closed.

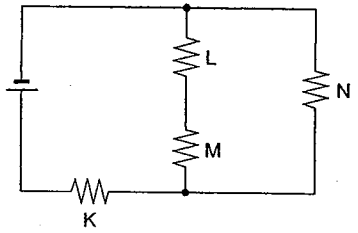


If the switch is then opened, what effects will be observed in the readings of the three meters? (All resistors have the same value.)

	V_1	V_2	A
A.	decreased	no change	decreased
B.	decreased	increased	decreased
C.	increased	decreased	increased
D.	increased	decreased	decreased

AUGUST 2003
ELECTRIC CIRCUITS

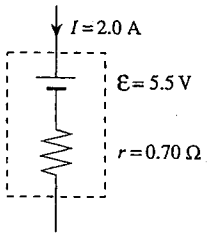
22. All the resistors shown in the circuit have the same resistance value.



Which resistor dissipates the most heat?

A. K
B. L
C. M
D. N

23. A battery is being charged by a 2.0 A current as shown in the diagram below.

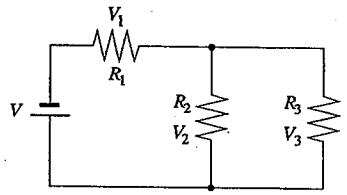


What is the terminal voltage of this battery?

A. 1.4 V
B. 4.1 V
C. 5.5 V
D. 6.9 V

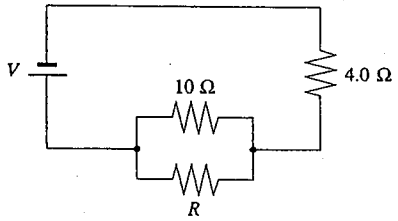
JANUARY 2004
ELECTRIC CIRCUITS

23. Which of the following statements is true for the electric circuit shown below, regardless of the resistors used?



A. $V_1 = V_2$
B. $V = V_2 + V_3$
C. $V = V_1 + V_3$
D. $V = V_1 + V_2 + V_3$

24. What value of R in the circuit shown below will cause the parallel combination (10 Ω and R) to dissipate the same power as the 4.0 Ω resistor?



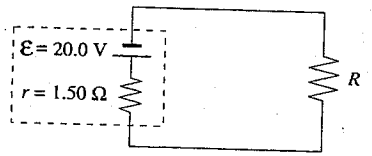
A. 0.26 Ω
B. 2.9 Ω
C. 6.0 Ω
D. 6.7 Ω

JUNE 2004
ELECTRIC CIRCUITS

21. Which of the following is always true for resistors in parallel or in series?

	Resistors in parallel	Resistors in series
A.	equal currents	equal currents
B.	equal currents	equal voltage drops
C.	equal voltage drops	equal currents
D.	equal voltage drops	equal voltage drops

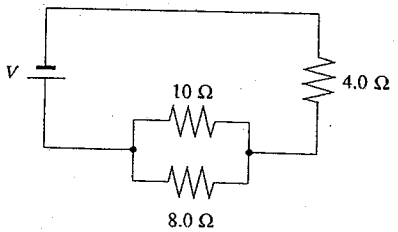
22. In the circuit shown below the voltage loss due to the battery's internal resistance is 2.0 V.



Determine the value of the load resistance R.

A. 12.0 Ω
B. 13.3 Ω
C. 13.5 Ω
D. 15.0 Ω

23. A resistor is added in parallel to the 4.0 Ω resistor shown in the diagram below.



What happens to the power dissipated by the 8.0 Ω resistor and by the 4.0 Ω resistor?

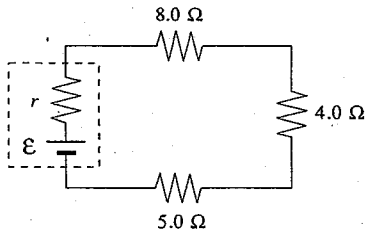
	$P_{8.0}$	$P_{4.0}$
A.	decreases	increases
B.	decreases	decreases
C.	increases	increases
D.	increases	decreases

AUGUST 2004
ELECTRIC CIRCUITS

22. The terminal voltage of a battery is always less than the emf of a battery when supplying current in a circuit because of a voltage drop due to

A. the terminal connections.
B. the battery's internal resistance.
C. heating of resistors in the circuit.
D. heating of the wires in the circuit.

23. When a resistor is added in parallel with the 4.0 Ω resistor in the circuit shown below, what happens to the voltage across the 5.0 Ω resistor and to the terminal voltage of the battery?



	Voltage Across 5.0 Ω	Terminal Voltage
A.	increases	decreases
B.	increases	increases
C.	decreases	decreases
D.	decreases	increases

ELECTROMAGNETISM

Magnetic forces

Magnetic induction

Electromagnetism	
Outcomes	**Questions**
It is expected that students will demonstrate an understanding of the nature of magnetic fields and magnetic forces.	
It is expected that students will:	
O1. state the rules that explain how magnetic poles interact with each other	1
O2. determine the direction of the magnetic field lines for a permanent magnet	
O3. use the right-hand rule to determine the magnetic field direction for a current-carrying wire or a solenoid	2
O4. determine the direction of the force exerted on a current-carrying conductor or a moving charge that is within a magnetic field	3, 4, 5, 6
O5. solve problems for a current-carrying conductor placed in a magnetic field, involving: • magnetic force • current • length of conductor in the field • magnetic field	7, 8
O6. solve problems for a charge moving through a magnetic field, involving: • magnetic force • charge • speed • magnetic field • centripetal force • mass • radius	9
O7. apply the principles of electromagnetism to qualitatively explain the operation of a cathode-ray tube	10
O8. solve problems for a solenoid, involving: • current • magnetic field (in the centre of the solenoid) • number of turns per metre of solenoid	11, 12
O9. give examples of practical uses for solenoids in the home and workplace	13
P1. solve problems for a conductor moving perpendicularly through a uniform magnetic field, involving: • electromotive force between the ends of the conductor • magnetic field • speed of the conductor • length of the conductor	14, 15, 16, 17
P2. define magnetic flux	
P3. calculate the magnetic flux through a loop of wire placed parallel or perpendicular to a magnetic field	
P4. identify, from appropriate diagrams, situations that would produce an induced emf in a coil	18, 19, 20
P5. apply Faraday's law to solve problems involving: • time • change in flux • induced emf • number of turns	
P6. apply Lenz's law to determine the direction of the induced current in a loop of wire	
P7. qualitatively describe how a generator uses induction to produce an electric current	21
P8. define back emf	22
P9. solve problems for DC motors involving: • current • back emf • armature resistance • voltage to motor	23, 24
P10. give evidence of current fluctuations due to back emf in common applications of motors	25
P11. solve problems for an ideal transformer, involving: • primary voltage • secondary voltage • number of primary windings • number of secondary windings • primary current • secondary current	26, 27, 28
P12. identify a transformer as step-up or step-down	
P13. give examples of the use of transformers in the home, workplace, and community	

Electromagnetism

Magnetic Forces

O1 State the rules that explain how magnetic poles interact with each other

O2 Determine the direction of the magnetic field lines for a permanent magnet

O3 Use the right-hand rule to determine the magnetic field direction for a current-carrying wire or a solenoid

O4 Determine the direction of the force exerted on a current-carrying conductor or a moving charge that is within a magnetic field

O5 Solve problems for a current-carrying conductor placed in a magnetic field, involving:

- *magnetic force*
- *current*
- *length of conductor in the field*
- *magnetic field*

O6 Solve problems for a charge moving through a magnetic field, involving:

- *magnetic force*
- *charge*
- *speed*
- *magnetic field*
- *centripetal force*
- *mass*
- *radius*

O7 Apply the principles of electromagnetism to qualitatively explain the operation of a cathode-ray tube

O8 Solve problems for a solenoid, involving:

- *current*
- *magnetic field (in the centre of the solenoid)*
- *number of turns per metre of solenoid*

O9 Give examples of practical uses for solenoids in the home and workplace

Solid metal is made up of tiny regions called domains which are essentially tiny bar-magnets. In most metals these domains are arrange haphazardly and point in all directions, thus all their magnetic fields cancel each other out.

In magnets these domains are aligned and their magnetic fields compound to make a single, large magnetic field that surrounds the magnet.

A magnet is attracted to ferromagnetic materials because its field temporarily aligns the domains of materials in proximity to it, turning into magnets. Therefore materials which do not have domains do not have magnetic properties.

The source of Earth's magnetic field is very different from that of artificial magnets. Metals in the Earth's crust become too warm to maintain magnetic properties past a depth of 20km or so. They are too malleable and the domains quickly lose alignment.

The Earth's magnetic field is caused by a dynamic system within the core. Molten iron and nickel flow through the magnetic field, inducing a current. The flow of current through metal creates a magnetic field. The Earth's magnetic field is thus self-sustaining.

It should also be noted that Earth's geographic north pole, the direction in which the north pole of a bar magnet will tend to point, is a magnetic south pole.

Magnetic lode stones (naturally occurring magnets) are simply masses of mostly iron whose domains have been aligned over an extended period of time by Earth's magnetic field.

Magnetic fields can be added as vectors.

Example: A magnetic field of 2.0T east and a field of 3.0T west interact to create a field with a net magnitude of 1.0T to the west.
This is why electromagnets can be so powerful. The fields around each coil add together to create a single magnetic field.

Gravitational fields are caused simply by the presence of matter. A large amount of matter is required to create a field of appreciable magnitude. The direction of an electric field is defined as the direction in which a test mass will move (usually toward the center of gravity of the body generating the field).

Much like gravitational fields, electric fields exist around charges. An electric field can also be created if a potential difference exists across a region (e.g. two metal plates attached to opposite terminals of a battery. An electric field exists between the plates). The direction of an electric field is defined as the direction in which a positive test charge will move inside the field.

Magnetic fields exist around magnets (masses, usually of iron, in which the domains are aligned).. They can also be created by moving electric charges. The direction of a magnetic field is defined as the direction in which the north pole (south-seeking pole) of a compass will point.

Oersted discovered that a moving charge, such as current through a wire, produces a magnetic field perpendicular to its motion. Faraday discovered that the motion of a magnetic field relative to a conductor (change in flux) creates a current in the conductor.

The magnetic field created by a single moving charge can be visualized as ripples moving out from the charge in the space directly behind the charge. The field dissipates as the charge moves on. A sustained current results in a sustained magnetic field.

The direction of a magnetic field around a conductor can be visualized using our hands: if we use the thumb and assume it indicates the direction of current flow in the conductor, then curling the fingers indicates the direction of the field. We use the right hand for conventional current and the left hand for electron flow current.

We denote this graphically, using a cross-section view of a wire, as follows.

A dot in the center of the wire indicates electron flow out of the plane of the page, toward the reader.

An "x" in the center of the wire indicates electron flow into the plane of the page, away from the reader.

The force a magnetic field exerts on a moving charge can be determined using the formula

$$F_m = QvB\perp$$

where F_m is the magnitude of the force, Q is the magnitude of the charge on the object, v is the magnitude of the objects velocity, and $B\perp$ is the magnitude of the magnetic field perpendicular to the particle's motion. We ignore signs associated with these quantities and use the left and right hand rules to determine the direction of the force.

We flatten the hand and extend the thumb perpendicular to the fingers. If the thumb indicates the direction of velocity, and the fingers indicate the direction of the magnetic field, then the force is said to come out of the palm. This is similar to how a magnetic field affects moving electric charges except the charges are now confined to a conductor. The force on the charge is now the force on the wire. The direction of the force is also found in the same manner. We use the left hand for electron flow current and the right hand for conventional current, with the thumb indicating the direction of the current along the wire, the fingers pointing in the direction of the magnetic field, and force coming out of the palm.

The magnitude of the force exerted by a magnetic field on a current carrying wire can be determined using the formula

$$F_m = I\ell B\perp$$

where F_m is the magnitude of the force, I is the current in the wire, ℓ is the length of wire exposed to the field, and $B\perp$ is the magnitude of the magnetic field perpendicular to the wire.

Moving a wire in a magnetic field is similar to moving a charge in a magnetic field because of the free electrons in the wire. The force produced on the free electrons in the wire results in a current. The direction of the charge is the direction the wire is moving and the resulting force on the free electrons in the wire is the direction of the induced electron flow.

Moving a wire in an external magnetic field will generate a voltage

$$V = \ell vB\perp$$

where V is the voltage, ℓ is the length of the wire exposed to the field, v is the velocity of the wire, and $B\perp$ is the magnitude of the magnetic field perpendicular to the wire's motion. The direction can once again be found using our hands. We use the thumb to indicate the direction of the wire's motion, the fingers for the direction of the field, and the palm indicates the direction of the current.

Cathode rays were discovered as a result of experiments being done on the discharge of electricity through rarefied gases. It was observed that something being emitted by the cathode caused the gas to glow at the far end of the tube. This something was determined to be deflected by both electric and magnetic fields. J. J. Thomson from these experiments determined that this cathode ray was made up of very small negatively charged particle and from this determined that cathode rays (electrons) were constituents of the atom and not atoms as others believed.

Magnetic Induction

P1 Solve problems for a conductor moving perpendicularly through a uniform magnetic field, involving:

- *electromotive force (emf) between the ends of the conductor*
- *speed of the conductor*
- *magnetic field*
- *length of the conductor*

P2 Define magnetic flux

P3 Calculate the magnetic flux through a loop of wire placed parallel or perpendicular to a magnetic field

The magnetic field strength (B) at any point inside a solenoid or coil is given by

$$B = \mu_0(\frac{N}{\ell})I$$

where μ_0 is the permeability of free space, N is the number of turns or coils, ℓ is the length of the solenoid, and I is the current through the solenoid.

In addition to using $\varepsilon = B\ell v$ to calculate the induced emf across the ends of a wire moving across magnetic field lines, we can also use a quantity known as magnetic flux. The magnetic flux (symbol: Φ) through a region is a measure of the number of magnetic field lines passing through that region. Thus we have the formula

$\Phi = BA$, where B is the magnetic field intensity in Teslas (T) and A is the area of the region in m^2. The units for magnetic flux are Webers (Wb) such that $1\text{Wb} = 1\text{T}\bullet\text{m}^2$.

P4 Identify, from appropriate diagrams, situations that would produce an induced emf in a coil

P5 Apply Faraday's law to solve problems involving:

- *time*
- *change in flux*
- *induced emf*
- *number of turns*

P6 Apply Lenz's law to determine the direction of the induced current in a loop of wire

P7 Qualitatively describe how a generator uses induction to produce an electric current

P8 Define back emf

P9 Solve problems for DC motors involving:

- *current*
- *back emf*
- *armature resistance*
- *voltage to motor*

P10 Give evidence of current fluctuations due to back emf in common applications of motors

P11 Solve problems for an ideal transformer, involving:

- *primary voltage*
- *secondary voltage*
- *number of primary windings*
- *number of secondary windings*
- *primary current*
- *secondary current*

P12 Identify a transformer as step-up or step-down

P13 Give examples of the use of transformers in the home, workplace, and community

In a transformer the power in and out of the transformer are the same but the voltage and current can be varied depending on the number of wraps of wire placed on the primary and secondary sides of the transformer.

Quantities of voltage and current are related by the following ratios

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

where N is the number of wire loops, V is the voltage, I is the current, p denotes the primary side, and s denotes the secondary side.

Alternating current (AC) is generated by turning a coil of wire inside a static magnetic field. Because of the motion of the coil any given wire on it is always changing the direction in which it cuts through the magnetic field. This causes the direction of the current to alternate, thus we call it alternating current.

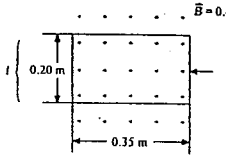
If we graph the voltage *vs.* time of "raw" AC we get a sine wave with an amplitude equal to the maximum voltage and a frequency equal to the number of coil rotations per second (usually 60Hz). The effective voltage is equal to the average absolute value of the voltage. This means we ignore the alternating nature of the current. To determine the effective voltage we multiply the maximum voltage by sin 45° (0.707). Effective current is determined in the same manner. We thus arrive at the following formulae:

$$V_{\text{eff}} = 0.707V_{\text{max}}$$
$$I_{\text{eff}} = 0.707I_{\text{max}}$$
$$P_{\text{eff}} = I_{\text{eff}}V_{\text{eff}} = (0.707)^2 P_{\text{max}} = 0.5P_{\text{max}}$$

When a current is first induced in a conductor it sets up a magnetic field around the conductor which opposes the field responsible for the initial current. The creation of the second magnetic field induces a current opposite the initial current, thus impeding the current. This effect is negligible for wires but much more significant when current is applied to coils. The result is that more energy is required to induce a current in a coil. This energy must however be conserved.

When the applied current is removed, the second magnetic field collapses, inducing current in the same direction as the applied current. This effect is called electrical inertia, or inductance. Thus the extra energy required to induce the initial current is released and conserved.

These two principles combine to form Lenz's Law. We see examples of this effect when we first start up electric motors (e.g. the lights dim slightly for a moment after turning on the vacuum cleaner).



In the above diagram, if the wire is pushed through this field to the left, an induced emf will not be generated until the magnetic flux through the loop starts changing. This occurs when the left side of the loop exits the field. Furthermore, the loop must travel perpendicular to the field in order to induce a voltage. At the point that an induced emf is generated, it can be shown that $\varepsilon = B\ell v$ is mathematically equivalent to $\varepsilon = \frac{\Delta\Phi}{\Delta t}$ for a loop such as this. This equation is known as Faraday's Law. This law states that the magnitude of the induced emf in a circuit is directly proportional to the rate of change of magnetic flux. For a circuit made up of N loops, the formula becomes $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$, where the negative sign is added to satisfy Lenz's law requirements for the direction of induced emfs. Another aspect of induced emf is the effect it has on electric motors as they spin faster and faster after being turned on. As the armature in a motor begins to turn, it begins to generate an induce emf, which according to Lenz's Law, acts in opposition to the voltage supplied to the motor. The so-called back emf or V_{back} limits the speed of the motor and provides a kind of internal resistance. This changes the flow, which also keeps the current in the armature down near reasonable levels. The back emf of a motor is calculated using the following:

$V_{back} = \varepsilon - Ir$, where ε is the emf supplied to the motor, I is the current through the armature, and r is the armature resistance.

At startup, a motor has not yet generated any back emf (the armature is not yet spinning) and so the above formula becomes $0 = \varepsilon - Ir$ or $\varepsilon = Ir$.

This is responsible for the large current surge in a motor that has just been turned on. In fact, it is not good for most motors to be turned on for extended periods of time with their armatures held stationary. The large current that results can damage the coils inside the motor through overheating.

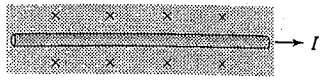
JANUARY 2000

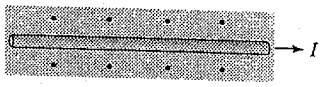
ELECTROMAGNETISM

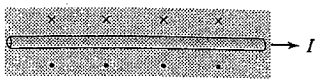
24. The direction of a magnetic field is determined to be the direction in which

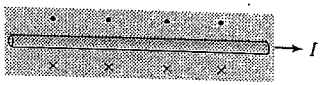
A. a positive charge would tend to move.
B. a negative charge would tend to move.
C. the north end of a compass needle would point.
D. the south end of a compass needle would point.

25. Which diagram shows the magnetic field created near a conductor carrying current towards the right?

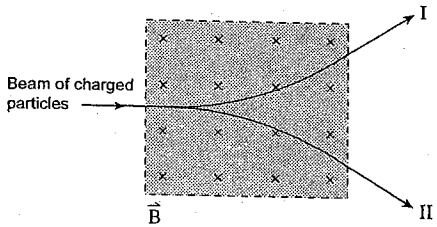
A. 

B. 

C. 

D. 

26. A beam of positively and negatively charged particles enters a magnetic field as shown. Which paths illustrate the positive and negative charges leaving the magnetic field region?



	Path of Positive Charges	Path of Negative Charges
A.	I	I
B.	I	II
C.	II	I
D.	II	II

27. A solenoid has a length of 0.30 m, a diameter of 0.040 m and 500 windings. The magnetic field at its centre is 0.045 T. What is the current in the windings?

A. 2.9 A
B. 3.0 A
C. 21 A
D. 170 A

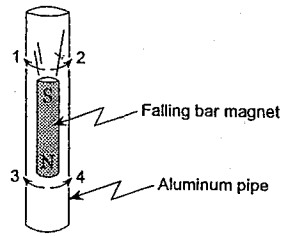
28. An aircraft with a wingspan of 24 m flies at 85 m/s perpendicular to a magnetic field. An emf of 0.19 V is induced across the wings of the aircraft. What is the magnitude of the magnetic field?

A. 9.3×10^{-5} T
B. 5.4×10^{-2} T
C. 6.7×10^{-1} T
D. 3.9×10^{2} T

29. As a carpenter drills into a beam, friction on the drill bit causes the armature of the drill to slow down. How will the back emf and the current through the armature change as the drill slows down?

	Back EMF	Current
A.	Increase	Increase
B.	Increase	Decrease
C.	Decrease	Increase
D.	Decrease	Decrease

30. The diagram shows a bar magnet falling through an aluminum pipe. Electric currents are induced in the pipe immediately above and below the falling magnet. In which direction do these currents flow?



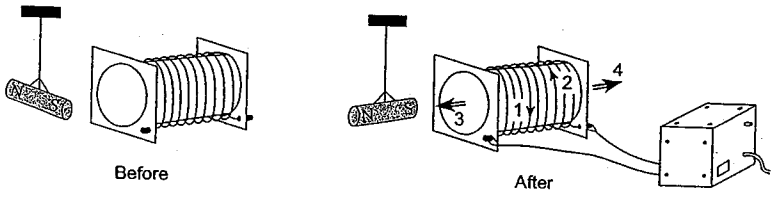
	Above the Magnet	Below the Magnet
A.	1	3
B.	1	4
C.	2	3
D.	2	4

JUNE 2000
ELECTROMAGNETISM

24. What are the units of magnetic flux?

A. T
B. Wb
C. T·m/A
D. N·m/C²

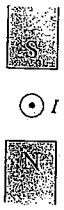
25. The diagram shows a magnet suspended near a solenoid. After the solenoid has been connected to a power supply, the magnet rotates to a new position with its south pole pointing towards the solenoid.



Which arrows show the direction of the current in the solenoid and the direction of the magnetic field caused by this current?

	DIRECTION OF CURRENT	DIRECTION OF MAGNETIC FIELD
A.	1	3
B.	1	4
C.	2	3
D.	2	4

26. The diagram shows a conductor between a pair of magnets. The current in the conductor flows out of the page.



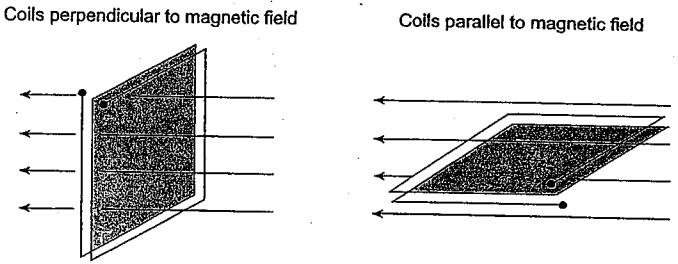
In what direction will the magnetic force act on the conductor?

A. up the page
B. down the page
C. towards the left
D. towards the right

27. A charged particle travels in a circular path in a magnetic field. What changes to the magnetic field and to the velocity of the particle would both cause the radius of its path to decrease?

	CHANGE TO THE MAGNETIC FIELD	CHANGE TO THE VELOCITY
A.	increase	increase
B.	increase	decrease
C.	decrease	increase
D.	decrease	decrease

28. The diagram below shows two coils in a magnetic field.



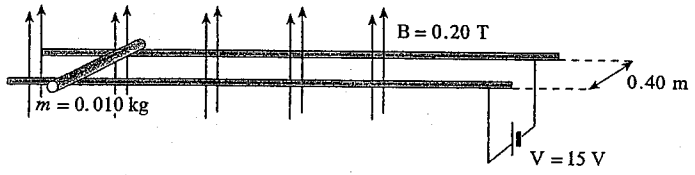
An electric current can be induced in the coil oriented with its plane

A. parallel to a constant magnetic field.
B. parallel to a changing magnetic field.
C. perpendicular to a constant magnetic field.
D. perpendicular to a changing magnetic field.

29. An electric motor is connected to a 12.0 V power supply. When the armature is prevented from rotating, the current is 8.0 A. When the motor is running at normal speed, the current is 2.0 A. What is the back emf in each case?

	BACK EMF WHEN STATIONARY	BACK EMF WHEN RUNNING
A.	0 V	9.0 V
B.	0 V	3.0 V
C.	12 V	9.0 V
D.	12 V	3.0 V

30. The diagram shows a 0.010 kg metal rod resting on two long horizontal frictionless rails which remain 0.40 m apart. The circuit has a resistance of 3.0 Ω and is located in a uniform 0.20 T magnetic field.

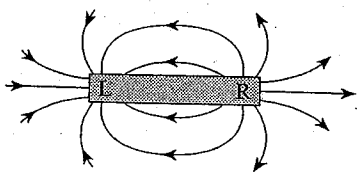


Find the initial acceleration and maximum velocity for the rod.

	Initial Acceleration	Maximum Velocity
A.	40 m/s^2	190 m/s
B.	40 m/s^2	300 m/s
C.	120 m/s^2	190 m/s
D.	120 m/s^2	300 m/s

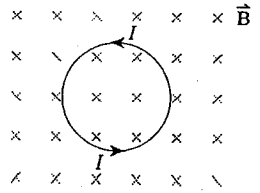
AUGUST 2000
ELECTROMAGNETISM

24. Identify the magnetic poles labelled L and R in the diagram shown.



	Pole L	Pole R
A.	North	North
B.	North	South
C.	South	North
D.	South	South

25. The diagram shows current *I* flowing in a circular coil located in a magnetic field.



The magnetic force acting on the coil will tend to cause it to

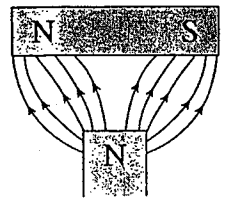
A. expand.
B. contract.
C. move up the page.
D. move down the page.

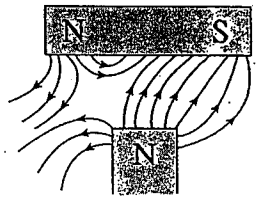
26. An aircraft whose wingspan is 15 m carries a static charge of 0.60 C. It travels at 240 m/s perpendicular to a 1.5×10^{-4} T magnetic field. What magnetic force does the aircraft experience?

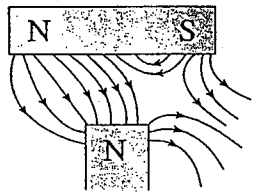
A. 0.022 N
B. 0.060 N
C. 0.54 N
D. 9.6×10^{5} N

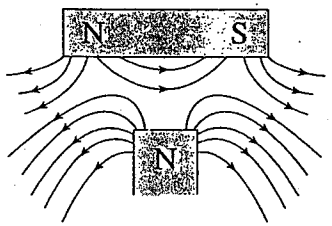
JANUARY 2001
ELECTROMAGNETISM

25. Which of the following diagrams best represents the magnetic field in the region between the two permanent magnets?

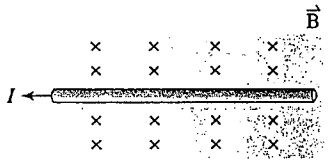
A. 

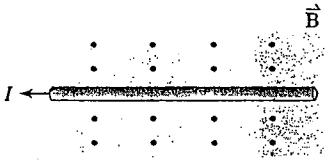
B. 

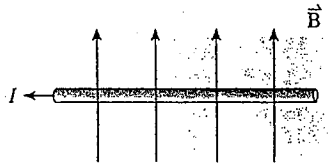
C. 

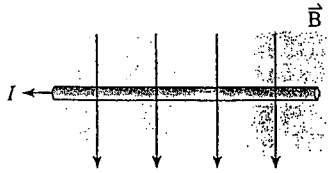
D. 

26. In which diagram would the current-carrying conductor experience a magnetic force out of the page?

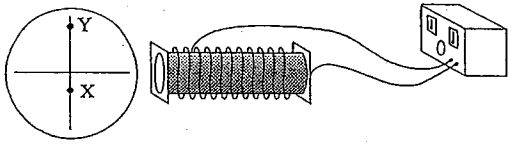
A. 

B. 

C. 

D. 

27. An undeflected electron beam strikes the centre of a cathode ray tube. A solenoid placed beside a cathode ray tube causes the electron beam to strike the screen at position X.



What changes to the magnitude and direction of the current in the solenoid would cause the electron beam to strike the screen at Y?

	Change to Current Magnitude	Change to Current Direction
A.	Increases	Remains the same
B.	Increases	Reverses
C.	Decreases	Remains the same
D.	Decreases	Reverses

28. A coil having 150 turns and a cross-sectional area of 0.042 m^2 is oriented with its plane perpendicular to a 0.12 T magnetic field. If the field increases to 0.66 T in 0.25 s, what emf is induced in the coil?

A. 9.8 V
B. 14 V
C. 20 V
D. 320 V

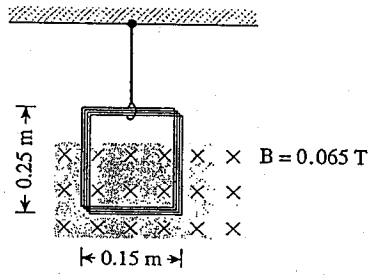
29. An electric motor rotates at various speeds and the current through the armature changes accordingly. Which pair of conditions occurs when the motor generates the greatest back emf?

	Speed	Current through the armature
A.	Fastest	Largest
B.	Fastest	Smallest
C.	Slowest	Largest
D.	Slowest	Smallest

30. A transformer connected to a 120 V ac supply has 7 000 primary and 350 secondary windings. It delivers a secondary current of 2.4 A. Find the primary current and secondary voltage.

	Primary Current	Secondary Voltage
A.	0.12 A	6.0 V
B.	0.12 A	2 400 V
C.	48 A	6.0 V
D.	48 A	2 400 V

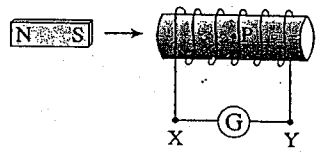
27. A coil of 25 turns of wire is suspended by a thread. When a current flows through the coil, the tension in the thread is reduced by 4.0×10^{-2} N.



What are the magnitude and direction of the current?

	MAGNITUDE OF CURRENT	DIRECTION OF CURRENT
A.	0.16 A	clockwise
B.	0.16 A	counter-clockwise
C.	4.1 A	clockwise
D.	4.1 A	counter-clockwise

28. A bar magnet is moving toward a solenoid.



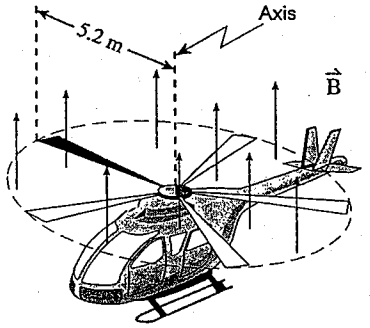
What is the direction of the current through the galvanometer and what is the direction of the magnetic field produced by this current at location P inside the solenoid?

	DIRECTION OF THE CURRENT THROUGH THE GALVANOMETER	DIRECTION OF THE MAGNETIC FIELD AT P
A.	From X to Y	Right
B.	From X to Y	Left
C.	From Y to X	Right
D.	From Y to X	Left

29. A dc motor has a resistance of 2.0 Ω. When connected to a 12 V source, with the motor rotating at its operational speed, a back emf of 5.5 V is generated. What is the current in the motor at operational speed?

A. 2.8 A
B. 3.3 A
C. 6.0 A
D. 8.8 A

30. The 5.2 m long metal rotor blades of a helicopter spin at 6.0 revolutions per second perpendicular to the earth's magnetic field of 4.7×10^{-5} T.



What is the magnetic flux swept out by the rotor blades in one revolution and what is the emf induced between the axis and tip of a rotor blade?

	MAGNETIC FLUX	EMF INDUCED
A.	4.0×10^{-3} Wb	2.4×10^{-2} V
B.	4.0×10^{-3} Wb	4.0×10^{-3} V
C.	2.4×10^{-2} Wb	2.4×10^{-2} V
D.	2.4×10^{-2} Wb	4.0×10^{-3} V

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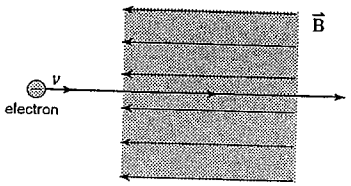
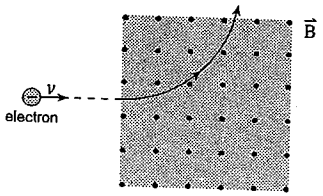
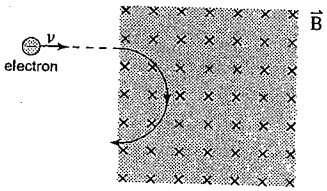
24. Which of the following devices commonly uses a solenoid?

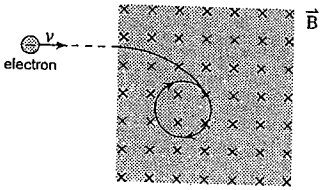
A. kettle
B. battery
C. television set
D. incandescent bulb

25. An electron, travelling with a constant velocity, enters a region of uniform magnetic field. Which of the following is **not** a possible pathway?

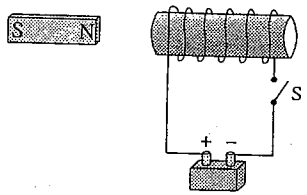
A.


B.


C.


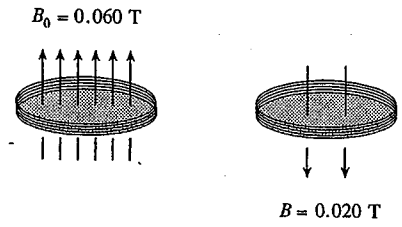
D.


26. A bar magnet is at rest, next to a fixed coil. When switch S is closed, the bar magnet will move



A. to the left.
B. to the right.
C. up the page.
D. down the page.

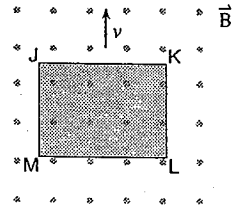
27. A 500-turn circular coil with an area of 1.54×10^{-2} m^2 is perpendicular to a 0.060 T field. The magnetic field changes to 0.020 T in the opposite direction in 0.12 s.



What is the average emf induced in the coil?

A. 5.1×10^{-3} V
B. 1.0×10^{-2} V
C. 2.6 V
D. 5.1 V

28. A metal block moves with a constant speed in a uniform magnetic field.



Which side of the block is positive?

A. JK
B. KL
C. LM
D. MJ

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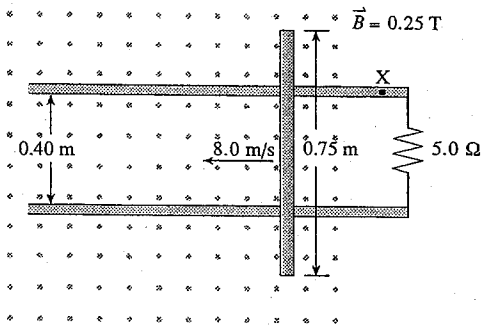
29. A 120 V dc motor has an armature resistance of 5.0 Ω and draws 6.0 A when it is operating normally. What is the starting current of the motor and the back emf when it is operating?

	STARTING CURRENT	BACK EMF WHEN OPERATING
A.	6.0 A	30 V
B.	6.0 A	90 V
C.	24 A	30 V
D.	24 A	90 V

30. A 0.75 m conducting rod is moved at 8.0 m/s across a 0.25 T magnetic field along metal rails. The electrical resistance of the system is 5.0 Ω.



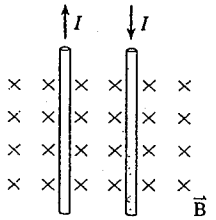
What are the magnitude and direction of the current through point X?

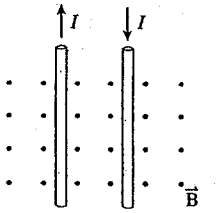
	MAGNITUDE OF CURRENT	DIRECTION OF CURRENT THROUGH X
A.	0.16 A	Left
B.	0.16 A	Right
C.	0.30 A	Left
D.	0.30 A	Right

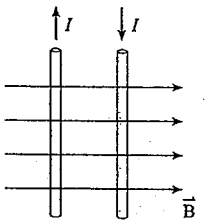
24. Transformers are commonly used in which electrical device?

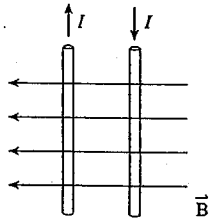
A. toaster
B. television set
C. electric kettle
D. incandescent bulb

25. In which diagram would an **external** magnetic field, $\vec{B}$, cause two current-carrying wires to move towards one another?

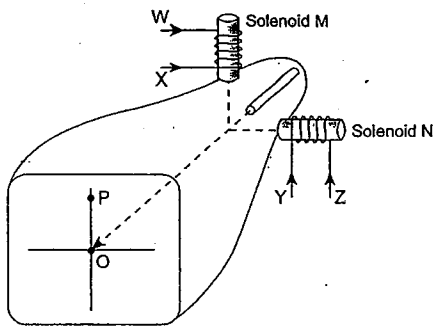
A.


B.


C.


D.


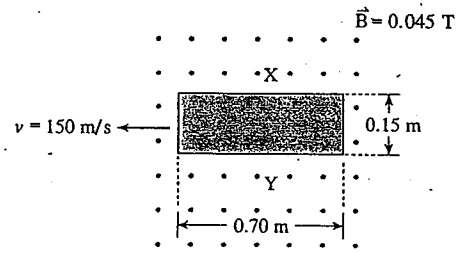
26. When there is no current in the solenoids, the electron beam in the cathode ray tube strikes the screen at the origin O.



In order to move the beam to position P, which solenoid is used and what is the direction of the current applied?

	SOLENOID	CURRENT DIRECTION
A.	M	W
B.	M	X
C.	N	Y
D.	N	Z

27. A solid conductor travels at 150 m/s across a uniform 0.045 T magnetic field. Which side is positively charged and what is the emf across this block?

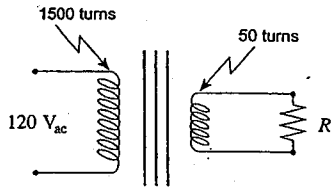


	POSITIVE SIDE	EMF
A.	X	1.0 V
B.	X	4.7 V
C.	Y	1.0 V
D.	Y	4.7 V

28. A motor operating at full speed draws a current of 4.0 A when connected to a 110 V source. The motor has an armature resistance of 3.5 Ω. What is the back emf at full speed?

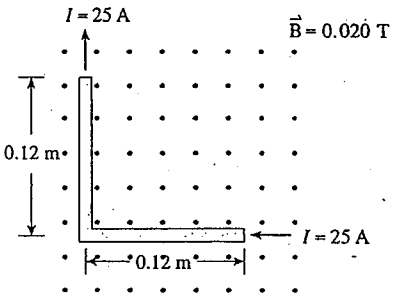
A. 14 V
B. 96 V
C. 110 V
D. 124 V

29. An ideal transformer with 120 V_{ac} on the primary coil supplies power to the resistor R. If this resistor dissipates 35 W, what is the current in the primary coil and in the secondary coil?



	CURRENT IN PRIMARY	CURRENT IN SECONDARY
A.	0.29 A	0.29 A
B.	0.29 A	8.8 A
C.	8.8 A	0.29 A
D.	8.8 A	8.8 A

30. What is the magnitude of the magnetic force on the L-shaped conductor?



A. 0 N
B. 6.0×10^{-2} N
C. 8.5×10^{-2} N
D. 1.2×10^{-1} N

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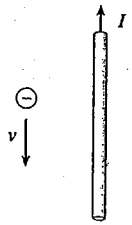
23. The direction of the magnetic field is the direction of force on a

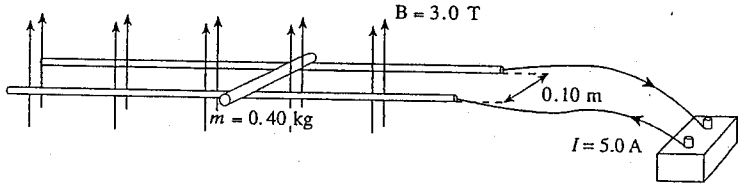
A. north magnetic pole.
B. south magnetic pole.
C. positively charged particle.
D. negatively charged particle.

24. What is the direction of the magnetic force on an electron moving near a current-carrying wire as shown?



A. left
B. right
C. into the page
D. out of the page

25. A 0.40 kg metal slider is sitting on smooth conducting rails as shown below.



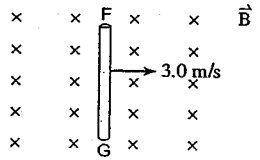
What is the magnitude and direction of the acceleration of the slider? (Ignore friction.)

	MAGNITUDE	DIRECTION
A.	0.42 m/s^2	left
B.	0.42 m/s^2	right
C.	3.8 m/s^2	left
D.	3.8 m/s^2	right

26. A 0.20 m long solenoid has 750 turns of copper wire and the magnetic field near its centre is measured to be 3.0×10^{-2} T. What is the current flowing through the solenoid?

A. 1.6 A
B. 6.4 A
C. 32 A
D. 160 A

27. A 0.050 m long conducting wire is moved through a 1.5 T magnetic field as shown below.



What is the magnitude of the emf generated between its ends, and in what direction do the electrons in the conductor initially move?

	EMF (V)	DIRECTION OF ELECTRON MOVEMENT
A.	0.23 V	towards F
B.	0.23 V	towards G
C.	4.5 V	towards F
D.	4.5 V	towards G

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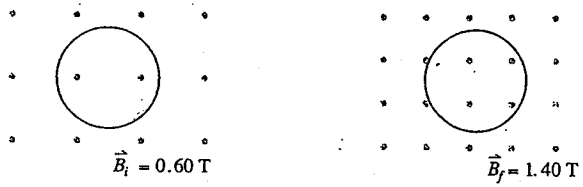
28. The circular loop of wire shown below has an area of 0.40 m^2 and is in a 0.60 T magnetic field. This field is increased to 1.40 T in 0.25 s.



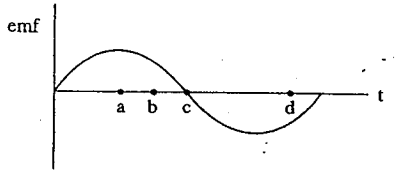
Determine the emf produced in the loop and the direction of current.

	EMF (V)	DIRECTION OF CURRENT
A.	1.3 V	clockwise
B.	1.3 V	counter-clockwise
C.	3.2 V	clockwise
D.	3.2 V	counter-clockwise

29. The load on an electric motor is gradually increased. Which one of the following quantities decreases? (Input voltage remains constant.)

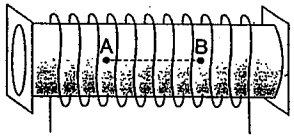
A. current
B. back emf
C. armature resistance
D. heat produced by armature

30. The graph below shows how the emf produced by an ac generator varies with time. At which point in time is the rate of flux change in the generator the greatest?



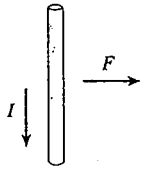
A. a
B. b
C. c
D. d

25. Which of the following best describes the magnetic field inside a current-carrying solenoid as you move from A to B.



	DIRECTION	MAGNITUDE
A.	constant	constant
B.	constant	changing
C.	changing	constant
D.	changing	changing

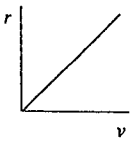
26. A section of conductor is carrying a current due south, as shown below.

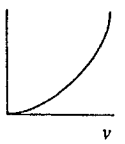


Due to the presence of a magnetic field, the conductor experiences a magnetic force to the right. What is the direction of the magnetic field?

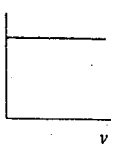
A. left
B. right
C. into the page
D. out of the page

27. A charged mass is accelerated to various speeds and then passed through a perpendicular magnetic field. Which of the graphs below is the best representation of how the radius of its circular path through the magnetic field varies with speed?

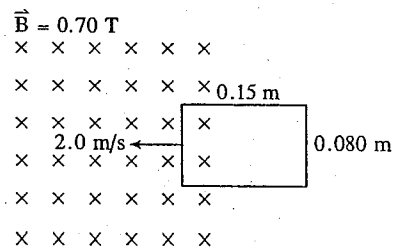
A. 

B. 

C. 

D. 

28. The single rectangular loop shown below is being pulled into the magnetic field at 2.0 m/s. Determine the emf developed in the loop.



A. 0.017 V
B. 0.11 V
C. 0.21 V
D. 0.64 V

29. You are using an electric drill to put a hole in a piece of wood when it hits a tough spot. The drill slows down and its motor heats up. Which of the choices below describes what has happened to the back emf and current?

	BACK EMF	CURRENT
A.	increased	increased
B.	decreased	decreased
C.	increased	decreased
D.	decreased	increased

30. Which of the following combinations in the primary coil of an ideal transformer causes an emf to be developed in the secondary coil?

	CURRENT	MAGNETIC FIELD
A.	constant	constant
B.	constant	changing
C.	changing	constant
D.	changing	changing

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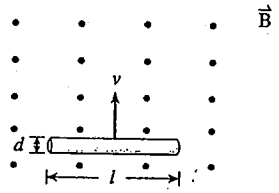
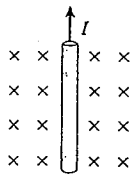
24. A length of conducting wire is moving perpendicular to a magnetic field as shown below.

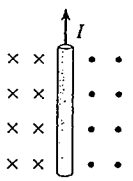


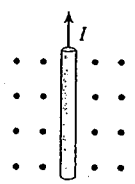
Which of the following does not affect the size of the emf produced between the ends of the wire?

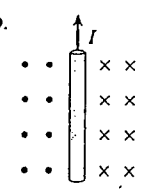
A. speed of wire
B. length of wire
C. thickness of wire
D. magnetic field strength

25. Which of the four diagrams below correctly depicts the magnetic field found on either side of a current carrying wire?

A. 

B. 

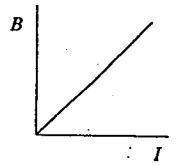
C. 

D. 

26. Charged particles having momentum p_1, pass perpendicularly through a magnetic field and their circular path has a radius of r. What would the radius be for particles with the same charge having momentum $p_2 = 2p_1$?

A. $2r$
B. $\frac{1}{2}r$
C. $\sqrt{2}r$
D. $\frac{r}{\sqrt{2}}$

27. The current through a solenoid is varied and the resulting magnetic field at its centre is recorded in each case. A graph of the magnetic field versus the current is produced.



Which of the following represents the slope of this graph?

A. $\frac{\mu_0 N}{l}$
B. $\frac{Nl}{\mu_0}$
C. $\frac{\mu_0 B}{N}$
D. $\frac{Il}{N}$

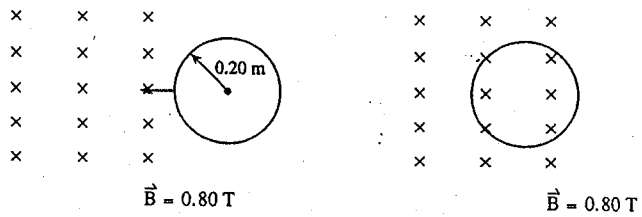
28. A refrigerator condenser motor draws a 10 A current at startup (armature not rotating) when attached to a 110 V source. When the motor is operating at normal speed the current is 0.20 A. What back emf is the motor producing at this normal speed?

A. 100 V
B. 108 V
C. 110 V
D. 112 V

29. The secondary coil in an ideal transformer has 5 times as many windings as the primary. If the current in the primary is 0.40 A, determine the current in the secondary, and the type of the transformer.

	CURRENT IN SECONDARY	TYPE OF TRANSFORMER
A.	0.080 A	step-up
B.	0.080 A	step-down
C.	2.0 A	step-up
D.	2.0 A	step-down

30. A circular loop of resistance 1.2 Ω is pulled a distance of 0.40 m into a perpendicular magnetic field as shown below.



An average current of 0.50 A is produced in the coil during this event. Calculate the constant speed with which the coil was pulled.

A. 0.10 m/s
B. 0.75 m/s
C. 1.9 m/s
D. 2.4 m/s

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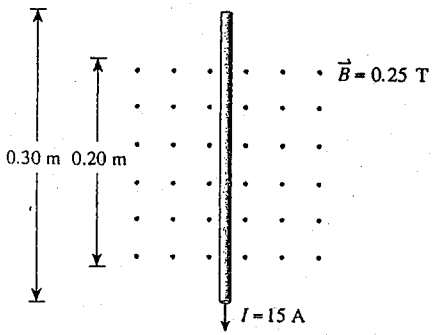
24. Which of the following are correct units for magnetic flux?

A. T
B. T/m
C. Wb
D. $Wb \cdot m^2$

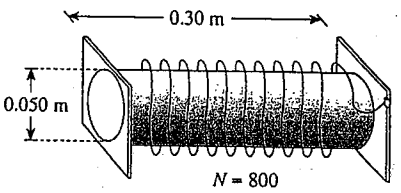
25. A conductor is placed in a magnetic field as shown.



What are the magnitude and direction of the magnetic force acting on this conductor when it carries a 15 A current?

	MAGNITUDE OF MAGNETIC FORCE	DIRECTION OF MAGNETIC FORCE
A.	0.75 N	To the left
B.	0.75 N	To the right
C.	1.1 N	To the left
D.	1.1 N	To the right

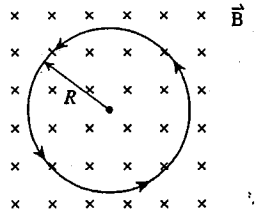
26. Consider the 800-turn solenoid shown in the diagram below.



What is the current in the windings that would produce a magnetic field of 0.060 T at the centre of this solenoid?

A. 3.0 A
B. 8.0 A
C. 18 A
D. 290 A

27. The path of a charged particle in a uniform magnetic field is circular when the initial velocity is perpendicular to the field.



Which of the following is a valid expression for the radius of this orbit in terms of the magnetic field strength, and the particle's momentum and charge?

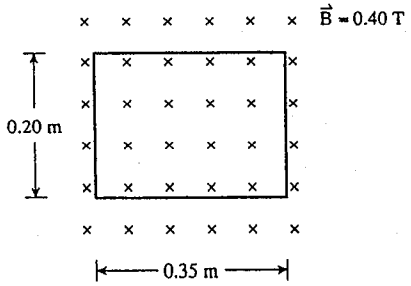
A. Bqp

B. $\frac{Bp}{q}$

C. $\frac{Bq}{p}$

D. $\frac{p}{Bq}$

28. A rectangular loop of wire is placed in a magnetic field as shown in the diagram.



If the loop is removed from the field in a time of 0.050 s, what is the induced emf?

A. 0.028 V
B. 0.28 V
C. 0.56 V
D. 5.7 V

29. A direct current motor operates from a 24.0 V supply. When the motor is operating the current through it is 1.50 A and the back emf is 22.0 V. What is the resistance of the motor's armature?

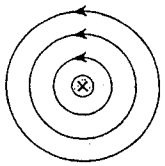
A. 0.75 Ω
B. 1.3 Ω
C. 15 Ω
D. 16 Ω

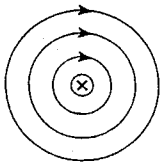
30. A certain step-down transformer has a 500-turn primary that operates at 120 V ac. Which one of the following sets of conditions could describe the secondary turns and voltage of this transformer?

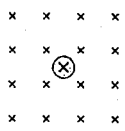
	SECONDARY TURNS	SECONDARY VOLTAGE
A.	400	96 V
B.	400	150 V
C.	2000	30 V
D.	2000	480 V

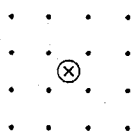
JUNE 2003
ELECTROMAGNETISM

24. Which one of the following diagrams best illustrates the magnetic field produced by a current-carrying wire?

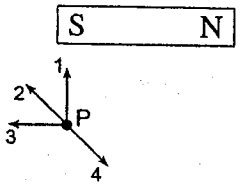
A. 

B. 

C. 

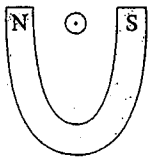
D. 

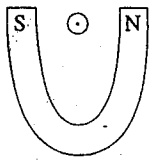
25. What is the direction of the magnetic field at point P due to the bar magnet?

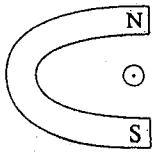


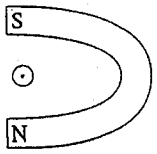
A. 1
B. 2
C. 3
D. 4

26. The diagrams below each illustrate a magnet and a conductor. In each case, the current in the conductor is out of the page. In which of these situations will there be a force on the conductor that points toward the top of the page?

A. 

B. 

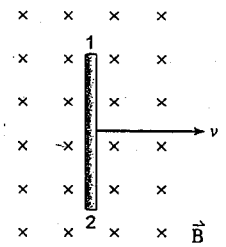
C. 

D. 

27. A positively charged object $\left(q = 1.6\times10^{-19}\ \text{C}\right)$ is travelling at 1.9×10^{4} m/s perpendicular to a 1.0×10^{-3} T magnetic field. If the radius of the resulting path is 0.40 m, what is the object's mass?

A. 3.4×10^{-27} kg
B. 3.1×10^{-19} kg
C. 2.1×10^{-9} kg
D. 0.77 kg

28. A conducting rod of length 0.25 m is moved to the right at 6.0 m/s as shown in the diagram. The induced emf is 3.0 V.



What is the magnitude of the magnetic field and which end of the conducting rod, 1 or 2, becomes positively charged?

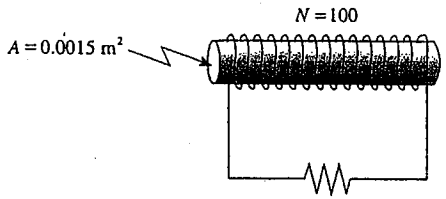
	MAGNETIC FIELD	POSITIVELY CHARGED END
A.	1.50 T	1
B.	1.50 T	2
C.	2.0 T	1
D.	2.0 T	2

AUGUST 2003
ELECTROMAGNETISM

29. A coil consisting of 50 loops of radius 4.0×10^{-2} m is placed with its plane perpendicular to a magnetic field that is increasing at a rate of 0.20 T/s. What is the magnitude of the emf induced in the coil?

A. 0.0010 V
B. 0.050 V
C. 0.40 V
D. 1.3 V

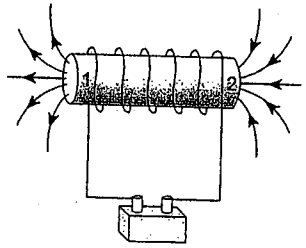
30. One hundred turns of wire are wrapped around an iron core with a cross-sectional area of 0.0015 m^2. The ends of the wire are connected to a resistor producing a circuit with a total resistance of 10.0 Ω.



If the magnetic field in the iron core changes from 3.0 T towards the left to 1.0 T towards the right, how much charge flows in the circuit?

A. 0.030 C
B. 0.060 C
C. 0.30 C
D. 0.60 C

24. Identify the magnetic poles 1 and 2 of the current-carrying solenoid in the diagram below.

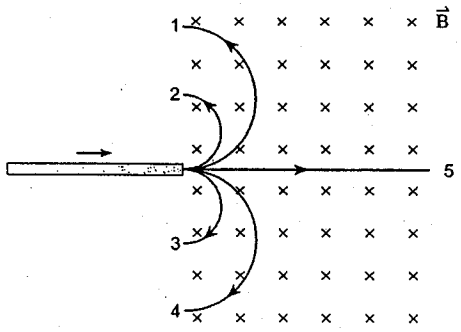


	POLE 1	POLE 2
A.	North	North
B.	North	South
C.	South	North
D.	South	South

25. Determine the direction of the magnetic force on the current-carrying conductor in the diagram below.

A. Towards the left
B. Towards the right
C. Towards the top of the page
D. Towards the bottom of the page

26. A beam made up of ions of various charges and masses enters a uniform magnetic field as shown.



One type of ion is observed to follow path 2. Which path describes the one taken by an oppositely charged ion with twice the mass and twice the charge? (Assume all ions have the same speed.)

A. Path 1
B. Path 3
C. Path 4
D. Path 5

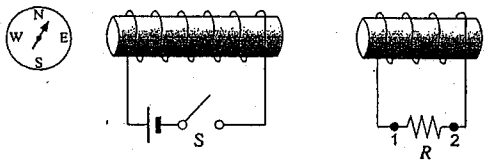
27. A step-down transformer is required to operate a 12 V, 25 W halogen lamp. Which of the following sets of conditions could apply to this transformer?

A. $N_p = 20,\ N_s = 200$
B. $V_p = 120\ \text{V},\ I_s = 0.21\ \text{A}$
C. $I_p = 2.1\ \text{A},\ I_s = 2.1\ \text{A}$
D. $V_p = 120\ \text{V},\ I_p = 0.21\ \text{A}$

28. A 0.25 m wire is perpendicular to a uniform 0.20 T magnetic field. What force is exerted on this wire when it carries a 15 A current?

A. 0.12 N
B. 0.75 N
C. 3.0 N
D. 6.0 N

29. As switch S is closed, in what direction does the compass needle point and what is the direction of the current through resistor R?



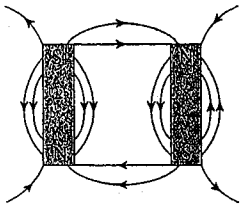
	Compass Needle Direction	Current Direction through R
A.	west	From 1 to 2
B.	west	From 2 to 1
C.	east	From 1 to 2
D.	east	From 2 to 1

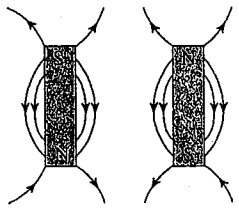
30. One method for determining masses of heavy ions involves timing their orbital period in a known magnetic field. What is the mass of a singly charged ion that makes 7.0 revolutions in 1.3×10^{-3} s in a 4.5×10^{-2} T field?

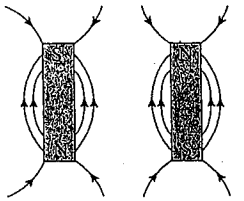
A. 2.1×10^{-25} kg
B. 1.3×10^{-24} kg
C. 6.5×10^{-23} kg
D. 5.0×10^{-20} kg

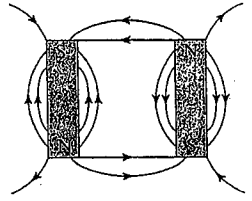
JANUARY 2004
ELECTROMAGNETISM

25. Which of the following best represents the magnetic field between two magnets?

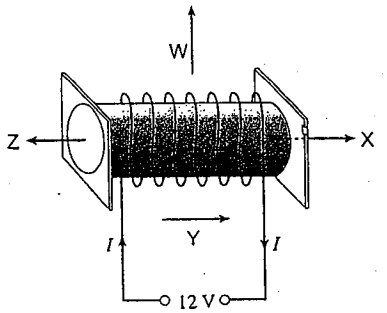
A. 

B. 

C. 

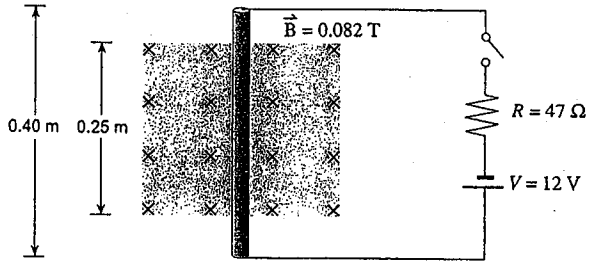
D. 

26. Which of the four arrows indicates the direction of the magnetic field when current flows in the solenoid shown below?



A. W
B. X
C. Y
D. Z

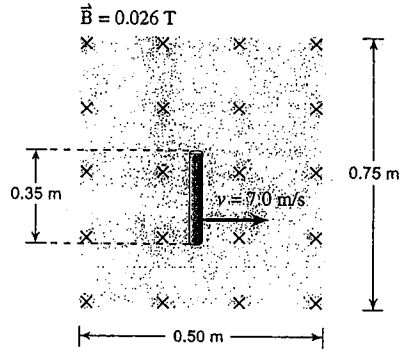
27. A 0.40 m length of copper rod is held perpendicularly to a 0.082 T magnetic field as shown.



The copper rod is connected to a 12 V power supply and a 47 ohm resistor. What are the magnitude and direction of the magnetic force on the copper rod when the switch is closed?

	Magnitude of Force (N)	Direction of Force
A.	5.2×10^{-3}	left
B.	5.2×10^{-3}	right
C.	8.4×10^{-3}	left
D.	8.4×10^{-3}	right

28. A 0.35 m length of a conducting rod is moving perpendicular to a 0.026 T magnetic field as shown.

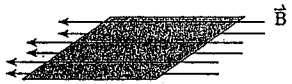


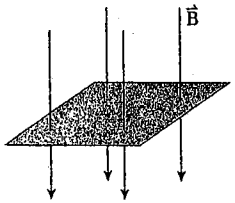
What is the potential difference as measured across the ends of the conducting rod?

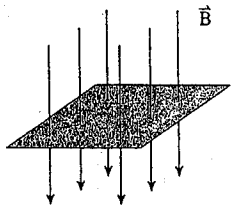
A. 0.0 V
B. 0.064 V
C. 0.091 V
D. 0.13 V

29. Which of the four situations below shows the greatest amount of magnetic flux for a rectangular coil?

A. 

B. 

C. 

D. 

30. An ideal 2.25 W transformer changes 120 V to 4.5 V for use in portable electronic devices. What is the current in the secondary windings and the ratio of primary coils to secondary coils in this transformer?

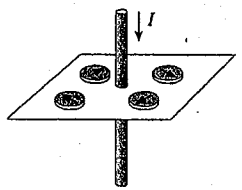
	SECONDARY CURRENT	RATIO OF PRIMARY TO SECONDARY COILS
A.	0.50 A	27 to 1
B.	0.50 A	1 to 27
C.	2.0 A	27 to 1
D.	2.0 A	1 to 27

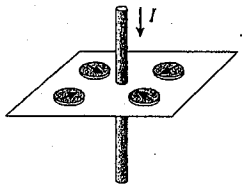
JUNE 2004
ELECTROMAGNETISM

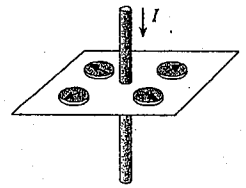
24. Protons and electrons travelling at high speeds enter a magnetic field **parallel** to their direction of travel. Which of the following is correct?

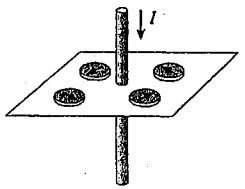
A. Only protons are deflected.
B. Only electrons are deflected.
C. Both protons and electrons are deflected.
D. Neither protons nor electrons are deflected.

25. Which of the following diagrams best shows the orientation for a set of four compasses placed around a current-carrying wire?

A. 

B. 

C. 

D. 

26. An electron travels at a speed of 1.4×10^{4} m/s while following a circular path of radius 0.020 m perpendicular to a magnetic field. What is the strength of the magnetic field?

A. 0.0 T
B. 4.0×10^{-6} T
C. 6.3×10^{-3} T
D. 4.1×10^{-2} T

27. A potential difference of 22 V is placed across a 570-turn solenoid that has a resistance of 4.9 Ω. The solenoid has a diameter of 0.052 m and is 0.37 m long. What is the magnetic field strength in the centre of this solenoid?

A. 8.7×10^{-3} T
B. 6.2×10^{-2} T
C. 1.2×10^{-1} T
D. 3.0×10^{-1} T

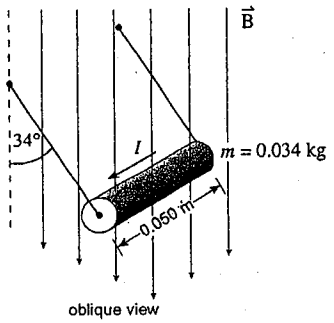
28. A 200-turn copper coil of radius 0.050 m is perpendicular to a 0.087 T magnetic field. The magnetic field collapses to zero in 0.63 s. What was the average induced emf in the coil during the collapse?

A. 0.0 V
B. 1.1×10^{-3} V
C. 0.22 V
D. 1.4 V

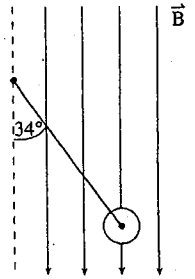
29. The coil of a motor has a resistance of 4.1 Ω. The motor is plugged into a 120 V outlet, and the coil develops a back emf of 118 V when rotating at normal speeds. Find the current when the motor first starts up and the current when it is operating at normal speeds.

A.	0.49 A	0.49 A
B.	0.49 A	29 A
C.	29 A	0.49 A
D.	29 A	29 A

30. A 0.034 kg copper rod is hung by two wires and placed in a constant magnetic field. A current of 14 A runs through the 0.050 m long copper rod, making it hang at an angle of 34° from the vertical as shown below.



oblique view



side view

What is the magnetic field strength holding the copper rod in this position?

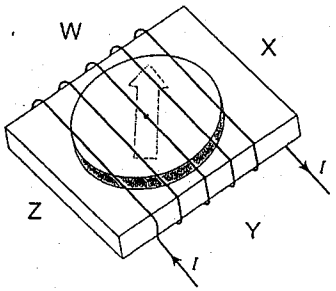
A. 2.7×10^{-1} T
B. 3.2×10^{-1} T
C. 3.9×10^{-1} T
D. 4.8×10^{-1} T

AUGUST 2004
ELECTROMAGNETISM

24. What particles make up the beam in a cathode ray tube?

A. atoms
B. protons
C. neutrons
D. electrons

25. A coil of copper wire is wrapped around a compass as shown. Which way will the compass needle point when current flows through the coil?

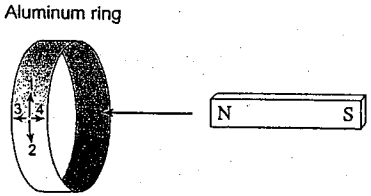


A. W
B. X
C. Y
D. Z

26. Protons move in circular paths of radius 1.2×10^{-2} m when travelling perpendicular to a 8.5×10^{-3} T magnetic field. What is the speed of these protons?

A. 9.9×10^{1} m/s
B. 4.2×10^{3} m/s
C. 9.8×10^{3} m/s
D. 1.8×10^{7} m/s

27. A magnet is moving towards an aluminum ring.



In which way will the current flow in the labelled portion of the ring as the magnet moves towards the ring?

A. towards 1
B. towards 2
C. towards 3
D. towards 4

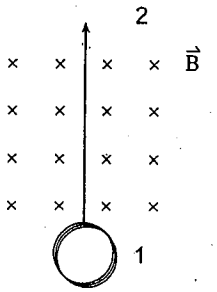
28. A 240 V motor draws 9.0 A of current at start up. At normal operating speeds the same motor only draws 2.5 A. What is the back emf of this motor at normal operating speeds?

A. 0.0 V
B. 67 V
C. 170 V
D. 240 V

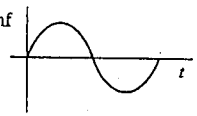
29. A transformer is made up of 200 turns in the primary windings and of 50 turns in the secondary windings. The primary voltage is 120 V and the secondary current is 0.12 A. What is the primary current and secondary voltage for this transformer?

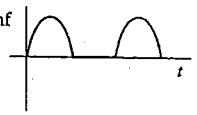
	Primary Current	Secondary Voltage
A.	0.030 A	30 V
B.	0.030 A	480 V
C.	0.48 A	30 V
D.	0.48 A	480 V

30. A coil moves at a constant velocity across a region of magnetic field as shown.

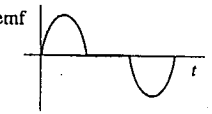


Which of the following **best** shows the emf vs. time graph for the emf induced in the coil as it moves from 1 to 2?

A. 

B. 

C. 

D. 

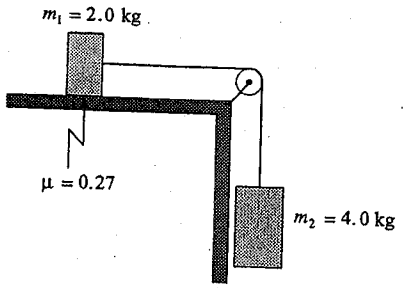
WRITTEN

RESPONSE

QUESTIONS

JANUARY 2000
WRITTEN RESPONSE

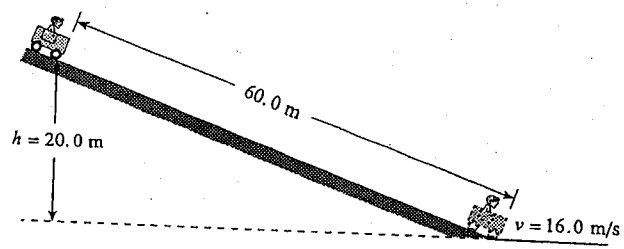
1. Two masses are connected by a light string over a frictionless massless pulley. There is a coefficient of friction of 0.27 between mass m_1 and the horizontal surface.



a) Draw and label a free body diagram showing the forces acting on mass m_1. **(2 marks)**

b) What is the acceleration of mass m_2? **(5 marks)**

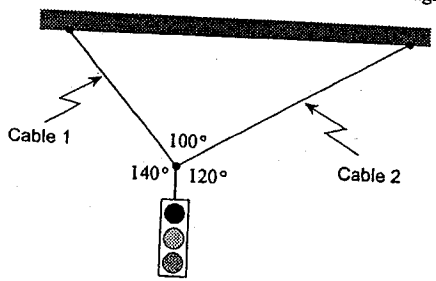
2. A 170 kg cart and rider start from rest on a 20.0 m high incline.



a) How much energy is transformed to heat? **(5 marks)**

b) What is the average force of friction acting on the cart? **(2 marks)**

3. A 35 kg traffic light is suspended from two cables as shown in the diagram.



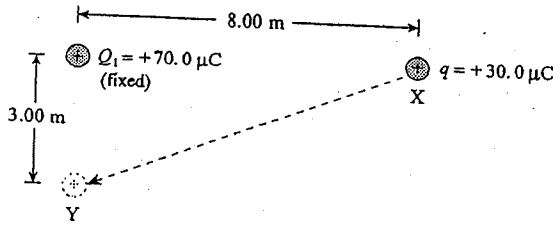
What is the tension in each of these cables? **(7 marks)**

4. A 5.0 kg rock dropped near the surface of Mars reaches a speed of 15 m/s in 4.0 s.

a) What is the acceleration due to gravity near the surface of Mars? **(2 marks)**

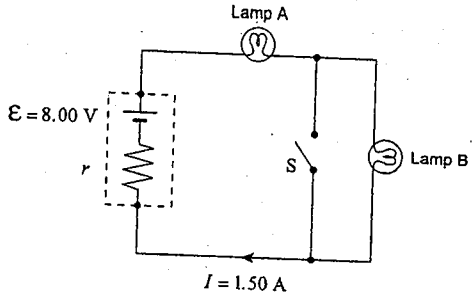
b) Mars has an average radius of 3.38×10^6 m. What is the mass of Mars? **(5 marks)**

5. A charge q of 30.0 μC is moved from point X to point Y.



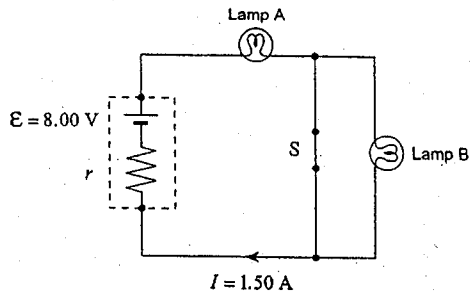
How much work is done on the 30.0 μC charge? $(1\ \mu C = 1 \times 10^{-6}\ C)$ **(7 marks)**

6. The circuit shown consists of an 8.00 V battery and two light bulbs. Each light bulb dissipates 5.0 W. Assume that the light bulbs have a constant resistance. Switch S is open.



a) If a current of 1.50 A flows in the circuit, what is the internal resistance r of the battery? **(4 marks)**

b) The switch S is now closed.



Lamp A will now be

i) ☐ brighter.
☐ the same brightness as before.
☐ dimmer.

(Check one response.) **(1 mark)**

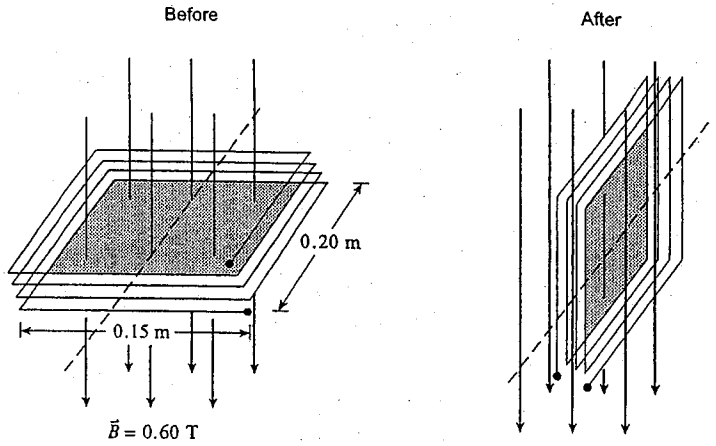
The battery's terminal voltage will now be

ii) ☐ greater than before.
☐ the same as before.
☐ less than before.

(Check one response.) **(1 mark)**

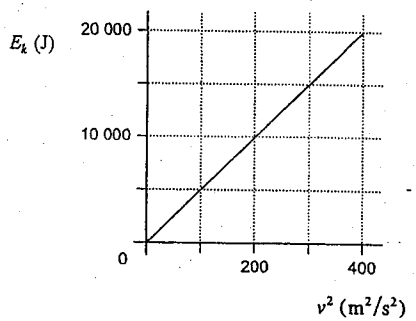
c) Using principles of physics, explain your answers to b). **(3 marks)**

7. The diagram shows a coil with 25 windings and dimensions 0.15 m by 0.20 m. Its plane is perpendicular to a magnetic field of magnitude 0.60 T.



If the coil rotates 90° in 4.17×10^{-2} s so that its plane is now parallel to the magnetic field, what average emf is induced during this time? **(7 marks)**

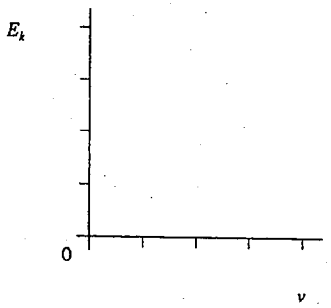
8. A student plots the graph below, showing the kinetic energy E_k of a motorbike versus the square of its velocity v^2.



a) What is the slope of this graph? **(2 marks)**

b) What does the slope represent? **(2 marks)**

c) Using the axes below, sketch the graph of kinetic energy E_k versus velocity v for this motorbike. There is no need to plot any data points. **(1 mark)**



9. A classmate insists a book cannot be held against a wall by pushing horizontally as shown in Diagram A. He insists that there must be a vertical force component provided by pushing against the book from below, as shown in Diagram B.

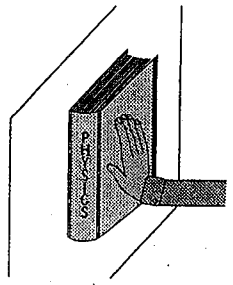


Diagram A

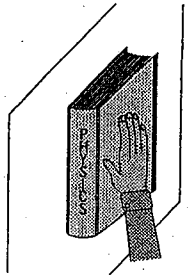
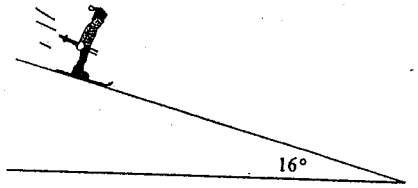


Diagram B

Using principles of physics, show that the situation in Diagram A is reasonable. **(4 marks)**

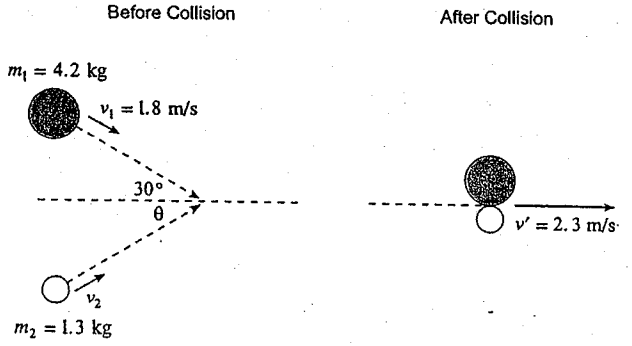
JUNE 2000
WRITTEN RESPONSE

1. A 75 kg Olympic skier takes 20 s to reach a speed of 25 m/s from rest while descending a uniform 16° slope.



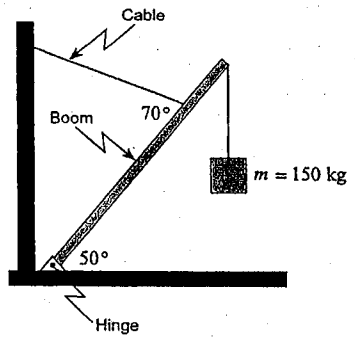
What is the coefficient of friction between the skis and the slope surface? **(7 marks)**

2. Two steel pucks are moving as shown in the diagram. They collide inelastically.



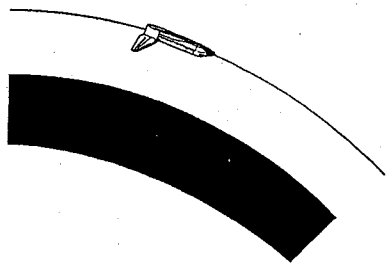
Determine the speed and direction (angle θ) of the 1.3 kg puck before the collision. **(7 marks)**

3. A uniform 6.0 m-long boom has a mass of 55 kg. It is kept in position by a restraining cable attached three-quarters of the way along the boom.



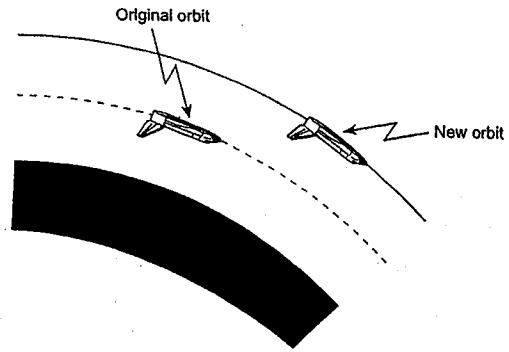
What is the tension in this cable when the boom supports a 150 kg mass as shown? **(7 marks)**

4. A space shuttle is placed in a circular orbit at an altitude of 3.00×10^5 m **above** Earth's surface.



a) What is the shuttle's orbital speed? **(5 marks)**

b) The space shuttle is then moved to a higher orbit in order to capture a satellite.



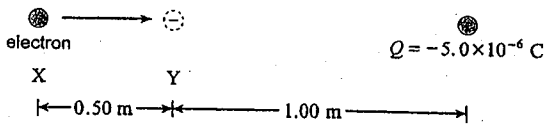
The shuttle's speed in this new higher orbit will have to be

- ☐ greater than in the lower orbit.
- ☐ less than in the lower orbit.
- ☐ the same as in the lower orbit.

(Check one response.) **(1 mark)**

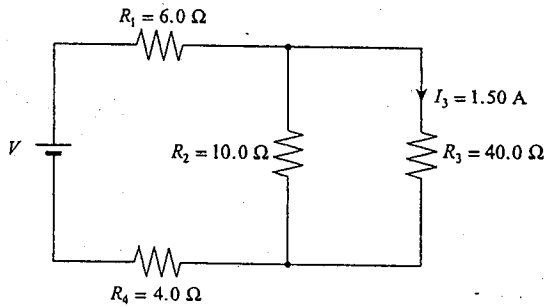
c) Using principles of physics, explain your answer to b). **(3 marks)**

5. a) How much work is done in moving an electron from point X to point Y? **(5 marks)**



b) What is the potential difference between point X and point Y? **(2 marks)**

6. A current of 1.50 A flows through the 40.0 Ω resistor.



What is the potential difference of the power supply? **(7 marks)**

7. A transformer has 840 primary and 56 secondary windings. The primary coil is connected to a 110 V ac power supply which delivers a 0.30 A current to the transformer.

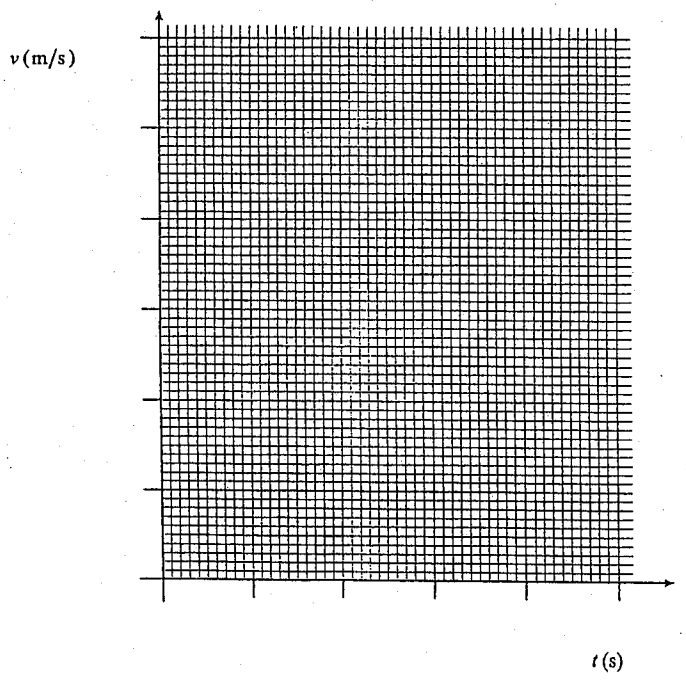
a) Find the secondary voltage. **(4 marks)**

b) Find the secondary current. **(3 marks)**

8. The data table shows the velocity of a car during a 5.0 s interval.

t(s)	0.0	1.0	2.0	3.0	4.0	5.0
v(m/s)	12	15	15	18	20	21

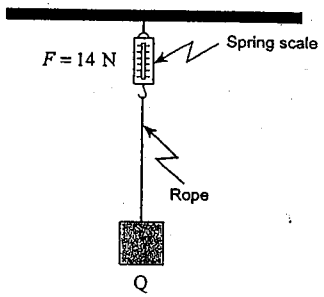
a) Plot the data and draw a best-fit straight line. **(2 marks)**



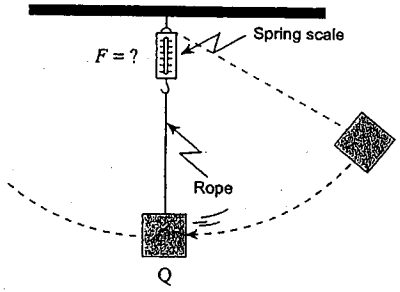
b) Calculate the area bounded by the graph and the time axis between $t = 0.0$ s and $t = 5.0$ s. **(2 marks)**

c) What does this area represent? **(1 mark)**

9. A mass is suspended by a string attached to a spring scale that initially reads 14 N as shown in Diagram 1.



The mass is pulled to the side and then released as shown in Diagram 2.



As the mass passes point Q, how will the reading on the spring scale compare to the previous value of 14 N? Using principles of physics, explain your answer. **(4 marks)**

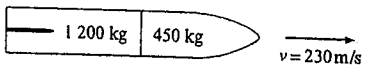
AUGUST 2000
WRITTEN RESPONSE QUESTIONS

1. An aircraft heads due south with a speed relative to the air of 44 m/s. Its resultant speed over the ground is 47 m/s. The wind blows from the west.

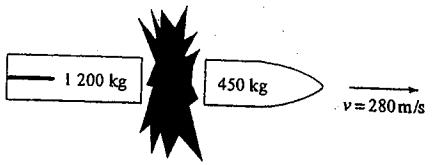
   a) What is the speed of the wind? **(4 marks)**

   b) What is the direction of the aircraft's path over the ground? **(3 marks)**

2. A space vehicle made up of two parts is travelling at 230 m/s as shown.



An explosion causes the 450 kg part to separate and travel with a final velocity of 280 m/s as shown.



   a) What was the momentum of the space vehicle before the explosion? **(2 marks)**

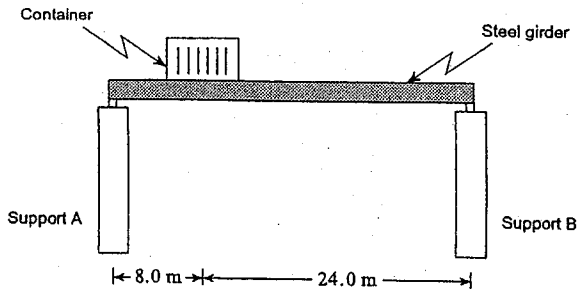
b) What was the magnitude of the impulse on the 1 200 kg part during the separation?
(3 marks)

c) Using principles of physics, explain what changes occur, if any, to the

i) momentum of the system as a result of the explosion. **(2 marks)**

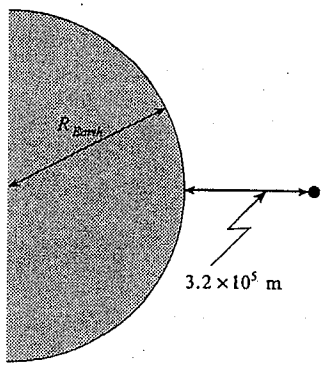
ii) kinetic energy of the system as a result of the explosion. **(2 marks)**

3. A uniform 1 200 kg steel girder is supported horizontally at its endpoints as shown in the diagram.



What are the upward forces at the girder end points when it is bearing a 3 700 kg shipping container 8.0 m from support A?
(7 marks)

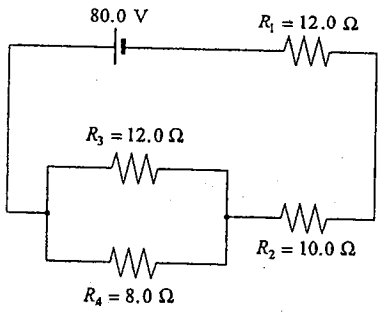
4. A 4.00×10^3 kg object is lifted from the earth's surface to an altitude of 3.2×10^5 m. How much work does this require?
(7 marks)



(Diagram not to scale.)

5. A proton, initially at rest at point X, will have what speed at point Y? **(7 marks)**

6. What is the power dissipated in the 8.0 Ω resistor in the circuit as shown? **(7 marks)**

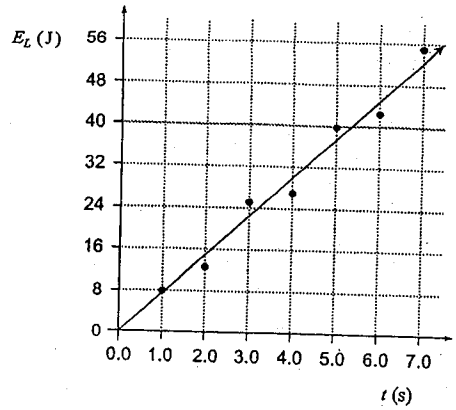


7. The magnetic field at the centre of a solenoid of length 0.25 m is 1.2×10^{-2} T. The current in the windings is 7.5 A.

a) How many windings does the solenoid have? **(4 marks)**

b) If the cross-sectional area of the solenoid is 8.5×10^{-4} m^2, what is the flux through it? **(3 marks)**

8. The graph shows the light energy E_L emitted by a bulb versus time t.



a) Find the power output of the bulb. **(2 marks)**

b) If this bulb is 20% efficient, find the power delivered to the bulb. **(3 marks)**

9. In your summer job with the Ministry of Transportation and Highways your supervisor has told you that street signs should no longer be suspended as shown in Diagram A. In order to save money, he would prefer a shorter, perfectly horizontal cable, as shown in Diagram B.

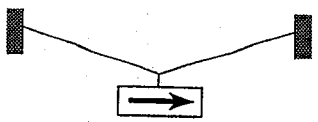


Diagram A

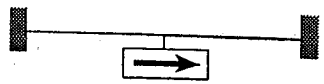
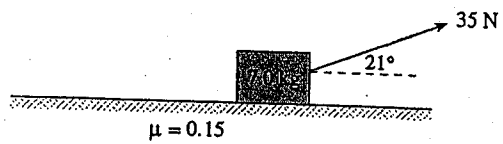


Diagram B

Using principles of physics, argue that the situation in Diagram B is not reasonable. **(4 marks)**

JANUARY 2001
WRITTEN RESPONSE QUESTIONS

1. A 35 N force applied at 21° to the horizontal is used to pull a mass as shown.

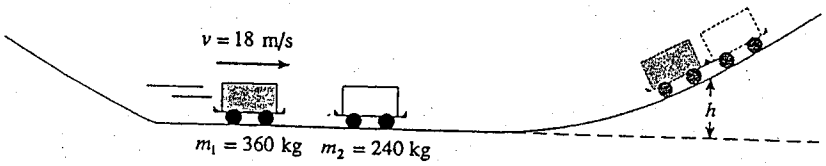


The coefficient of friction between the floor and the mass is 0.15.

a) Draw and label a free body diagram showing the forces acting on the mass. **(2 marks)**

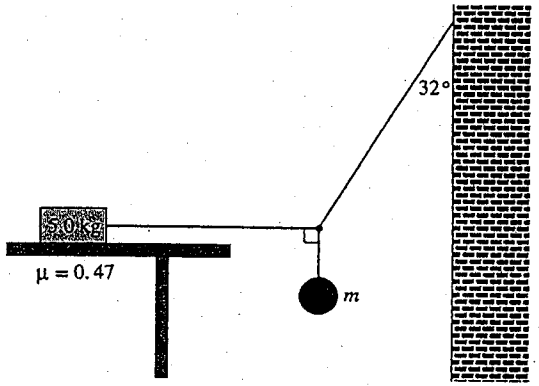
b) What is the acceleration of the mass? **(5 marks)**

2. A 360 kg roller coaster car travelling at 18 m/s collides inelastically with a stationary 240 kg car on a section of horizontal track as shown in the diagram below.



To what maximum height, h, do the combined cars travel before rolling back down the hill? (Assume no friction.) **(7 marks)**

3. An object of mass, m, is suspended by two cords connected to a wall and to a 5.0 kg block resting on a table as shown.

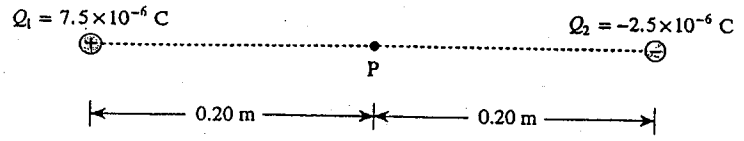


A coefficient of friction of 0.47 exists between the 5.0 kg block and the table. What is the maximum mass, m, that can be hung from the cords before the 5.0 kg block begins to move? **(7 marks)**

4. a) Mars has a mass of 6.37×10^{23} kg and a radius of 3.43×10^{6} m. What is the gravitational field strength on its surface? **(4 marks)**

b) What thrust force must the rocket engine of a Martian lander exert if the 87.5 kg spacecraft is to accelerate upwards at 1.20 m/s^2 as it leaves the surface of Mars? **(3 marks)**

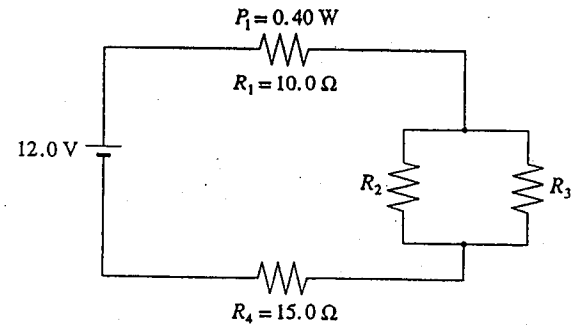
5. Electric charges are arranged as shown in the diagram below.



What is the electric field (magnitude and direction) at point P midway between the charges?

(7 marks)

6. In the circuit below, resistor R_1 dissipates 0:40 W. Resistors R_2 and R_3 are identical.



What is the resistance of R_2?

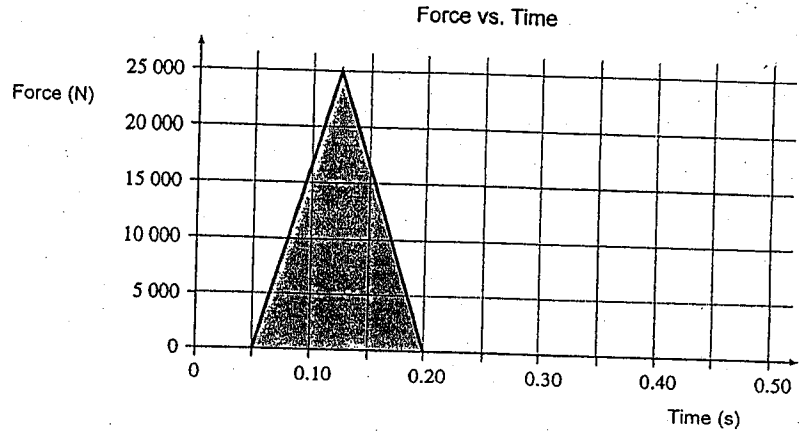
(7 marks)

7. a) A proton moves with a speed of 3.6×10^5 m/s at right angles to a uniform 5.0×10^{-5} T magnetic field. What is the radius of curvature for the motion of the proton? **(5 marks)**

b) Describe the path of the proton in the magnetic field and use principles of physics to explain the proton's motion.

(4 marks)

8. During a motor vehicle accident an unbelted passenger experienced a force which varied with time as shown on the graph.



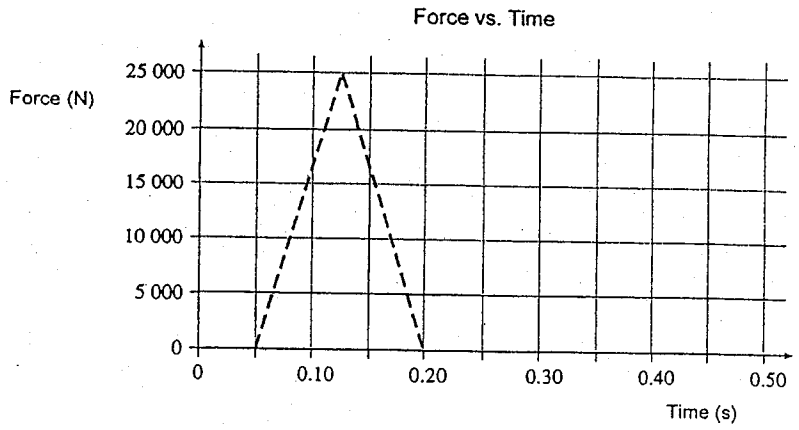
a) Calculate the area of the shaded region in the graph.

(1 mark)

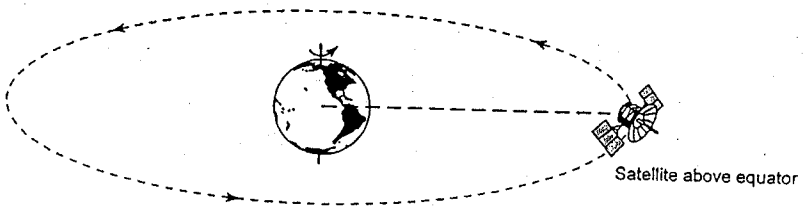
b) What does this area represent?

(2 marks)

c) If the passenger was wearing a seatbelt properly, the maximum force would have been one third the force experienced without the seatbelt. Sketch on the graph below how the force on the belted passenger might have varied with time. **(2 marks)**



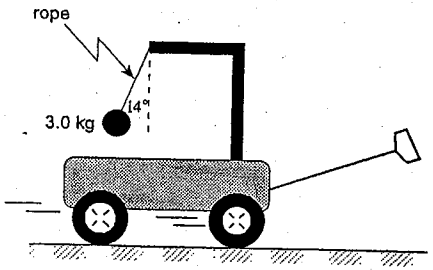
9. Geostationary satellites appear to remain stationary to an observer on Earth. Such satellites are placed in orbit far above the equator.



Using principles of physics, explain why such satellites all have the same orbital radius. **(4 marks)**

JUNE 2001
WRITTEN RESPONSE QUESTIONS

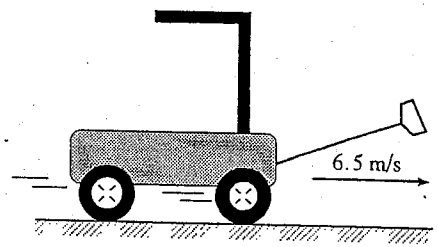
1. A 3.0 kg mass hangs at one end of a rope that is attached to a support on a child's wagon as shown in the diagram. The wagon is pulled to the right. (You may ignore air resistance.)



a) Draw and label a free body diagram showing the forces acting on the mass. **(2 marks)**

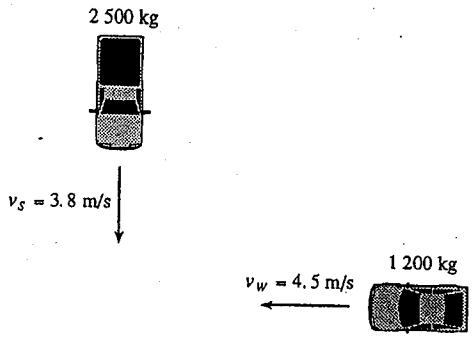
b) What is the acceleration of the wagon? **(3 marks)**

c) On the diagram below, sketch the position of the mass when the cart reaches a constant velocity of 6.5 m/s. **(1 mark)**



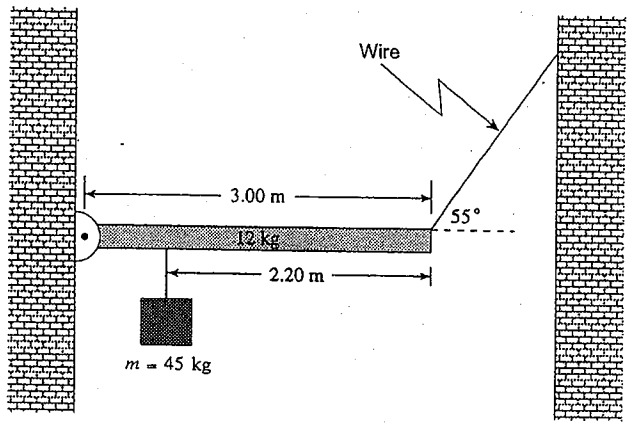
d) Using principles of physics, explain why the mass will be in this position. **(3 marks)**

2. Sally is driving south in her 2 500 kg pickup truck at 3.8 m/s when she collides with Willy driving west in his 1 200 kg car at 4.5 m/s.



The two vehicles lock together and slide over the wet parking lot. Find the speed and direction of the damaged vehicles immediately after the collision. **(7 marks)**

3. A uniform 12 kg beam of length 3.00 m holding a 45 kg mass is attached by a wire to a wall as shown.



What is the tension in the wire? **(7 marks)**

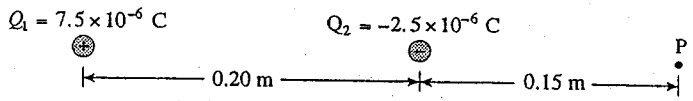
4. An 884 kg satellite in orbit around a planet has a gravitational potential energy of -5.44×10^{10} J. The orbital radius of the satellite is 8.52×10^{6} m and its speed is 7.84×10^{3} m/s.

a) What is the mass of the planet? **(3 marks)**

b) What is the kinetic energy of the satellite? **(2 marks)**

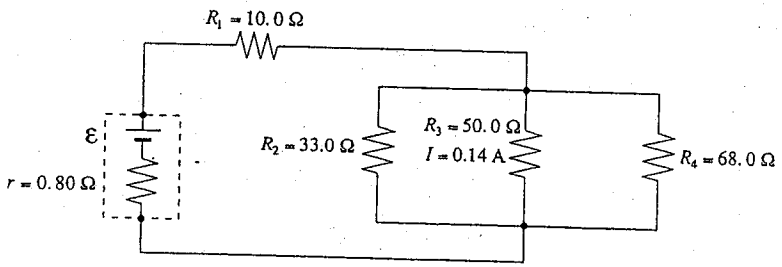
c) What is the total energy of the satellite? **(2 marks)**

5. Electric charges Q_1 and Q_2 are arranged as shown in the diagram below.



What is the electric potential at point P? **(7 marks)**

6. The current through the 50.0 Ω resistor in the circuit below is 0.14 A.



a) Determine the emf of the battery. **(5 marks)**

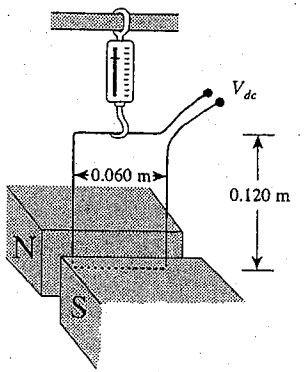
b) Determine the power dissipated in the battery's internal resistance. **(2 marks)**

7. Protons travelling at 2.2×10^5 m/s enter at right angles to a magnetic field. The field is produced by a 0.16 m long solenoid. A current of 5.3 A flows through the 820 turns of wire of the solenoid.

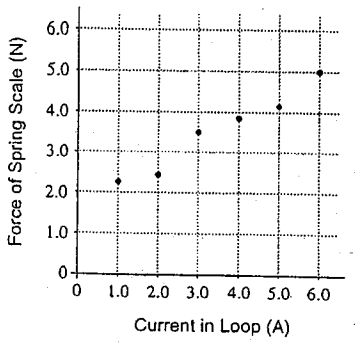
a) What is the magnetic field in the solenoid? **(3 marks)**

b) What is the radius of curvature of the proton beam in the magnetic field of the solenoid? **(4 marks)**

8. A rectangular loop is suspended by a spring scale between magnetic poles. The loop is 0.60 m wide by 0.120 m high.



As the current in the loop is varied, the readings of the spring scale and current are plotted on a graph.

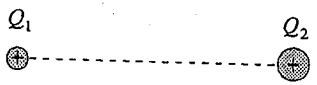


a) What is the weight, in newtons, of the loop? **(1 mark)**

b) What is the slope of the best fit line? **(2 marks)**

c) What is the magnitude of the magnetic field? **(2 marks)**

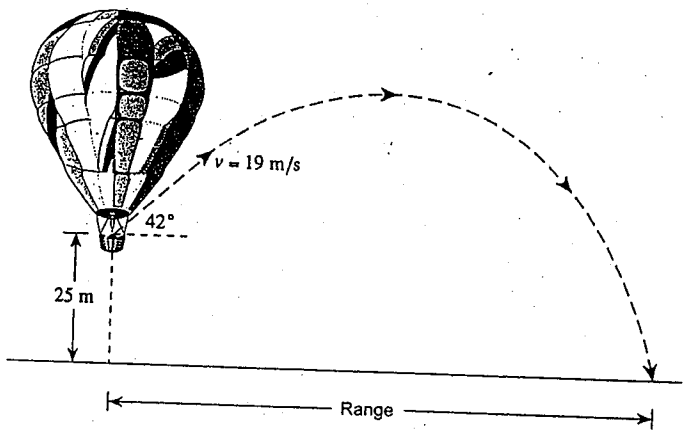
9. A student decides to investigate how electric field varies along the line connecting two positive point charges. Charge Q_2 is greater than charge Q_1.



Using principles of physics, describe the electric field along the line from Q_1 to Q_2. **(4 marks)**

AUGUST 2001
WRITTEN RESPONSE

1. A 0.50 kg ball is thrown at 42° above the horizontal at 19 m/s from a stationary hot air balloon 25 m above the ground.



What is the range? **(7 marks)**

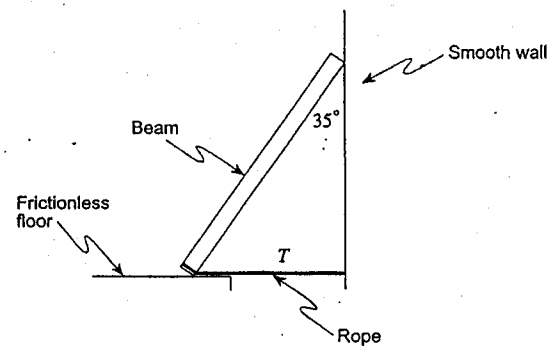
2. A rocket motor, capable of generating a 24 N·s impulse, is attached to a stationary frictionless 3.0 kg cart. The rocket motor is ignited.

a) What will the velocity of the cart be immediately after the rocket motor burns out? **(3 marks)**

b) What is the resulting kinetic energy of the cart? **(2 marks)**

c) A frictionless cart of larger mass will end up with less kinetic energy when powered by an identical rocket motor. Using principles of physics, explain this result. **(4 marks)**

3. A 24 kg beam of length 2.4 m leans against a smooth wall. A horizontal rope tied to the wall and the beam holds the beam on a frictionless floor as shown.

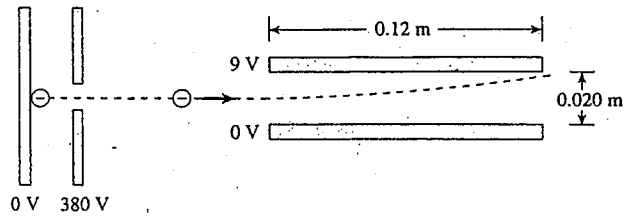


a) Draw a labelled free-body diagram for the forces acting on the beam. **(2 marks)**

b) What is the tension in the rope? **(5 marks)**

4. A spacecraft of mass 470 kg rests on the surface of an asteroid of radius 1 400 m and mass 2.0×10^{12} kg. How much energy must be expended so that the spacecraft may rise to a height of 2 800 m above the surface of the asteroid? **(7 marks)**

5. A beam of electrons is directed to a region between oppositely charged parallel plates as shown in the diagram below.



a) The electron beam is produced by accelerating electrons through an electric potential difference of 380 V. What is the speed of the electrons as they leave the 380 V plate? **(3 marks)**

b) What is the electrostatic force on electrons in the region between the horizontal plates when they are connected to a 9.0 V potential difference? **(4 marks)**

6. A 12 V battery transfers 33 C of charge to an external circuit in 7.5 s.

a) What current flows through the circuit? **(2 marks)**

b) What is the resistance of the circuit? **(2 marks)**

c) What is the power output of the battery? **(2 marks)**

d) The external circuit is most likely to consist of

- ☐ a bulb.
- ☐ a kettle.
- ☐ a calculator.

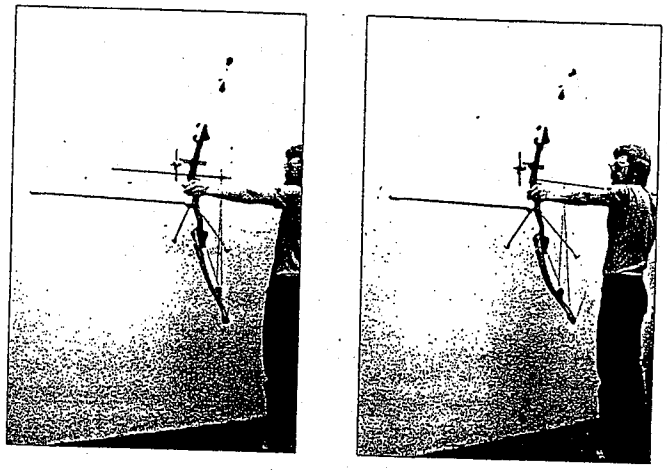
(Check one response.) **(1 mark)**

7. An electron travelling at 7.7×10^6 m/s enters at right angles into a uniform magnetic field. Inside the field the path of the electron has a radius of 3.5×10^{-2} m.

a) What is the magnitude of the magnetic field? **(4 marks)**

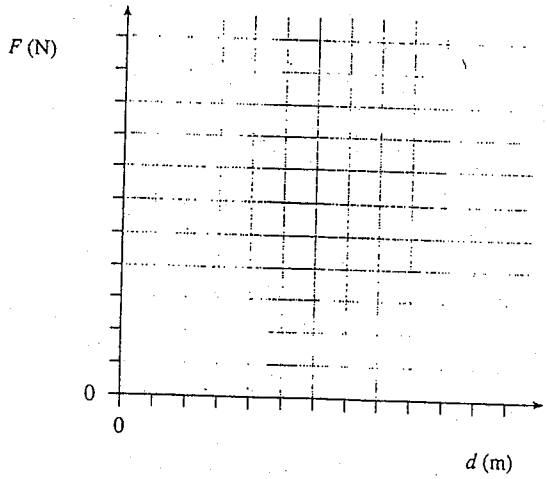
b) If the magnetic field is produced at the centre of a solenoid by a current of 0.62 A, what is the number of turns per unit length of the solenoid? **(3 marks)**

8. As a compound bow was drawn back, the applied forces and displacements were recorded.



F (N)	0	31	65	84	122	160	186	180	175	184	180
d (m)	0	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50

a) Plot a force vs. displacement graph below. **(2 marks)**



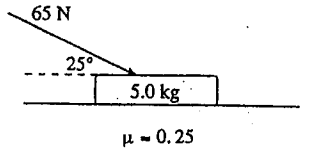
b) How much energy was stored in this compound bow? **(3 marks)**

9. Two identical light bulbs, wired in parallel to a battery, are equally bright. When one of the bulbs burns out, however, the other bulb is observed to glow brighter. Using principles of physics, explain why the battery causes the remaining bulb to glow more brightly. **(4 marks)**

JANUARY 2002

WRITTEN RESPONSE QUESTIONS

1. A 65 N force is applied to a 5.0 kg object as shown.



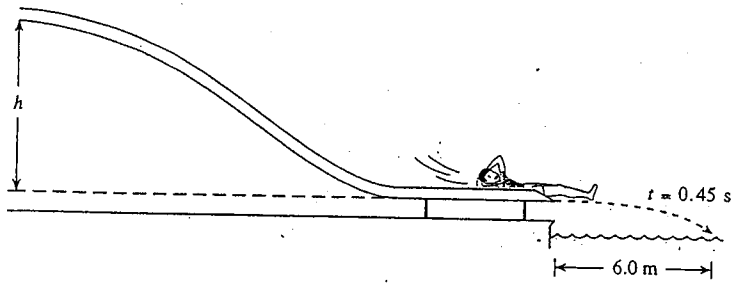
$\mu = 0.25$

The coefficient of friction between the object and the horizontal surface is 0.25.

a) Draw and label a free body diagram showing the forces acting on the object. **(2 marks)**

b) What is the acceleration of the object? **(5 marks)**

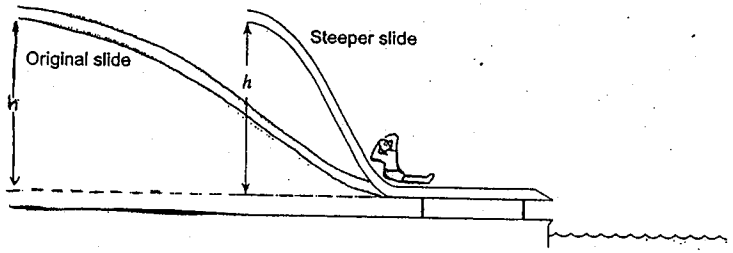
2. A water slide is made so that swimmers, starting from rest at the top, leave the end of the slide travelling horizontally as shown.



One person is observed to hit the water at a horizontal distance of 6.0 m from the end of the slide 0.45 s after leaving the slide. The effects of friction and air resistance are negligible.

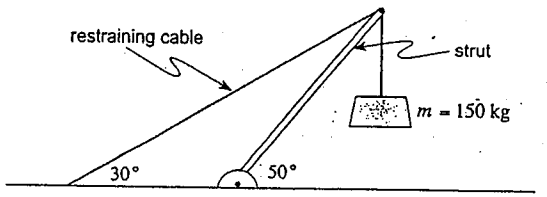
a) From what vertical height, h, did the person start? **(5 marks)**

b) Another slide has the same vertical height, h, as the original slide, but has a much steeper slide angle.



The same person is observed to go down this steep slide. Using principles of physics, explain how the new horizontal distance from the edge of the slide compares with the first situation. The effects of friction and air resistance are negligible. **(4 marks)**

3. The crane shown in the diagram below is made up of a strut and a restraining cable. The strut is uniform in cross section with a length of 6.0 m and a mass of 85 kg.



What is the tension in the restraining cable while the crane is supporting a 150 kg load? **(7 marks)**

4. What minimum energy is required to take a stationary 3.5×10^3 kg satellite from the surface of the Earth and put it into a circular orbit with a radius of 6.88×10^6 m and an orbital speed of 7.61×10^3 m/s? (Ignore Earth's rotation.) **(7 marks)**

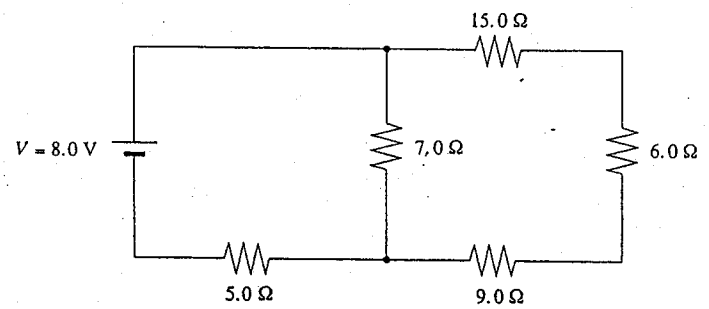
5. A 12 V battery from a car is used to operate a 65 W headlight.

   a) How much energy does the headlight use in 1.5 hours? **(2 marks)**

   b) What total charge passes through the headlight during this time? **(3 marks)**

   c) What is the total number of electrons that pass through the headlight during this time period? **(2 marks)**

6. What is the potential difference across the 6.0 Ω resistor in the circuit shown? **(7 marks)**



7. A proton travelling at 2200 m/s enters a 0.15 T magnetic field perpendicularly.

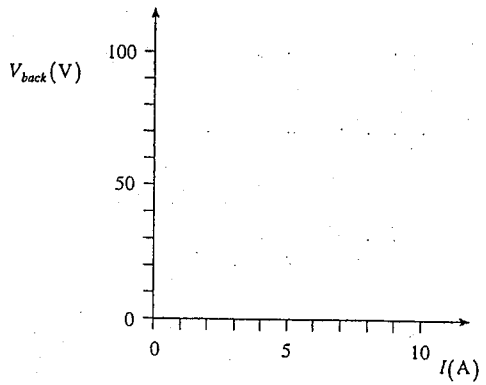
   a) What is the magnitude of the proton's acceleration while travelling through the magnetic field? **(4 marks)**

   b) What is the radius of the proton's circular path while travelling through the magnetic field? **(3 marks)**

8. A constant voltage is applied to an electric motor being used to lift a series of masses onto a truck. The current through the motor and its back emf are recorded for each different load. This data is shown below.

I(A)	V_{back}(V)
1.5	98
3.5	84
5.0	76
6.0	70
8.0	54

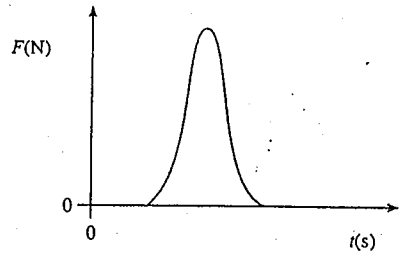
   a) Plot the data on the graph below and draw the best fit straight line. **(2 marks)**



   b) Determine the magnitude of the slope of the line. **(1 mark)**

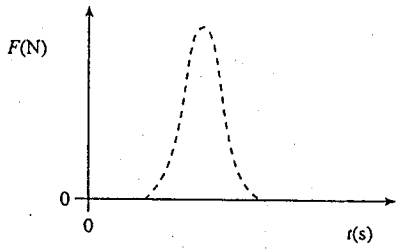
   c) What does the magnitude of the slope of this line represent? **(2 marks)**

9. In sports such as golf, tennis and baseball, a player exerts a force over a time interval on a ball, as shown on the graph, in order to give it a high speed.



Players are instructed to "follow through" on their swing. A weaker player may not exert as large a force but may give the ball a higher speed than a stronger player.

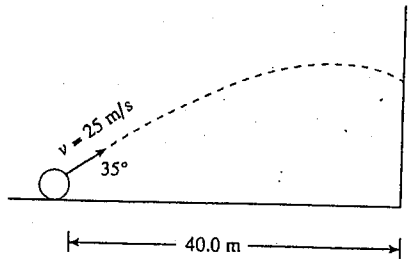
a) Sketch on the graph below how a weaker player can overcome the force handicap. **(1 mark)**



b) Explain how the player can impart a greater impulse on a ball. **(3 marks)**

JUNE 2002
WRITTEN RESPONSE QUESTIONS

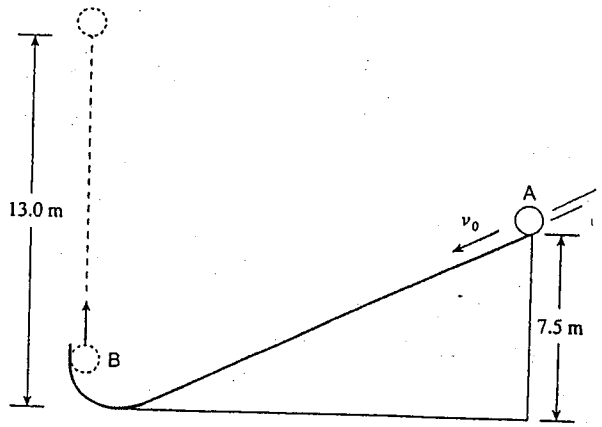
1. A projectile is launched towards a wall as shown in the diagram below.



With what velocity (magnitude and direction) does the projectile hit the wall? **(7 marks)**

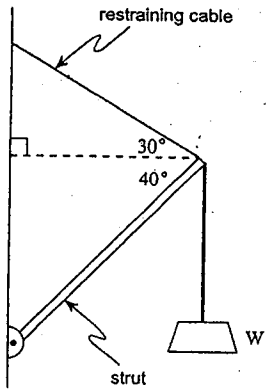
2. A 0.50 kg ball starting from position A which is 7.5 m above the ground, is projected down an incline as shown. Friction produces 10.7 J of heat energy.

The ball leaves the incline at position B travelling straight upward and reaches a height of 13.0 m above the floor before falling back down.



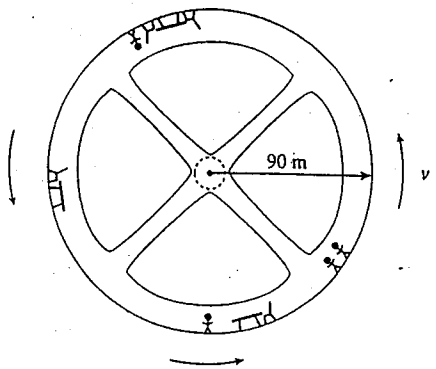
What was the initial speed, v_0, at position A? Ignore air resistance. **(7 marks)**

3. The crane assembly shown in the diagram below consists of a uniform 4.0 m long 65 kg strut and a restraining cable.



What is the maximum weight W that can be supported by this crane if the maximum tension that the restraining cable can withstand is 2400 N? The vertical rope is strong enough to support any required load.
(7 marks)

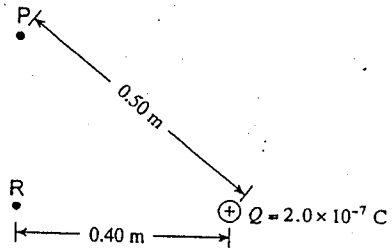
4. A space station of radius 90 m is rotating to simulate a gravitational field.



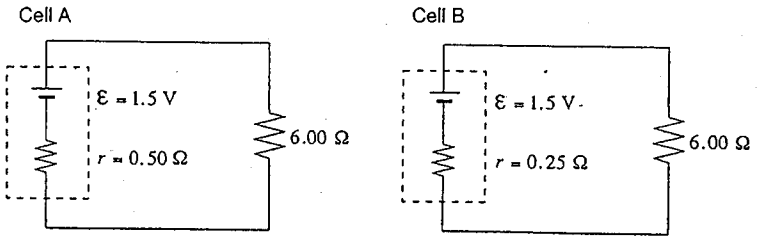
a) What is the period of the space station's rotation so that a 70 kg astronaut will experience a normal force by the outer wall equal to 60% of his weight on the surface of the earth?
(5 marks)

b) What would be the effect experienced by the astronaut if the space station rotated faster so that the period of rotation was decreased? Explain your predicted effect. **(4 marks)**

5. What is the electric potential difference between points P and R due to the fixed point charge Q?
(7 marks)

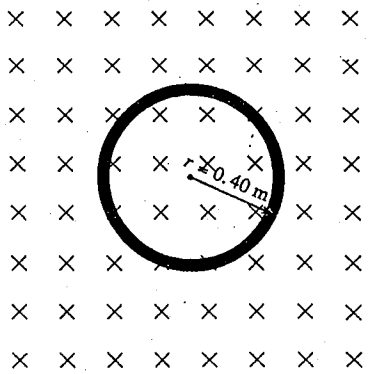


6. Each of the two cells shown is connected to an external 6.00 Ω resistor.



With supporting calculations, state which cell delivers the greater power to the 6.00 Ω resistor.
(7 marks)

7. A coil of wire containing 50 loops is lying on a flat surface in a 0.60 T magnetic field pointing directly into the surface.



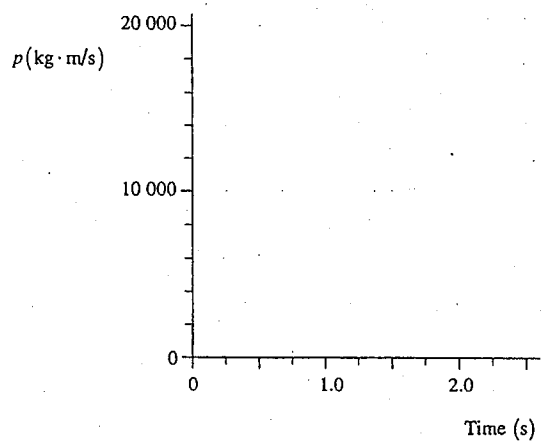
The magnetic field then changes to a value of 0.10 T in the opposite direction in 2.10 s. What is the average emf induced in the coil during the time that the magnetic field was changing? **(7 marks)**

8. As a formula one race car accelerates uniformly from rest, its momentum is recorded at regular time intervals. This data is shown below.

Time (s)	p(kg · m/s)
0.50	3 800
1.0	8 300
1.5	11 500
2.0	16 800
2.5	19 000

8. CONTINUED.....

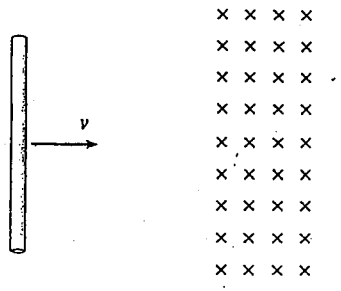
a) Plot the data on the graph below and draw the best fit straight line. **(2 marks)**



b) Determine the slope of the line (include units). **(1 mark)**

c) What does the slope of this line represent? **(2 marks)**

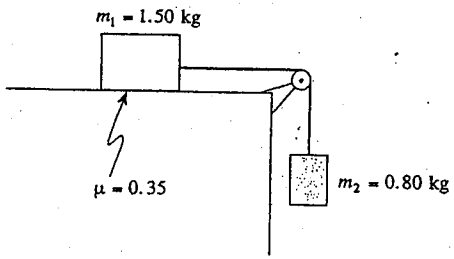
9. A steel rod passes through a region where a magnetic field exists.



The rod slows as it passes through the magnetic field. Using principles of physics, explain why this happens. **(4 marks)**

AUGUST 2002
WRITTEN RESPONSE

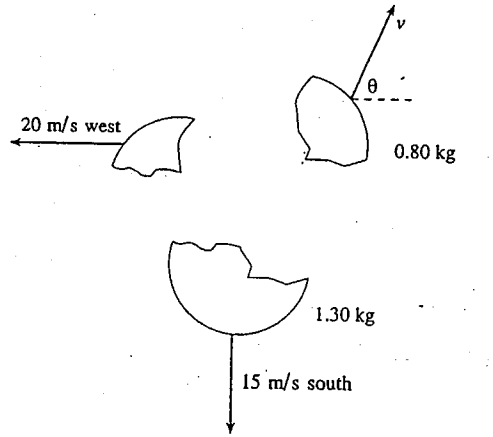
1. Two masses are connected by a light string passing across a frictionless pulley as shown in the diagram below. The coefficient of friction between mass m_1 and the horizontal surface is 0.35.



a) Draw and label a free body diagram showing the forces acting on mass m_1. **(2 marks)**

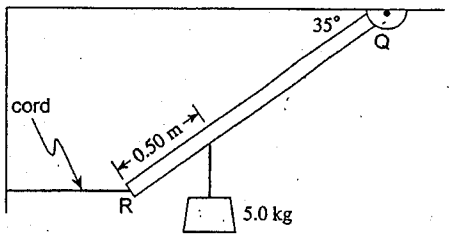
b) What is the tension in the connecting string? **(5 marks)**

2. A 3.00 kg object initially at rest explodes into three fragments as shown in the diagram below.



What are the speed and direction of the 0.80 kg fragment? **(7 marks)**

3. A uniform 2.4 m beam RQ has a mass of 3.0 kg. The beam is hinged at Q and held in place by a horizontal cord attached at R. A 5.0 kg mass is suspended 0.50 m from R.

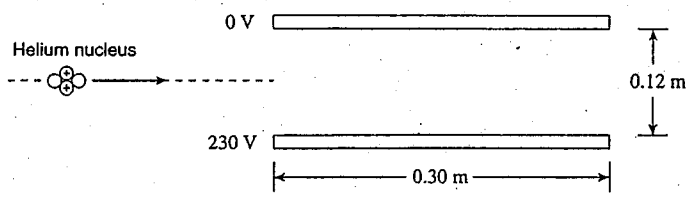


What is the tension in the horizontal cord? (7 marks)

4. A 720 kg communication satellite is in synchronous orbit around the planet Mars. This synchronous orbit matches the period of rotation so that the satellite appears to be stationary over a position on the equator of Mars. What is the orbital radius of this satellite? (7 marks)

Planetary Data for Mars
Mass: 6.42×10^{23} kg
Period of rotation: 8.86×10^{4} s

5. A helium nucleus having twice the charge and four times the mass of a proton is travelling with high velocity when it enters a set of charged plates as shown.

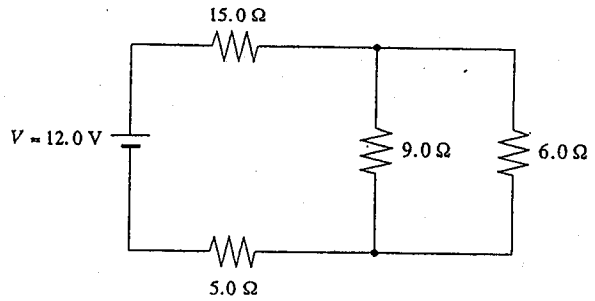


a) Find the magnitude of the acceleration of the helium nucleus due to these plates. **(5 marks)**

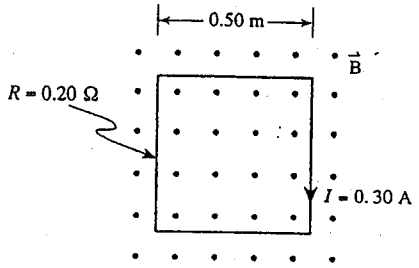
b) A proton travelling at the same velocity as the helium nucleus is then sent through these same plates. Explain, using principles of physics, why the acceleration of the proton is larger than that of the helium nucleus. **(4 marks)**

6. How much energy does the 6.0 Ω resistor dissipate in 15 seconds in the circuit shown?

(7 marks)



7. The single square loop of copper wire with a resistance of 0.20 Ω has a current of 0.30 A due to a continuously increasing magnetic field.



At what rate, in T/s, is the magnetic field increasing?

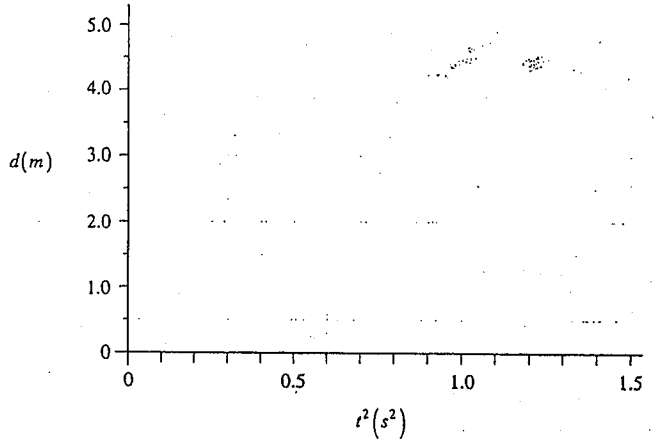
(7 marks)

8. The first colonists on Mars conduct a physics experiment by dropping a small mass (from rest) and recording its displacement at regular time intervals. This data is shown below.

$d\ (m)$	$t\ (s)$	
0.30	0.40	
0.60	0.60	
1.20	0.80	
1.80	1.00	
2.70	1.20	

a) Plot a graph of displacement versus time squared and draw the best fit straight line.

(2 marks)

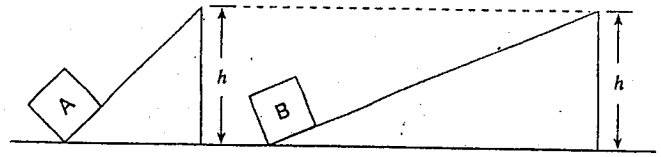


b) Determine the slope of the line.

(2 marks)

c) Based on this experiment, what is the acceleration due to gravity on Mars? **(1 mark)**

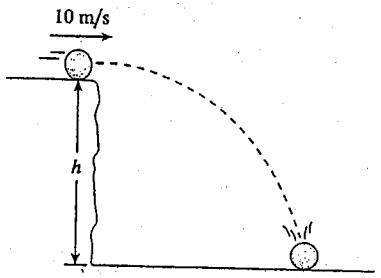
9. Identical blocks are placed on inclines as shown. The coefficients of friction between the blocks and the inclined surfaces are identical.



Both blocks are then pushed to the top of each incline at the same constant speed. Using principles of physics, explain which block required more work to reach the top of the incline.
(4 marks)

JANUARY 2003
WRITTEN RESPONSE QUESTIONS

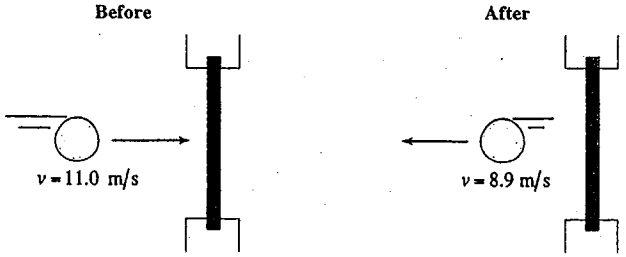
1. A blue ball rolls off the cliff shown below at 10 m/s and hits the ground with a speed of 30 m/s.



a) What is the vertical component of the ball's impact velocity? **(4 marks)**

b) How high (h) is the cliff? **(3 marks)**

2. a) A 0.120 kg ball travelling at 11.0 m/s impacts a solid massive steel wall. The ball bounces straight back at 8.9 m/s.

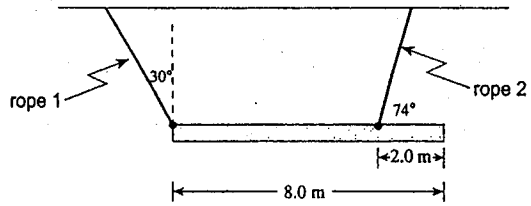


If the ball was in contact with the steel wall for 0.17 s, what is the magnitude of the force that the steel wall imparted on the ball? **(5 marks)**

b) An identical ball with the same initial speed as in part a) is then thrown towards a glass window. The glass window cracks and the ball stops in 0.17 s.

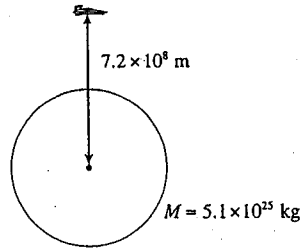
Using principles of physics, explain which ball, from part a) or part b), experiences the greater force. **(4 marks)**

3. The 8.0 m uniform beam shown below, suspended horizontally by two ropes, has a mass of 75 kg.



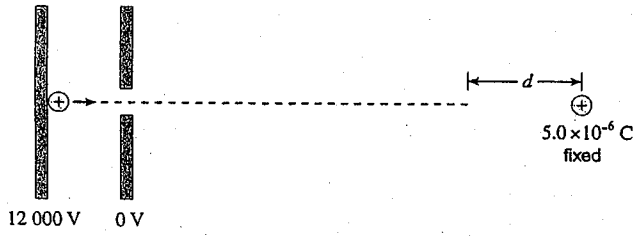
Determine the tension in rope 1 and the tension in rope 2. **(7 marks)**

4. A 12 000 kg spaceship is 7.2×10^8 m from the centre of a planet that has a mass of 5.1×10^{25} kg.



The spaceship gains 9.0×10^{11} J of kinetic energy as it falls to the planet's surface. What is the radius of this planet? **(7 marks)**

5. A proton, accelerated from rest through a potential difference of 1.2×10^4 V, is directed at a fixed 5.0×10^{-6} C charge.

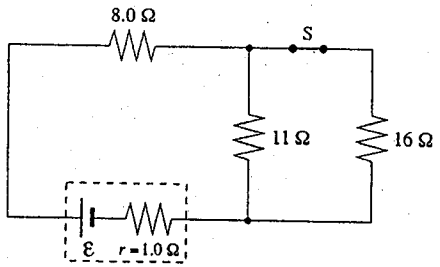


(Diagram not to scale.)

a) What is the speed of the proton as it leaves the parallel plates? **(4 marks)**

b) What is the distance d from the fixed charge when the proton is stopped? **(3 marks)**

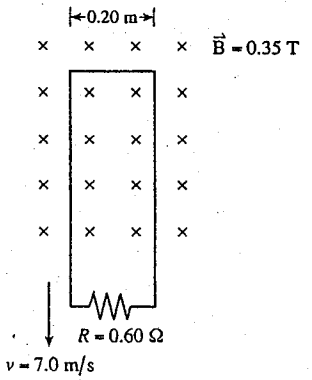
6. The terminal voltage of the battery is 5.8 V.



a) What is the emf of this battery? **(6 marks)**

b) What is the effect on the emf of the battery when switch S is opened? **(1 mark)**

7. A rectangular wire loop with a resistance of 0.60 Ω is pulled out of a magnetic field at 7.0 m/s as shown in the diagram.



a) What is the current in the loop? **(5 marks)**

b) What is the direction of the current in the loop? **(2 marks)**

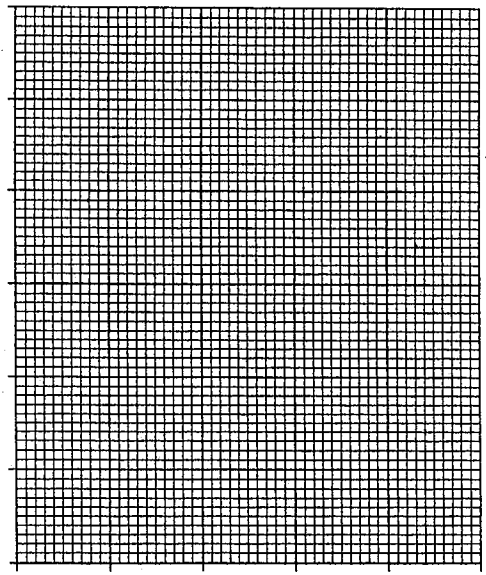
- ☐ clockwise
- ☐ counter-clockwise

8. The following data is collected in a kinematics experiment using a toy car.

t (s)	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
v (m/s)	0.35	0.46	0.59	0.70	0.83	0.94	1.10	1.18

a) Plot the data on a v vs. t graph and extrapolate your line back to $t = 0$. **(2 marks)**

v (m/s)

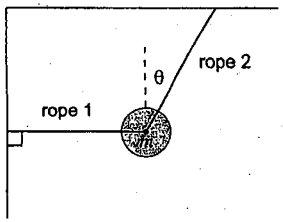


t (s)

b) What is the displacement of the toy car from $t = 0$ to $t = 0.90$ s? **(2 marks)**

c) What does the y-intercept of the graph represent? **(1 mark)**

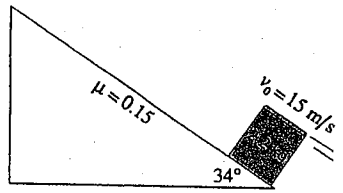
9. A mass suspended by two ropes is shown below. It is noticed that for any angle θ used for rope 2, the tension in rope 2 is always greater than the tension in rope 1.



Using principles of physics, explain why this is the case. **(4 marks)**

JUNE 2003
WRITTEN RESPONSE QUESTIONS

1. A 2.2 kg can of paint is projected up an inclined plane with an initial velocity of 15 m/s as shown below.

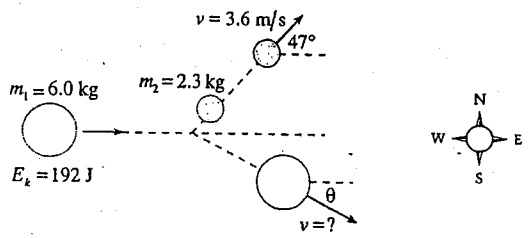


a) Determine the magnitude of the force due to friction which acts on the paint can as it slides up the incline. **(2 marks)**

b) Determine the magnitude of the net force on the paint can as it slides up the incline. **(3 marks)**

c) Determine how far the paint can slides up the incline before stopping. **(2 marks)**

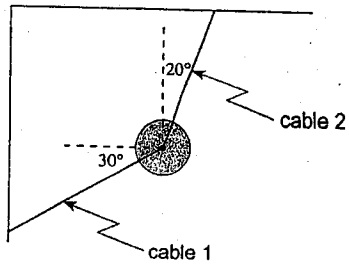
2. A 6.0 kg ball having a kinetic energy of 192 J was travelling due east when it underwent an oblique collision with a stationary 2.3 kg ball. The 2.3 kg ball travelled at 3.6 m/s at an angle of 47° north of east after the collision.



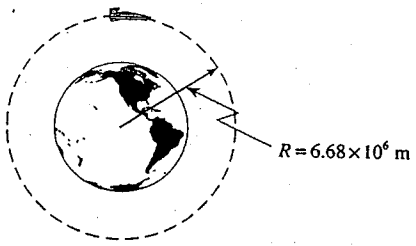
(Diagram not to scale.)

What was the velocity (magnitude and direction) of the 6.0 kg ball after the collision? **(7 marks)**

3. A wrecking ball is suspended by two cables as shown below. If the tension in cable 2 is 12 000 N, what is the weight of the wrecking ball? **(7 marks)**

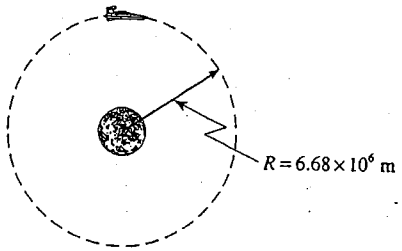


4. A 3.2×10^4 kg spacecraft is in a circular orbit of radius 6.68×10^6 m around the earth.



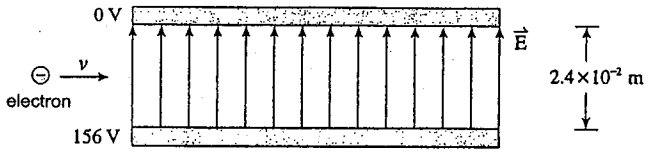
a) Calculate the period of this spacecraft. **(5 marks)**

b) If this spacecraft is then placed into an orbit of the same radius around the moon,



explain how and why the period of this spacecraft would be different than when it was orbiting the earth. **(4 marks)**

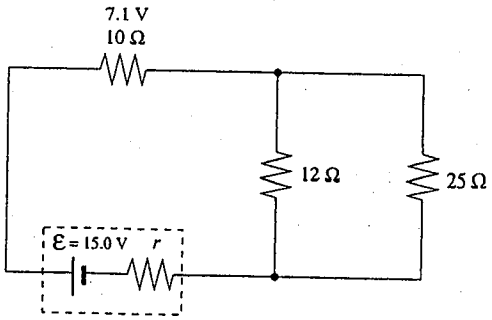
5. An electron with a speed of 3.3×10^{7} m/s is directed between charged parallel plates as shown.



a) What are the magnitude and direction of the electrostatic force on the electron while it is between the plates? **(5 marks)**

b) What is the magnitude of the acceleration of the electron while it is between the plates? **(2 marks)**

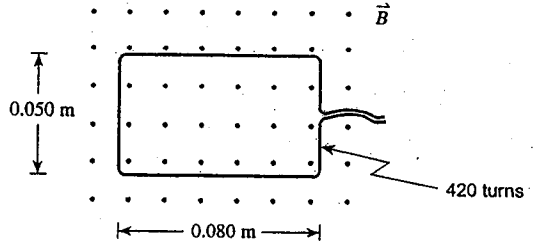
6. The potential difference across the 10 Ω resistor is 7.1 V.



a) What is the power dissipated by the 25 Ω resistor? **(4 marks)**

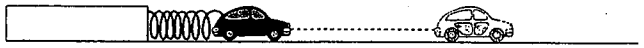
b) What is the internal resistance of the battery? **(3 marks)**

7. A 420-turn rectangular coil is positioned as shown in a 0.14 T magnetic field.



The magnetic field strength is increased over a 0.20 s interval, inducing an average emf of 1.8 V in the coil. What is the final magnetic field strength? **(7 marks)**

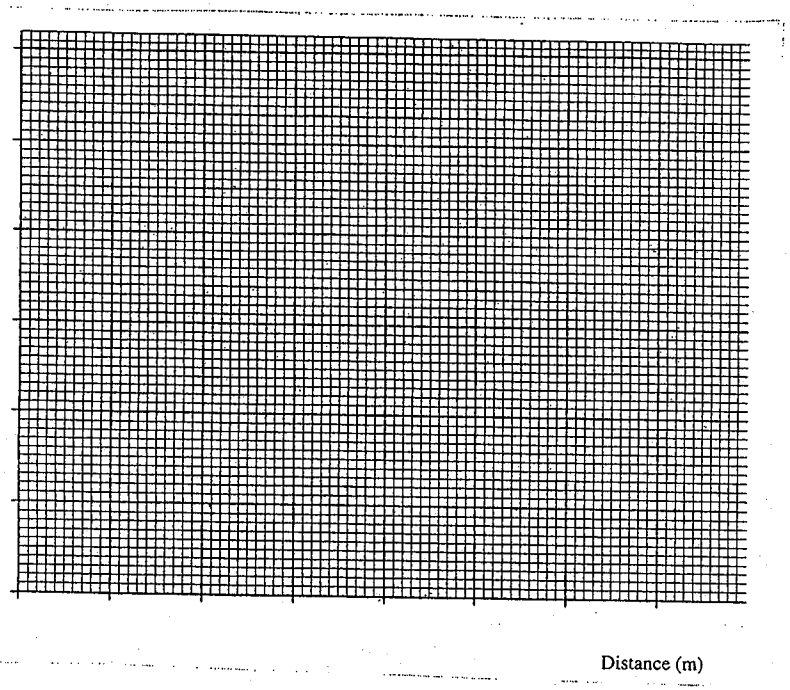
8. A small toy car is placed in a spring-loaded launcher.



The force needed to compress the spring is recorded as a function of distance.

a) Plot a graph of force vs. distance using the data table shown. **(2 marks)**

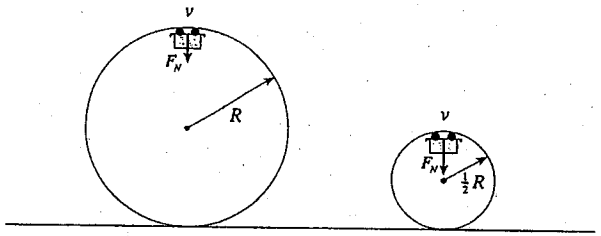
Force (N)	Distance (m)
7.5	0.020
13.2	0.035
14.8	0.040
19.1	0.050
23.0	0.060
29.5	0.080



b) Calculate the area under this graph from distance = 0.0 m to distance = 0.080 m. **(2 marks)**

c) What does this area represent? **(1 mark)**

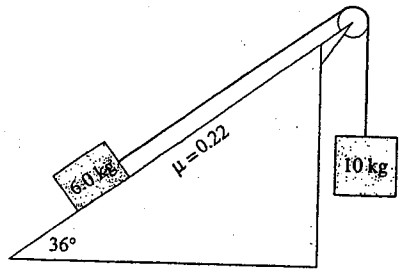
9. During a roller coaster ride, the riders move through two loops, the second being one-half the radius of the first. The riders, however, travel at the same speed at the top of each of these two loops.



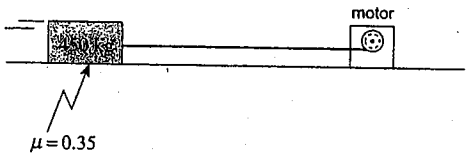
Using principles of physics, explain why the riders would experience a greater normal force at the top of the second smaller loop than at the top of the first, larger loop. **(4 marks)**

AUGUST 2003
WRITTEN RESPONSE QUESTIONS

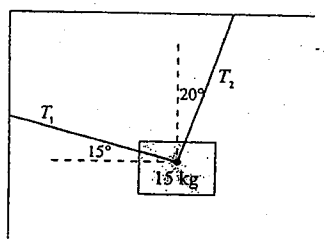
1. Determine the acceleration of the system of masses shown below when it is released. **(7 marks)**



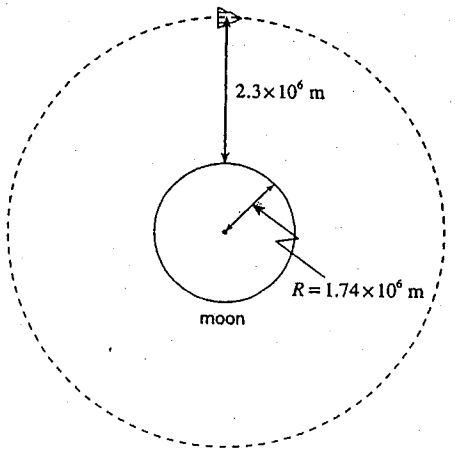
2. A motor using 3.7×10^{3} W is 81% efficient. This motor is pulling a 450 kg block along a horizontal surface. If the coefficient of friction is 0.35, what is the speed of the block?
(7 marks)



3. A 15 kg store sign is hung using two ropes as shown below. Determine the tension in each rope.
(7 marks)

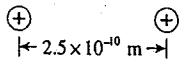


4. A 1500 kg satellite orbits the moon at an altitude of 2.3×10^{6} m.

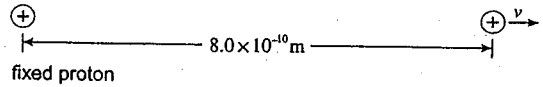


What is the period of the satellite?
(7 marks)

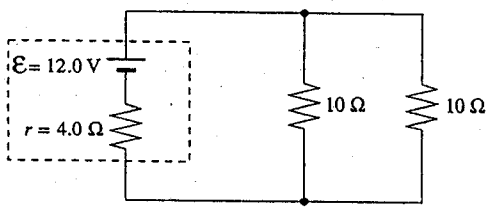
5. Two protons are initially held at rest 2.5×10^{-10} m apart.



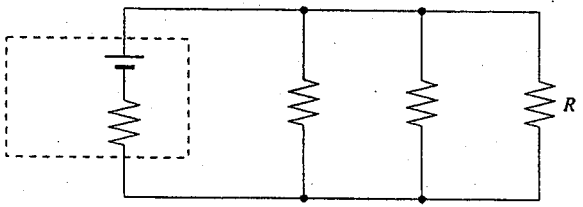
If one of the protons is released as shown below, what is its speed when it is 8.0×10^{-10} m from the fixed proton?
(7 marks)



6. a) For the circuit below, what is the terminal voltage of the battery? **(4 marks)**



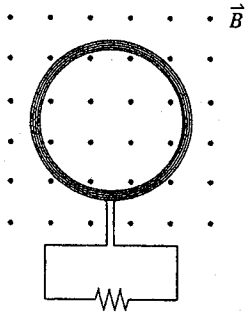
b) If resistor R is added in parallel to the circuit as shown, what is the effect on the terminal voltage? **(1 mark)**

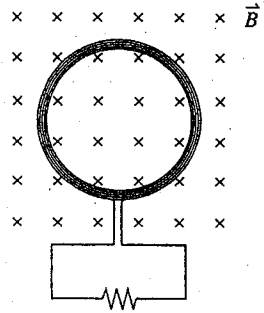


- ☐ increase
- ☐ no change
- ☐ decrease

c) Using principles of physics, explain your choice for b). **(4 marks)**

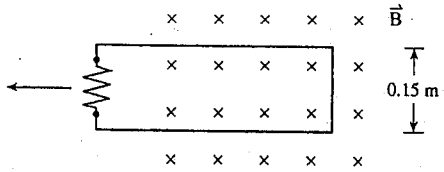
7. A 0.120 m diameter coil consisting of 200 loops is placed in a 0.35 T magnetic field. The magnetic field is changed to 0.25 T in the opposite direction in 0.80 s.





What is the magnitude of the current through the 33 Ω resistor connected to the coil? (Ignore the resistance of the coil.) **(7 marks)**

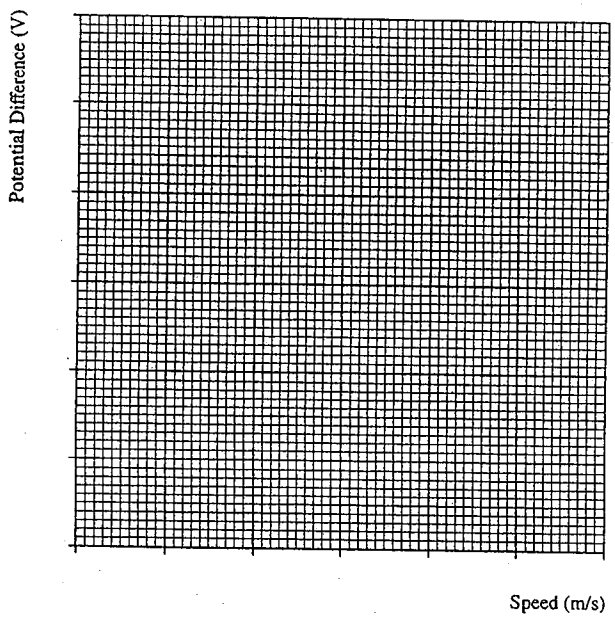
8. A conducting loop is pulled at various speeds through a region of constant magnetic field strength.



A student measures the potential difference across the resistor in the loop for each trial and records the following data.

POTENTIAL DIFFERENCE (V)	SPEED (m/s)
0.10	1.5
0.17	2.5
0.20	3.0
0.24	4.0
0.34	5.5
0.41	6.0

a) Plot a graph of the potential difference vs. speed. **(2 marks)**



b) Calculate the slope of your graph. (Include units.) **(1 mark)**

c) What is the strength of the magnetic field? **(2 marks)**

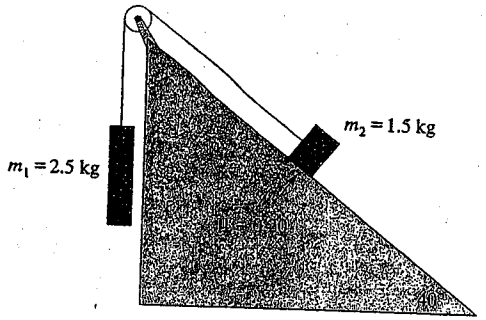
9. A crate is being accelerated across a rough concrete floor by a rope as shown in position 1 below. It is noticed that when the rope is lifted to a small angle θ as shown in position 2 the acceleration of the crate increases (F remains the same).

Position 1 Position 2

Using principles of physics, explain why this is the case. **(4 marks)**

JANUARY 2004
WRITTEN RESPONSE QUESTIONS

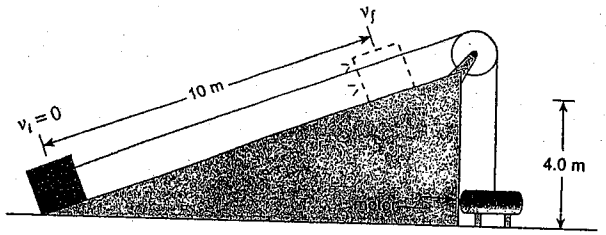
1. A system of masses is connected by a light cord passing over a pulley as shown in the diagram.



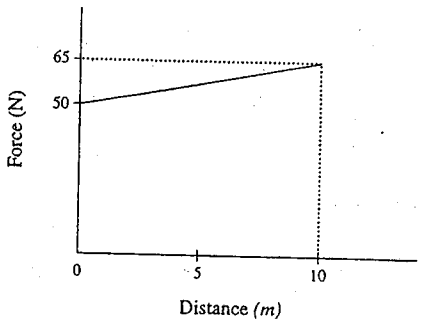
a) Draw a labelled free body diagram for mass m_2. **(2 marks)**

b) What is the magnitude of the acceleration of the system of masses? **(5 marks)**

2. An electric motor and a rope are used to pull a 10 kg crate of car parts up an inclined plane as shown below. The crate starts out from rest on the ground and ends up with speed v_f at a height of 4.0 m above the ground.



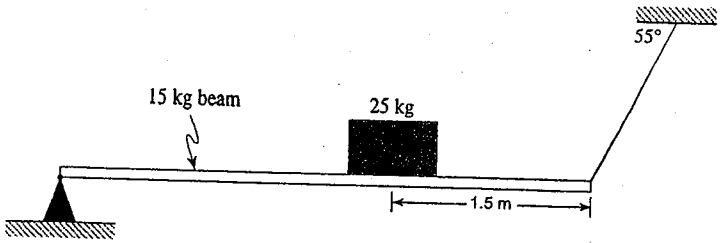
The graph below shows the force exerted on the crate by the motor as it is pulled 10 m up the inclined plane.



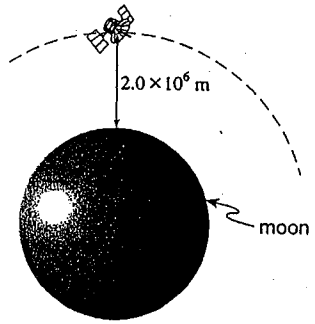
a) How much work is done on the crate by the electric motor from $d = 0$ m to $d = 10$ m? **(3 marks)**

b) 150 J of heat energy is produced through friction during the 10 m pull. What is the final speed of the crate at $d = 10$ m? **(4 marks)**

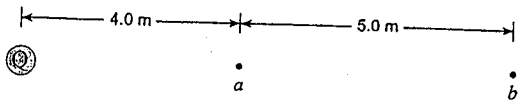
3. A uniform 4.0 m long beam with a mass of 15 kg rests on a pivot at one end and is kept horizontal by a cable at the other end. The beam is supporting a 25 kg mass as shown. What is the tension in the cable? **(7 marks)**



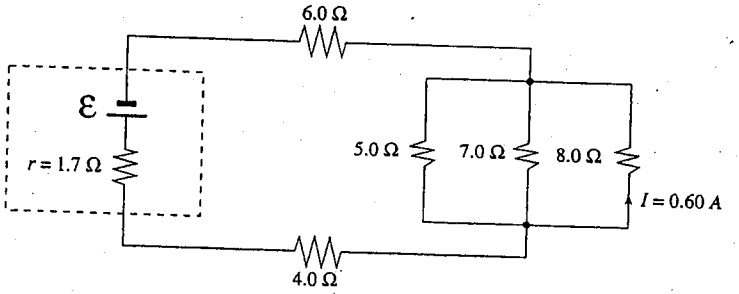
4. A stationary 1.60×10^3 kg vehicle is taken from the surface of the moon and placed into a circular orbit at a height of 2.0×10^6 m above the surface of the moon. Its speed in this orbit is 1.15×10^3 m/s. How much work is required for this process? **(7 marks)**



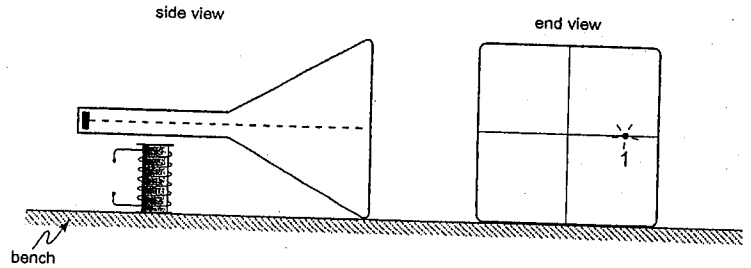
5. The potential difference in moving from position a to position b $(\Delta V_{a->b})$ in the diagram below is equal to +400 V. Determine the size and polarity of the charge Q. **(7 marks)**



6. The current through the 8.0 Ω resistor shown below is 0.60 A. Determine the terminal voltage of the battery. **(7 marks)**

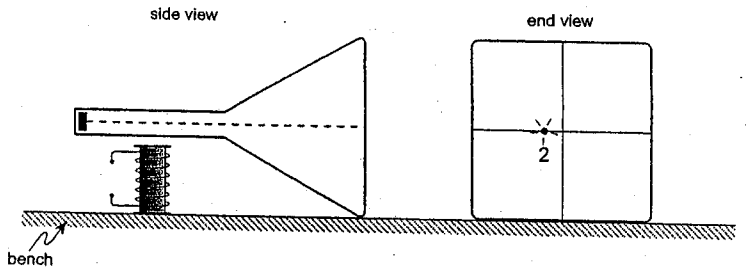


7. A solenoid placed beneath a cathode ray tube as shown below produces a magnetic field of 0.011 T on the electron beam causing it to hit the screen at position 1.



a) The electrons that make up the beam travel at 4.7×10^7 m/s. What is the acceleration of the electrons in this field? **(5 marks)**

7. b) The electron beam is then made to strike the screen at position 2. What two changes were made to the current in the solenoid? State the effect on the electron beam produced by each change. **(4 marks)**



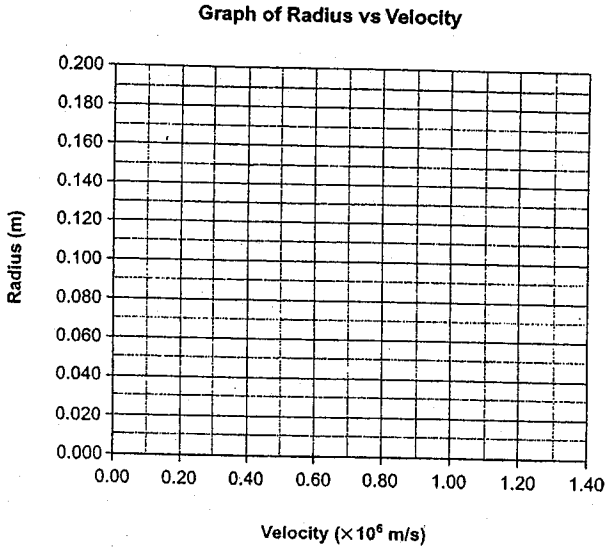
Change in Current	Effect
i)	
ii)	

- ❑ same as before
- ❑ smaller than before

8. In an experiment, protons are accelerated to different velocities and then subjected to a constant perpendicular magnetic field. The radii of the paths of the protons are measured against their velocities. The data is shown below.

Radius (m)	0.061	0.095	0.132	0.149	0.174
Velocity ($\times 10^6$ m/s)	0.44	0.76	0.98	1.16	1.31

a) Plot the data on the graph below and draw the best fit straight line. **(2 marks)**



b) Determine the slope of the line. (Include units.) **(2 marks)**

c) Electrons replace the protons in the above experiment. The slope of the line will now be: **(1 mark)**

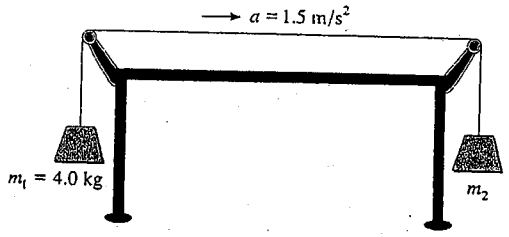
- ❑ larger than before
- ❑ same as before
- ❑ smaller than before

9. An object is dropped from a significant height above the surface of the Moon. It is observed to fall with increasing acceleration. Using principles of physics, give an explanation for this observation.

(4 marks)

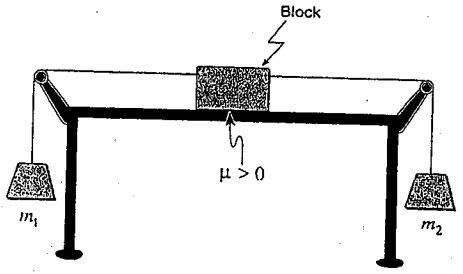
JUNE 2004
WRITTEN RESPONSE QUESTIONS

1. Two masses are connected by a light cord passing over frictionless pulleys as shown in the diagram below.



a) What is m_2 if the system accelerates as shown? **(5 marks)**

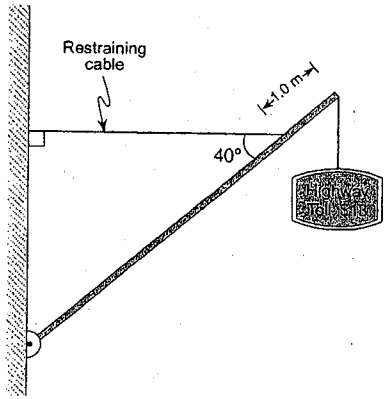
A block is then added to the system.



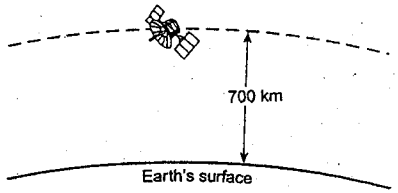
b) Adding the block decreases the acceleration of the system. Identify and explain two reasons for this decrease. **(4 marks)**

2. A 4300 kg truck travelling at 21 m/s in the direction of 31° north of east collides with a stationary 1500 kg car. After the collision, the car has a speed of 15 m/s due east. What is the resulting speed of the truck? **(7 marks)**

3. A sign is suspended from the end of a 6.0 m long uniform pole of mass 25 kg as shown. If the mass of the sign is 36 kg, what is the tension in the horizontal restraining cable? **(7 marks)**



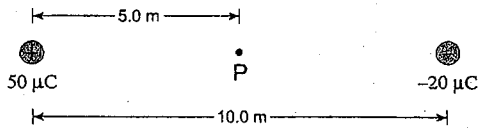
4. A 4.20×10^4 kg satellite orbits the earth at an altitude of 700 km $\left(7.00\times10^5\ \text{m}\right)$.



a) What is the satellite's orbital speed at this altitude? **(4 marks)**

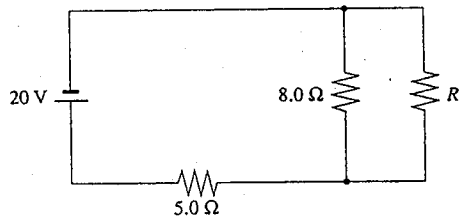
b) What is the satellite's total energy at this altitude? **(3 marks)**

5. a) Determine the electric potential, relative to zero at infinity, at point P, midway between the two charges, shown below. **(5 marks)**

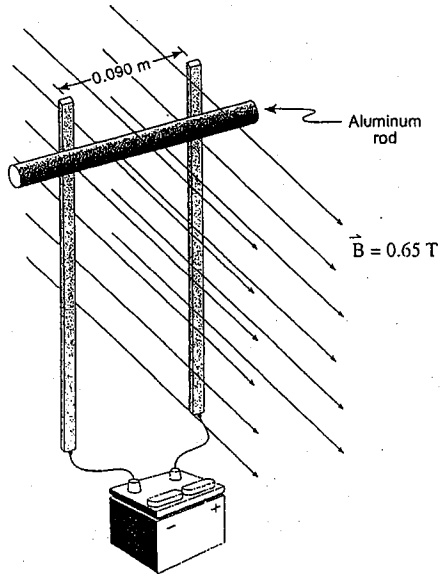


b) How much work would it take to move a $-15\ \mu\text{C}$ charge from point P to a position infinitely far away? **(2 marks)**

6. The 8.0 Ω resistor in the circuit shown below dissipates 45 J of heat energy in 5.0 s. Determine the value of the resistor R. **(7 marks)**

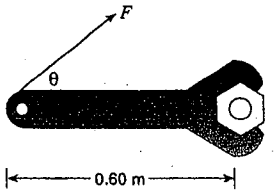


7. A 0.13 kg aluminum rod maintains contact with two vertical metal rails. A voltage is applied across the metal rails and a horizontal magnetic field of 0.65 T exists across the whole apparatus as shown.



What current must flow through the aluminum rod to have it remain stationary? **(7 marks)**

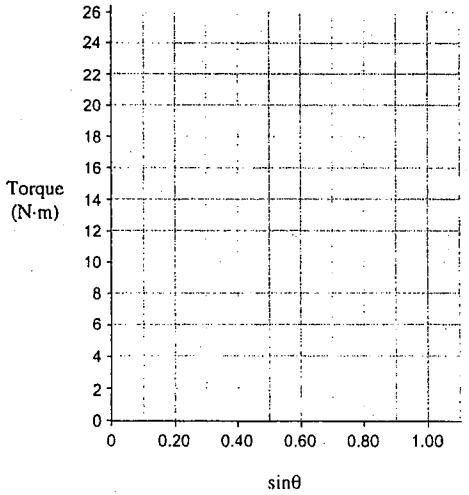
8. A student uses a wrench to apply a constant force to turn a nut. He applies the force at various angles and measures the amount of torque produced at each of the angles.



The torque data collected by the student along with the sine of the angles is shown below:

Torque (N·m)	4.0	11	17	22	25
sinθ	0.14	0.42	0.66	0.86	0.98

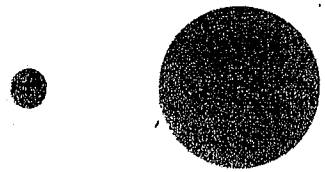
a) Plot a graph of torque versus $\sin\theta$ on the graph below. **(2 marks)**



b) Calculate the slope of your line including units. **(1 mark)**

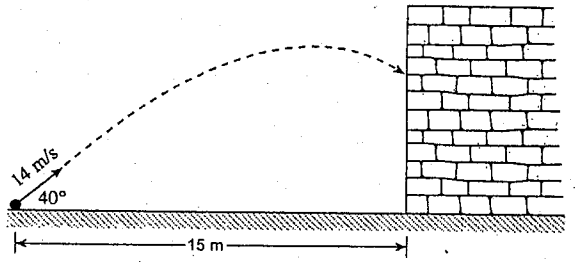
c) Use the slope of your graph to determine the amount of constant force the student used throughout his experiment. **(2 marks)**

9. A small plastic ball carrying a positive charge is held near a fixed large positively charged sphere as shown below. It is then released. Explain how and why the acceleration of the plastic ball changes as it moves away from the sphere. **(4 marks)**



AUGUST 2004 :
WRITTEN RESPONSE QUESTIONS

1. A 2.5 kg projectile is launched towards a brick wall as shown.



a) What are horizontal and vertical components of the launch velocity? **(2 marks)**

b) How much time does it take for the projectile to reach the wall? **(2 marks)**

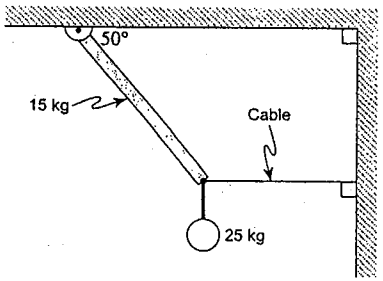
c) What is the projectile's impact speed with the wall? **(3 marks)**

2. A 5.30 kg wagon is moving at 2.00 m/s to the right. A 0.180 kg blob of putty moving at 32.0 m/s also to the right strikes the wagon and sticks to it.

a) With what speed will the wagon and the putty move after the collision? **(5 marks)**

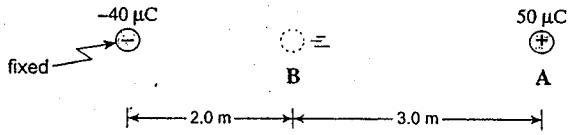
b) Suppose the wagon had instead been struck by a ball with the same mass and speed as the putty and the ball rebounded to the left after the collision. How would the speed of the wagon compare with your answer to a)? Using principles of physics, give an explanation for your prediction. **(4 marks)**

3. A 4.0 m long uniform pole with a mass of 15 kg is pivoted at one end and held in position by a horizontal cable at the other end. If a 25 kg mass is suspended from the end of the pole, what is the tension in the horizontal cable? **(7 marks)**



4. A 7.5×10^{4} kg space vehicle leaves the surface of the earth with a speed of 1.3×10^{4} m/s. What will its speed be when it is infinitely far from the earth? **(7 marks)**

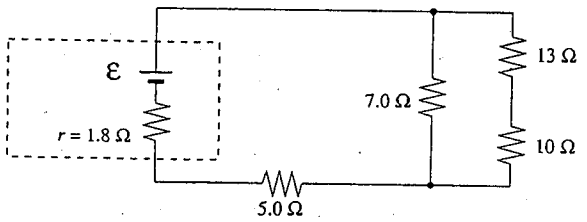
5. A 1.0×10^{-3} kg styrofoam ball carrying 50 μC of charge is released from rest from position A as shown in the diagram below. ($1\,\mu C = 1\times10^{-6}$ C)



a) Determine the change in electric potential energy, ΔE_p, of the ball as it moves from position A to position B. **(5 marks)**

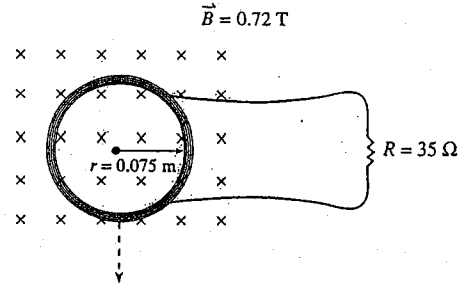
b) What is the speed of the ball as it reaches position B? $(v_i = 0$ at A$)$ **(2 marks)**

6. The internal resistance of the battery shown in the circuit below dissipates 10 W of power. Determine the current through the 13 Ω resistor. **(7 marks)**



16C

7. A 480-turn circular coil of radius 0.075 m is placed in a perpendicular magnetic field of 0.72 T. The coil is connected to a resistor of 35 Ω as shown.



a) Calculate the average current through the resistor as the coil is removed from the magnetic field in a time of 0.22 s. **(6 marks)**

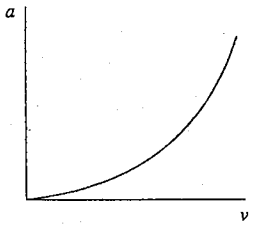
b) In which direction will the current flow in the coil? **(1 mark)**

- ☐ clockwise
- ☐ counterclockwise

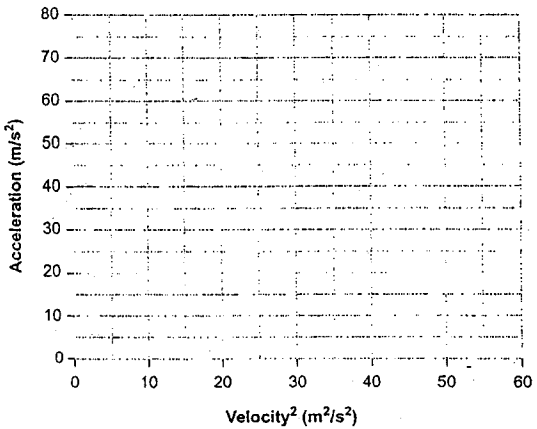
8. A student measures the acceleration of a lab cart as it moves at different speeds around a circular horizontal path. The data collected by the student is shown below:

ACCELERATION (m/s²)	5.7	12.9	25.2	40	49.7	72
VELOCITY (m/s)	2.0	3.0	4.2	5.3	5.9	7.1

When a graph of acceleration versus velocity is plotted a curve results as shown.

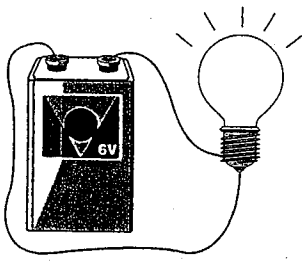


a) Manipulate the **velocity data** and use it to plot a straight line on the graph below. **(3 marks)**



b) Calculate the slope of this graph including units. **(2 marks)**

9. Explain why a 6.0 V battery feels warm to the touch when it is being used to run a low resistance light bulb. **(4 marks)**



MULTIPLE

CHOISE

ANSEWR

KEY

Physics 12
January 2000 Provincial Examination

ANSWER KEY / SCORING GUIDE

CURRICULUM:

	Organizers	Sub-Organizers
1.	Vector Kinematics in Two Dimensions *and* Dynamics *and* Vector Dynamics	A, B C, D
2.	Work, Energy and Power *and* Momentum	E F, G
3.	Equilibrium	H
4.	Circular Motion *and* Gravitation	I J
5.	Electrostatics	K, L
6.	Electric Circuits	M, N
7.	Electromagnetism	O, P

PART A: Multiple Choice (each question worth TWO marks)

Q	K	C	CO	PLO	Q	K	C	CO	PLO
1.	B	K	1	B1	16.	D	K	4	J3, A10
2.	D	U	1	A6	17.	B	U	4	J9
3.	C	U	1	B8	18.	C	H	4	J10, 2
4.	C	K	1	D5	19.	A	K	5	K6
5.	C	U	2	E2	20.	C	U	5	L6, 3
6.	D	K	2	F1	21.	C	U	5	K5, L8
7.	B	U	2	F4	22.	D	U	6	M6
8.	B	U	2	F7, 6	23.	B	U	6	M5, N2
9.	C	U	2	G3	24.	C	K	7	O2
10.	A	K	3	H4	25.	D	U	7	O3
11.	A	U	3	H2	26.	B	U	7	O4
12.	C	H	3	H5, 11	27.	C	U	7	O8
13.	C	K	4	I1	28.	A	U	7	P1
14.	C	U	4	I4	29.	C	U	7	P9
15.	A	U	4	I4, 5	30.	B	H	7	P6

Multiple Choice = 60 marks