2 Mechanics

2.1 Motion

Name: ………………………………. Date: ……………………………….

Motion worksheet

For this worksheet use g = 9.81 ms^{-2}.

1 A ball rolls down a 445 m slope from rest. If it accelerates at a rate of 3.16 ms^{-2}, determine the time it takes to reach the bottom of the slope and the ball's final velocity.

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2 How far does a car travel in 45 seconds if it has an acceleration of 0.32 ms^{-2}? Assume that it starts from rest.

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3 A toy car starts from rest and accelerates at a uniform rate of 4.0 ms^{-2} for 3.0 seconds. It then maintains a uniform speed for 12.0 seconds. Finally it takes 6.0 seconds to decelerate uniformly to rest. Find the total distance travelled and the average speed of the entire trip.

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4 A car travels 25.0 km of a 50.0 km trip at an average speed of 40.0 kmh^{-1}. It travels the second half of its journey at an average speed of 80.0 kmh^{-1}. A truck makes the same trip but spends half of its time at an average speed of 40.0 kmh^{-1} and the other half of its time at an average speed of 80.0 kmh^{-1}. Which vehicle got there in the shortest period of time? Show your work.

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5 A speeding car is travelling at a constant speed of 44 ms^{-1} when it passes a stationary police car. The police car immediately accelerates uniformly from rest at a rate of 2.2 ms^{-2}. If the car does not slow down and the police officer maintains the rate of acceleration, how long will it take the police car to catch the speeding car?

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6 Two balls are 8.0 metres apart and moving directly towards each other. If the first ball is moving at a speed of 2.5 ms^{-1} with respect to the ground and the second ball 3.5 ms^{-1} with respect to the ground, where will they collide?

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7 A helicopter is ascending at a constant speed of 12 ms^{-1} and drops a package from a height of 64 m. How long will it take the package to reach the ground? Assume there is no air resistance.

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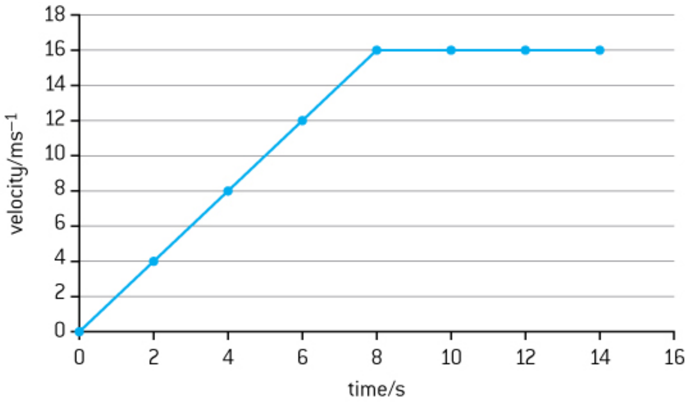
8 Use this graph to determine the following:



a the acceleration during the first 8 seconds.

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b the displacement of the whole trip.

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c the average velocity of the whole trip.

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9 A football is kicked from the ground with an initial speed of 16 ms^{-1} at an angle of 24° to the horizon. At what two times will the ball have a height of 1.0 m? Assume the kick happens at $t = 0$ s.

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10 A rock is thrown from the top of a 36 m high cliff with an initial speed of 12 ms^{-1} at an angle of 52° to the horizon. How long will it take the rock to reach the bottom of the cliff?

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2 Mechanics

2.2 Forces

Name: ……………………………… Date: ………………………………

Forces worksheet

1 A stationary 16 kg mass moves a distance of 84 metres in 14 seconds when a horizontal force is applied. If the level surface is frictionless, determine the applied force.

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2 A 15 kg box is pushed with a constant horizontal force of 85 N along a level surface. If the box moves with a uniform velocity of 6.0 ms^{-1}, how much net force is required to accelerate it uniformly to 12 ms^{-1} in 2.0 s?

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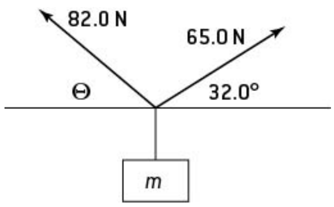
3 The following system is in equilibrium. What is the mass of the object?



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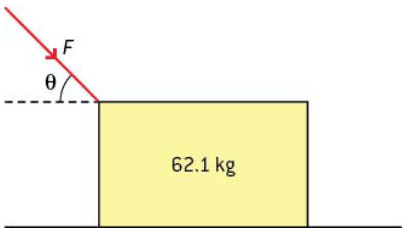
4 A constant force of 245 N is applied at a 48.2° angle to a mass of 62.1 kg as shown below. If the mass moves at a constant speed of 3.28 ms^{-1}, determine its coefficient of dynamic friction.



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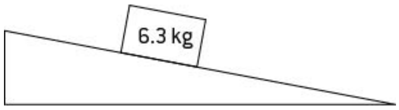
5 A mass of 6.3 kg is held on an inclined plane that has an angle of 2.4° with the horizontal. If the coefficient of static friction is 0.032, will the mass slide down the plane when released?



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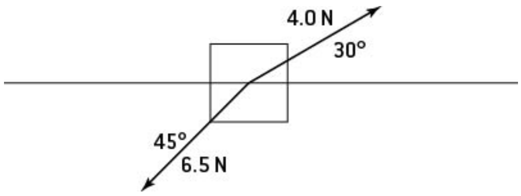
6 Forces of 4.0 N and 6.5 N act on the 25 kg mass shown below. Find its acceleration.



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2.3 Work, energy, and power

Name: ……………………………… Date: ………………………………

Energy transformations

Ignore air resistance and friction for the following problems.

1 A 3.00 kg rock is dropped from the top of a 12.0 m high cliff. Using the conservation of energy, find the following.

a The gravitational potential energy at the top of the cliff.

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b The gravitational potential energy after it has fallen 4.00 m.

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c The kinetic energy after it has fallen 4.00 m.

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d The gravitational potential energy after it has fallen 6.00 m.

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e The kinetic energy after it has fallen 6.00 m.

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f The gravitational potential energy just as it hits the ground.

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g The kinetic energy just as it hits the ground.

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2 What do you notice about the sum of the kinetic and gravitational potential energies at heights of 12.0 m, 8.00 m, and 6.00 m in question 1?

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3 Assuming that all of the elastic potential energy gets transferred to kinetic energy, what speed will a 0.57 kg ball leave a spring that is compressed 0.13 m? The spring constant is 25 Nm^{-1}.

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4 How much work is done against gravity in lifting a 72 kg mass to 0.65 m?

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5 A 0.88 kg ball is moving at 4.2 ms^{-1} across a level, frictionless surface when it encounters an incline. How high above the ground will the ball travel?

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6 A 2.6 kg toy car is rolling down a frictionless incline that makes an angle of 23° with the horizontal. The initial speed of the car is 4.3 ms^{-1}. What will be the speed of the car 26 m down the incline?

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2.3 Work, energy, and power

Name: ……………………………… Date: ………………………………

Work, power, and efficiency

1 A 65 kg boy runs up a flight of stairs totalling 3.4 m in height. If he does this in 12 seconds, determine his work against gravity and his total power.

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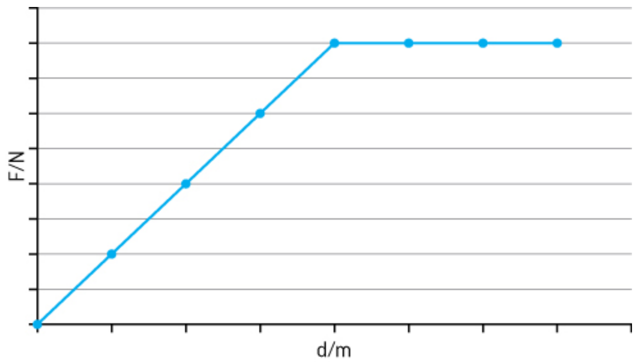
2 Use the graph below to determine the amount of work done during the 4.0 m on a 12 kg object that is starting from rest on a horizontal surface. What is its velocity at that point in time?



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3 The power supplied to a 92% efficient motor is 5600 W. If the motor operates a lifting device that is 62% efficient, what is the output power?

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4 4600 J of energy is supplied to a motor that lifts a weight of 440 N a height of 8.9 m. What is the efficiency of the motor?

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2.4 Momentum and impulse

Name: ……………………………. Date: ……………………………….

Momentum and impulse questions

1 An 1800 kg car accelerates from rest at 3.6 ms^{-2} for 11 seconds. What impulse did it gain?

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2 A 0.006 kg bullet travelling at 360 ms^{-1} embeds itself in a stationary 5.2 kg block of wood. What is the combined velocity of the bullet-wood combination after the collision?

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3 A 4.0 kg object moving at 6.0 ms^{-1} catches a 3.0 kg object moving at 1.0 ms^{-1} in the same direction. After the collision the 4.0 kg object has slowed down to 4.0 ms^{-1}. What is the velocity of the 3.0 kg object just after the collision?

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4 A 57 kg object at rest reacts chemically and breaks into two parts. A 34 kg piece moves at 1.2 ms^{-1} to the left. What is the size and velocity of the other piece?

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5 A 60.0 kg boy standing on a 5.0 kg skateboard is holding two identical rocks each of mass 3.0 kg. He throws them both in front of himself at the same time with a velocity of 4.0 ms^{-1} with respect to the skateboard. Determine the final velocity of the boy if friction is ignored.

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Constant acceleration

1. A body travelling at $5 ms^{-1}$ accelerates at $20 ms^{-2}$ for 100m. What will its final velocity be?

$$a = \frac{v-u}{t}$$

$$s = \left(\frac{u+v}{2}\right)t$$

$$s = ut + 1/2\,at^2$$

$$v^2 = u^2 + 2as$$

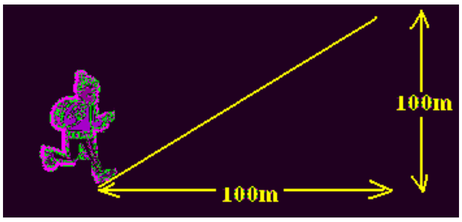
2. A body travelling at $2 ms^{-1}$ accelerates to $8 ms^{-1}$ in 2s. Find its displacement.

3. A body is thrown downwards with a velocity of $10 ms^{-1}$. Assuming the acceleration due to gravity is $10 ms^{-2}$ calculate its displacement after 2s?

4. A boy standing on the edge of a cliff throws a stone upwards with a velocity of $5 ms^{-1}$. If the cliff is 50m high how much time does it take for the stone to hit the bottom of the cliff?

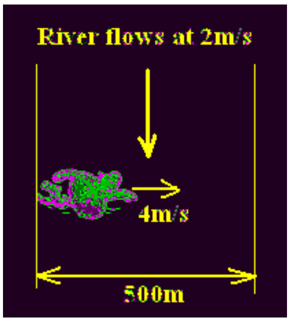
Distance, Displacement and Speed

1. A person walks up a hill as shown in the diagram.



a) How many meters does the person walk?

2. A person swims across a river as shown in the diagram.



a) How many seconds does the swimmer take to cross the river?

b) How far downstream will the swimmer be swept in the time taken to cross the river?

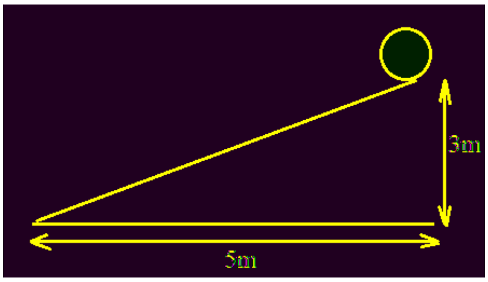
c) What is the final displacement of the swimmer?

3. The distance from Flekke to Dale is 6km on the line shown on the map. The direction is 20° East of North.

a) How far to the North of Flekke is Dale?

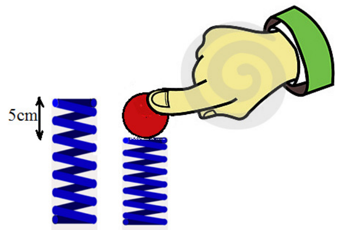
Energy and Power

1. A 2kg ball rolls down the slope shown. Calculate the loss of PE.



2. A 2kg ball is pushed onto a spring of spring constant 100N/cm as shown. (It's a very strong finger by the way)

(a) Calculate elastic PE stored in the spring



(b) Calculate the maximum height reached by the ball

3. A machine is used to lift a 50kg mass 4m vertically in 10s.

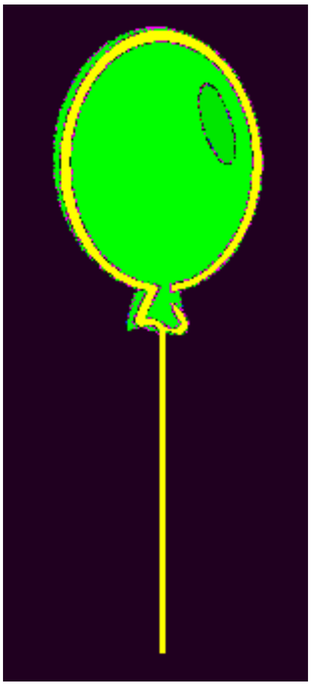
(a) Calculate the increase in PE

(b) Calculate the power of the machine.

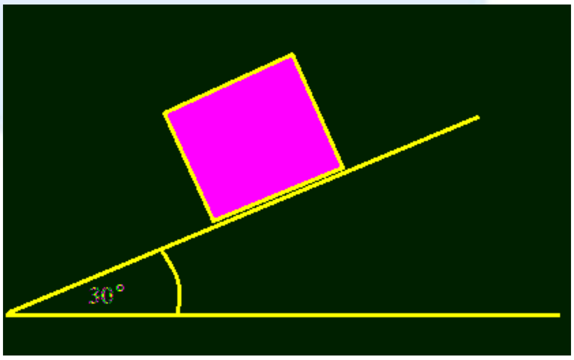
<u>Formulae</u>
$KE = \frac{1}{2}mv^2$
$PE=mgh$
$EPE=\frac{1}{2}kx^2$
$P=E/t$

Forces

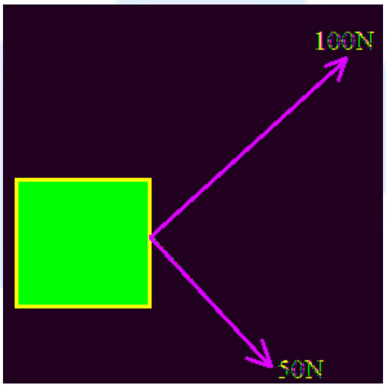
1. A Helium balloon is held stationary with a string as shown. Draw and name all the forces acting on the balloon.



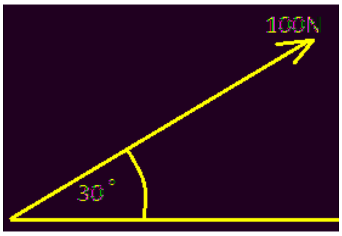
2. A box rests on a slope as shown in the diagram. Draw and label the forces acting on the box.



3. Two perpendicular ropes are use to pull a load along the ground as shown in the diagram. Calculate the resultant force.

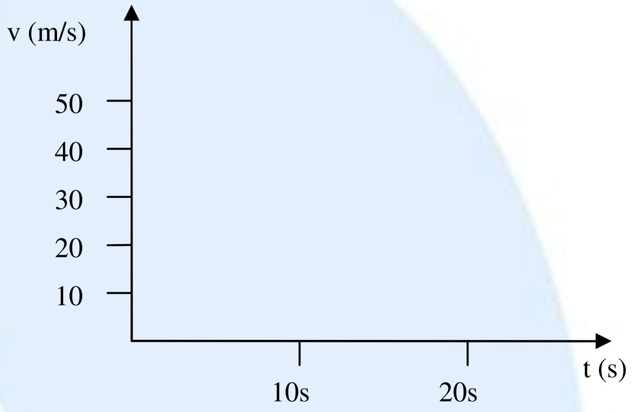


4. A Force acts at a 30° angle to the horizontal as shown. Calculate the Horizontal component of the force.



Graphs of Motion

1. A car travelling at 10m/s accelerates at a constant rate for 20s until its velocity is 40m/s.



a. Using the axis above draw v-t graph for this motion.
b. Use the graph to calculate the distance traveled

c. Use the graph to calculate the acceleration.

2. The motion of a car travelling a long a straight road can be split into 3 stages:
   (i) 30s of constant acceleration from rest.
   (ii) 60s of constant velocity
   (iii) 10s of braking to stop

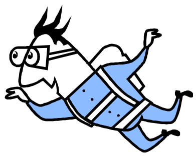
Draw displacement – time, velocity – time and acceleration – time graphs for this motion

Newton's 1st

1. State Newton's 1st law.

2. A freefall parachutist falls with constant velocity.

(a) Label the Forces acting on the parachutist in the diagram.



(b) What can you deduce about the size of these forces?

3. A plastic football is held underneath the water in a swimming pool and released. The mass of the ball is 500g and the upthrust it experiences is 40N.

(a) Draw the forces on the ball in the diagram.

(b) What is the resultant force?

(c) What can you deduce about the motion of the ball?

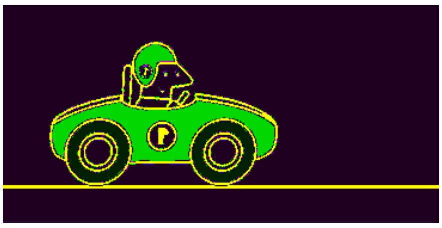
4. Calculate the momentum of a 1200kg car travelling at $20ms^{-1}$.

<u>Formulae</u>
P=mv

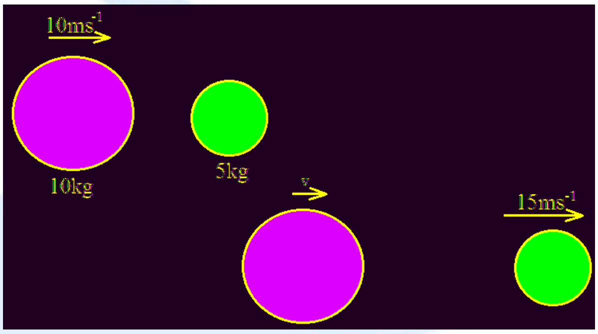
Newton's 3rd

1. State Newton's 3rd law of motion.

2. When a car accelerates the friction of the tyres push the ground backwards. Use Newton's 3rd law to deduce what happens to the car.



3. Two balls collide as shown in the diagram. Use the principle of conservation of momentum to calculate the velocity of the big ball.



4. Calculate the impulse of the big ball in the previous question.

Formulae
$p=mv$
Impulse = Δmv

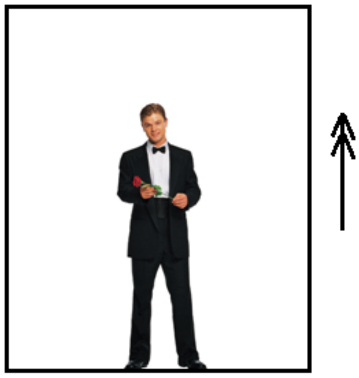
Newton's 2nd

1. State Newton's 2nd law of motion.

2. A man is standing in a lift that is accelerating upwards at a rate of $2ms^{-2}$.

(a) Draw the forces acting on the man

(b) If the mass of the man is 60kg calculate the Normal Force acting on his feet.



3. Forces act on the 50kg mass as shown

(a) Calculate the acceleration of the mass.

(b) If the original momentum is zero calculate the momentum of the box after 2s.

Formulae
F=ma

Projectiles

1. A ball is projected as shown in the diagram.

Formulae

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$a = \frac{v-u}{t}$$

$$s = \frac{(u+v)}{2}t$$

(a) Draw a line showing the possible path of the ball.

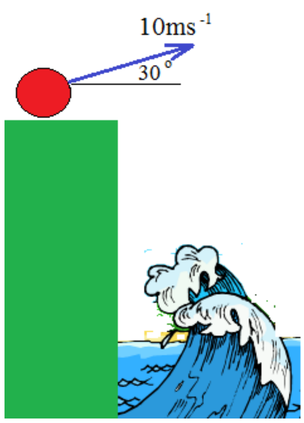
(b) Calculate the vertical component of the balls velocity.

(c) Using your answer to (b) calculate the time of flight.

(d) Calculate the horizontal velocity of the ball.

(e) Using your answer to (c) and (d) calculate the balls range.

2. The ball above is projected with the same angle and velocity from a 10m high sea cliff. Calculate the time taken for the ball to hit the sea.

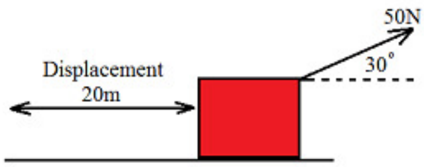


Work and Energy

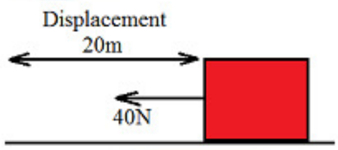
1. Define work.

2. Calculate the amount of work done by the force in the following situations where the box is travelling to the right.

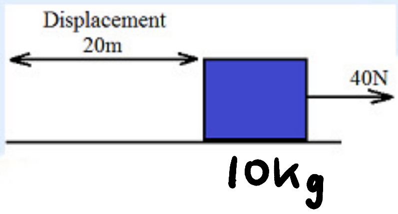
   (a)



   (b)



3. A body is accelerated by a force as shown in the diagram. Calculate the final velocity of the body.



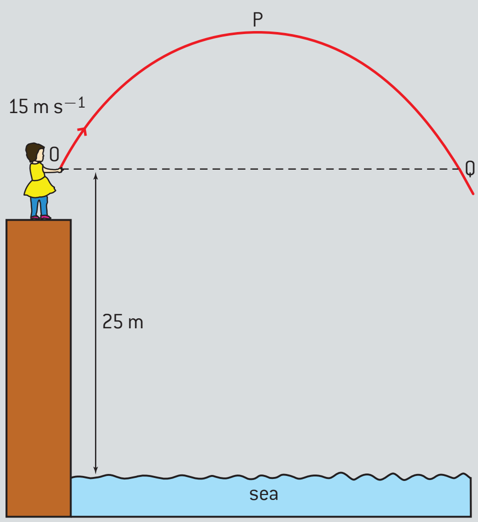
4. Calculate the KE of a 1000kg car travelling at $30ms^{-1}$.

Formulae
$W = Fx\cos\theta$
$KE = \frac{1}{2}mv^2$

Questions

1 *(IB)*

Christina stands close to the edge of a vertical cliff and throws a stone at 15 m s^{-1} at an angle of 45° to the horizontal. Air resistance is negligible.



Point P on the diagram is the highest point reached by the stone and point Q is at the same height above sea level as point O. Christina's hand is at a height of 25 m above sea level.

a) At point P on a copy of the diagram above draw arrows to represent:

(i) the acceleration of the stone (label this A)

(ii) the velocity of the stone (label this V).

b) Determine the speed with which the stone hits the sea. (8 marks)

2 *(IB)*

Antonia stands at the edge of a vertical cliff and throws a stone vertically upwards.

The stone leaves Antonia's hand with a speed $v = 8.0$ m s^{-1}. The time between the stone leaving Antonia's hand and hitting the sea is 3.0 s. Assume air resistance is negligible.

a) Calculate:

(i) the maximum height reached by the stone

(ii) the time taken by the stone to reach its maximum height.

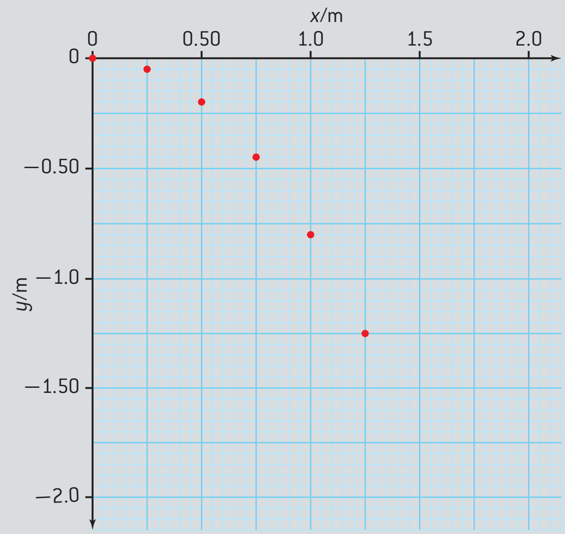
b) Determine the height of the cliff. (6 marks)

3 *(IB)*

A marble is projected horizontally from the edge of a wall 1.8 m high with an initial speed V.

A series of flash photographs are taken of the marble and combined as shown below. The images of the marble are superimposed on a grid that shows the horizontal distance x and vertical distance y travelled by the marble.

The time interval between each image of the marble is 0.10 s.



Use data from the photograph to calculate a value of the acceleration of free fall. (3 marks)

4 *(IB)*

A cyclist and his bicycle travel at a constant velocity along a horizontal road.

a) (i) State the value of the resultant force acting on the cyclist.

(ii) Copy the diagram and draw labelled arrows to represent the vertical forces acting on the bicycle.

(iii) Explain why the cyclist and bicycle are travelling at constant velocity.

b) The total mass of the cyclist and bicycle is 70 kg and the total resistive force acting on them is 40 N. The initial speed of the cycle is 8.0 m s^{-1}. The cyclist stops pedalling and the bicycle comes to rest.

(i) Calculate the magnitude of the initial acceleration of the bicycle and rider.

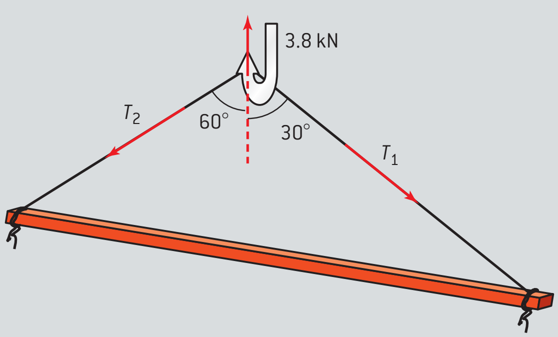
(ii) Estimate the distance taken by the bicycle to come to rest from the time the cyclist stops pedalling.

(iii) State and explain *one* reason why your answer to b)(ii) is an estimate.

(13 marks)

5 A car of mass 1000 kg accelerates on a straight flat horizontal road with an acceleration $a = 0.30$ m s^{-2}. The driving force T on the car is opposed by a resistive force of 500 N. Calculate T. (3 marks)

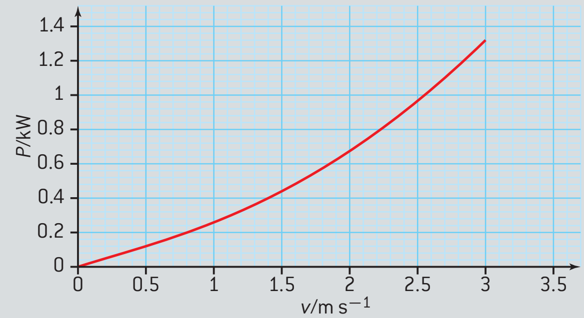
6 A crane hook is in equilibrium under the action of three forces as shown in the diagram.



Calculate T_1 and T_2. (4 marks)

7 *(IB)*

A small boat is powered by an outboard motor of variable power P. The graph below shows the variation with speed v of the power P for a particular load.



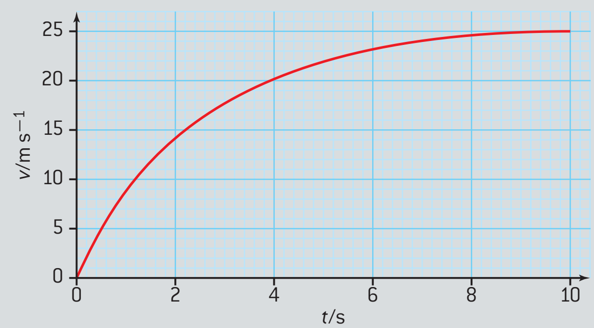
For a steady speed of 2.0 m s^{-1}:

a) use the graph to determine the power of the boat's engine

b) calculate the frictional (resistive) force acting on the boat. (3 marks)

8 *(IB)*

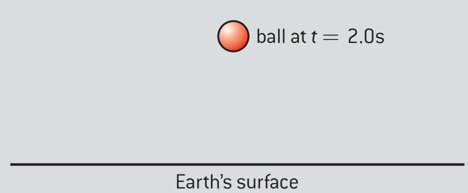
The graph shows the variation with time t of the speed v of a ball of mass 0.50 kg that has been released from rest above the Earth's surface.



The force of air resistance is *not* negligible.

a) State, without any calculations, how the graph could be used to determine the distance fallen.

b) (i) Copy the diagram and draw and label arrows to represent the forces on the ball at 2.0 s.



(ii) Use the graph to show that the acceleration of the ball at 2.0 s is approximately 4 m s^{-2}.

(iii) Calculate the magnitude of the force of air resistance on the ball at 2.0 s.

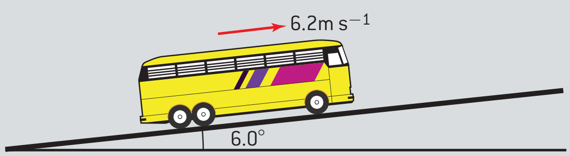
(iv) State and explain whether the air resistance on the ball at $t = 5.0$ s is smaller than, equal to, or greater than the air resistance at $t = 2.0$ s.

c) After 10 s the ball has fallen 190 m.

(i) Show that the sum of the potential and kinetic energies of the ball has decreased by about 800 J. (14 marks)

9 *(IB)*

A bus is travelling at a constant speed of 6.2 m s^{-1} along a section of road that is inclined at an angle of 6.0° to the horizontal.



a) (i) Draw a labelled sketch to represent the forces acting on the bus.

(ii) State the value of net force acting on the bus.

b) The total output power of the engine of the bus is 70 kW and the efficiency of the engine is 35%.

Calculate the input power to the engine.

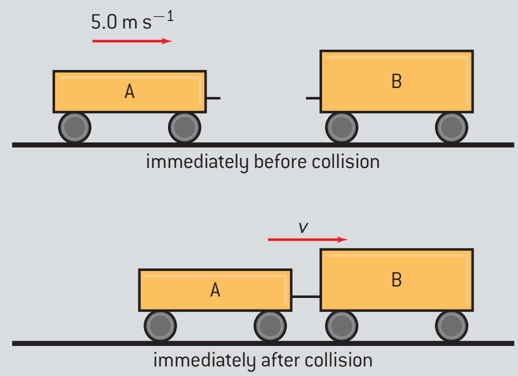
c) The mass of the bus is 8.5×10^3 kg.

Determine the rate of increase of gravitational potential energy of the bus.

d) Using your answer to c (and the data in b), estimate the magnitude of the resistive forces acting on the bus. (12 marks)

10 *(IB)*

Railway truck A moves along a horizontal track and collides with a stationary truck B. The two join together in the collision. Immediately before the collision, truck A has a speed of 5.0 m s^{-1}. Immediately after collision, the speed of the trucks is *v*.



The mass of truck A is 800 kg and the mass of truck B is 1200 kg.

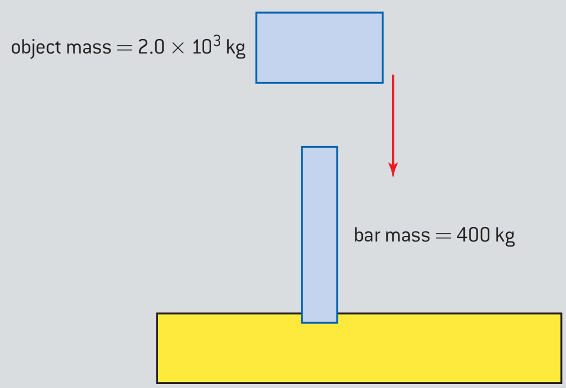
a) (i) Calculate *v*.

(ii) Calculate the total kinetic energy lost during the collision.

b) Suggest where the lost kinetic energy has gone. (6 marks)

11 *(IB)*

Large metal bars are driven into the ground using a heavy falling object.



The falling object has a mass 2000 kg and the metal bar has a mass of 400 kg.

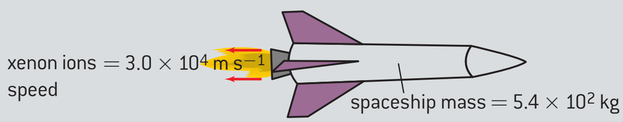
The object strikes the bar at a speed of 6.0 m s^{-1}. It comes to rest on the bar without bouncing. As a result of the collision, the bar is driven into the ground to a depth of 0.75 m.

a) Determine the speed of the bar immediately after the object strikes it.

b) Determine the average frictional force exerted by the ground on the bar. (7 marks)

12 *(IB)*

An engine for a spacecraft uses solar power to ionize and then accelerate atoms of xenon. After acceleration, the ions are ejected from the spaceship with a speed of $3.0 \times 10^4\,m\,s^{-1}$.

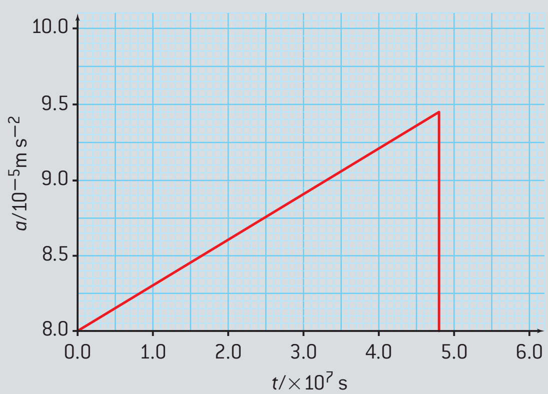


The mass of one ion of xenon is 2.2×10^{-25} kg

a) The original mass of the fuel is 81 kg. Determine how long the fuel will last if the engine ejects 77×10^{18} xenon ions every second.

b) The mass of the spaceship is 5.4×10^2 kg. Determine the initial acceleration of the spaceship.

The graph below shows the variation with time t of the acceleration a of the spaceship. The solar propulsion engine is switched on at time $t = 0$ when the speed of the spaceship is 1.2×10^3 m s^{-1}.

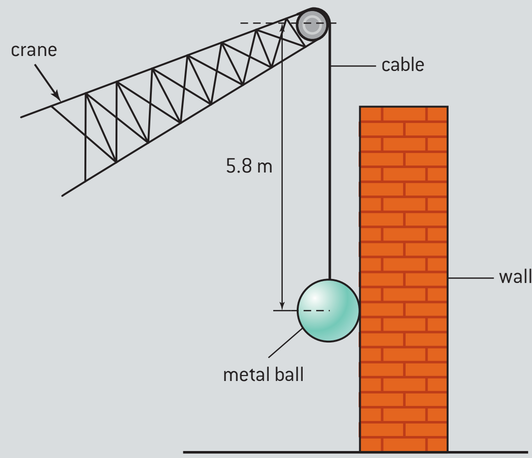


c) Explain why the acceleration of the spaceship increases with time.

d) Using data from the graph, calculate the speed of the spaceship at the time when the xenon fuel has all been used. (15 marks)

13 *(IB)*

A large metal ball is hung from a crane by means of a cable of length 5.8 m as shown below.



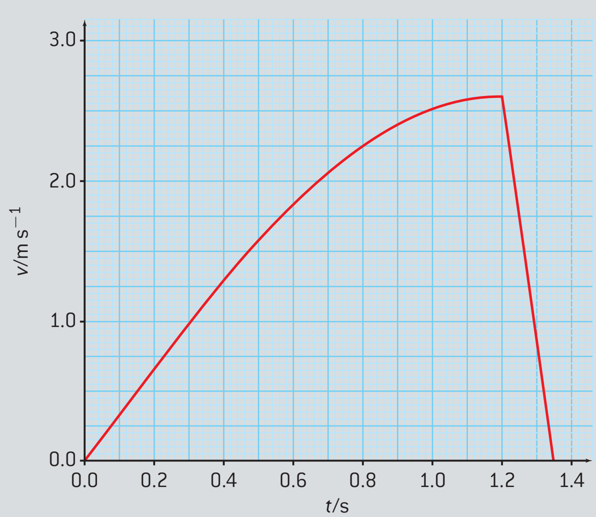
To knock a wall down, the metal ball of mass 350 kg is pulled away from the wall and then released. The crane does not move. The graph below shows the variation with time t of the speed v of the ball after release.

The ball makes contact with the wall when the cable from the crane is vertical.

a) For the ball just before it hits the wall use the graph, to estimate the tension in the cable. The acceleration of free fall is $9.8\,m\,s^{-2}$.

b) Determine the distance moved by the ball after coming into contact with the wall.

c) Calculate the total change in momentum of the ball during the collision of the ball with the wall. (7 marks)



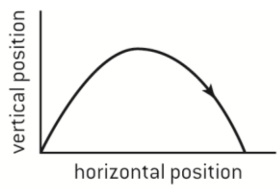
IB Physics

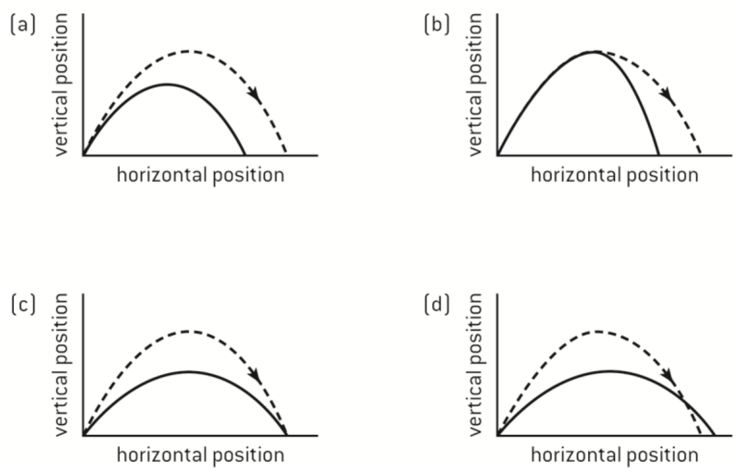
Assessment paper: 2 Mechanics

1. A ball initially at rest, takes time *t* to fall through a vertical distance *h*. If air resistance is ignored, the time taken for the ball to fall from rest through a vertical distance *9h* is

A. *3t.*
B. *5t.*
C. *9t.*
D. *10t.* (1)

2. The graph at the top of the diagram below shows the path of a projectile in the absence of air resistance. Which one of the following diagrams best represents the path of the projectile under the same initial conditions when the air resistance is taken into account? *(The path in absence of air resistance is shown for comparison as a dotted line.)*





(1)

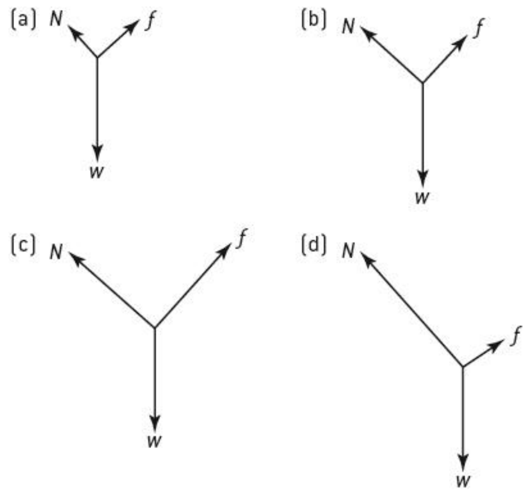
3. A raindrop falling through air reaches a terminal velocity before hitting the ground. At terminal velocity, the frictional force on the raindrop is

A. zero.
B. less than the weight of the raindrop.
C. greater than the weight of the raindrop.
D. equal to the weight of the raindrop. (1)

4. Which one of the following objects is in equilibrium?

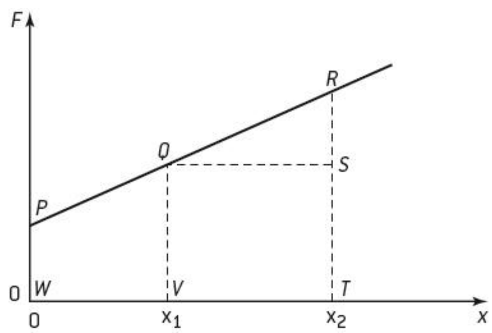
A. A stone trapped in the tread of a rotating tyre.
B. An air molecule as a sound wave passes through the air.
C. A steel ball falling at constant speed through oil.
D. An electron moving through a metal under the action of a potential difference. (1)

5. A friction force *f* is acting on a block of weight *w* sliding down an incline at a constant speed. The force *N* is the normal reaction of the incline of the block. Which of the following free-body diagrams best represents the forces acting on the block?



(1)

6. The diagram below shows the variation with displacement *x* of the force *F* acting on an object in the direction of the displacement.



Which area represents the work done by the force when the displacement changes from x_1 to x_2?

A. QRS
B. WPRT
C. WPQV
D. VQRT (1)

7. A machine lifts an object of weight 1.5×10^3 N to a height of 10 m. The machine has an overall efficiency of 20%. The work done by the machine in raising the object is

A. 3.0×10^3 J
B. 1.2×10^4 J
C. 1.8×10^4 J
D. 7.5×10^4 J (1)

8. An electric train develops a power of 1.0 MW when travelling at a constant speed of 50 ms^{-1}. The net resistive force acting on the train is

A. 50 MN.
B. 200 kN.
C. 20 kN.
D. 200 N. (1)

9. A rocket is fired vertically. At its highest point, it explodes. Which one of the following describes what happens to its total momentum and total kinetic energy as a result of the explosion?

	Total momentum	**Total kinetic energy**
A.	unchanged	increased
B.	unchanged	unchanged
C.	increased	increased
D.	increased	unchanged

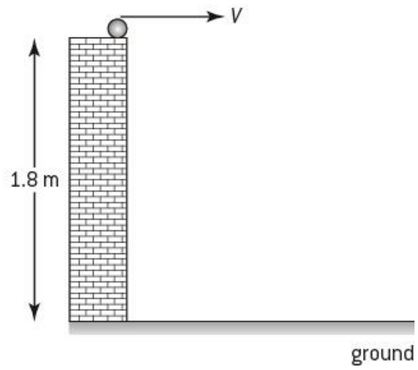
(1)

10. A constant force is applied to a ball of mass *m*. The velocity of the ball changes from v_1 to v_2. The impulse received by the ball is

A. $m(v_1 + v_2)$.
B. $m(v_1 - v_2)$.
C. $m(v_1^2 + v_2^2)$.
D. $m(v_1^2 - v_2^2)$. (1)

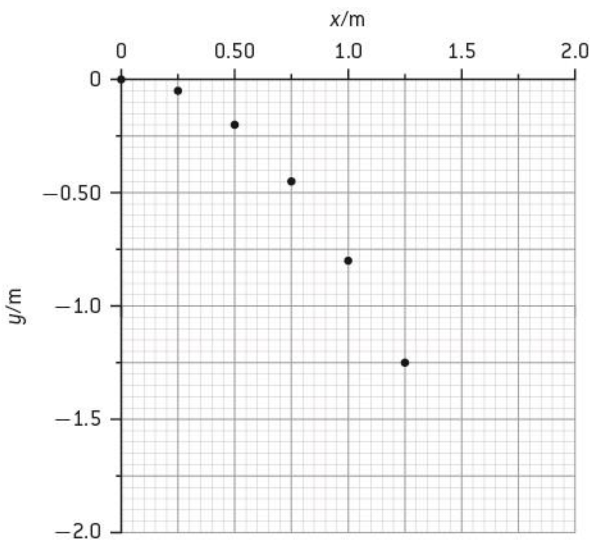
Turn over for data analysis questions

1. This question is about projectile motion.
A marble is projected horizontally from the edge of a wall 1.8 m high with an initial speed *V*.



A series of flash photographs are taken of the marble. The photographs are combined into a single photograph as shown below. The images of the marble are superimposed on a grid that shows the horizontal distance *x* and vertical distance *y* travelled by the marble.

The time interval between each image of the marble is 0.10 s.



a) On the image of the marble at $x = 0.5$ m and $x = 1.0$ m, draw arrows to represent the horizontal velocity V_H and vertical velocity V_V. (2)

b) On the photograph, draw a suitable line to determine the horizontal distance *d* from the base of the wall to the point where the marble hits the ground. Explain your reasoning.

....

....

.... (3)

c) Use data from the photograph to calculate a value of the acceleration of free fall.

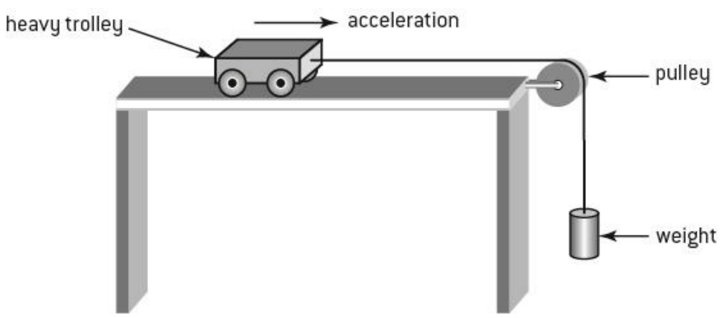
....

....

.... (3)

(Total 8 marks)

2. This question is about an experiment designed to investigate Newton's second law.
In order to investigate Newton's second law, David arranged for a heavy trolley to be accelerated by small weights, as shown below. The acceleration of the trolley was recorded electronically. David recorded the acceleration for different weights up to a maximum of 3.0 N. He plotted a graph of his results.



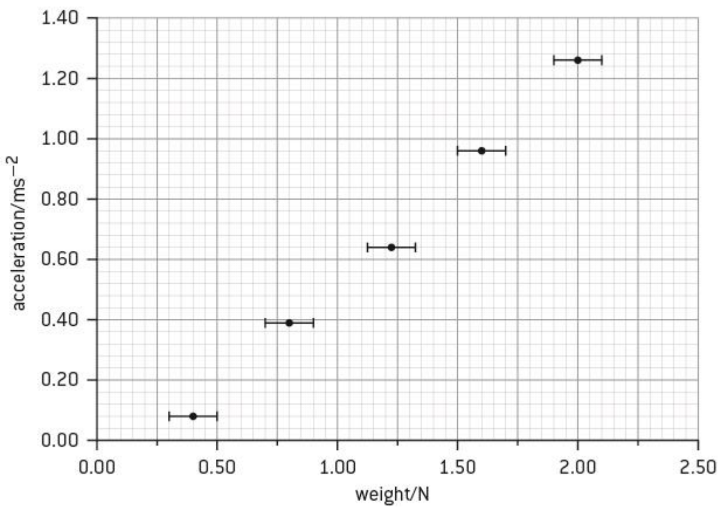
a) Describe the graph that would be expected if two quantities are proportional to one another.

....

....

.... (2)

b) David's data are shown on the next page, with uncertainty limits included for the value of the weights. Draw the best-fit line for these data. (2)



c) Use the graph to

(i) explain what is meant by a *systematic* error.

....

....

....

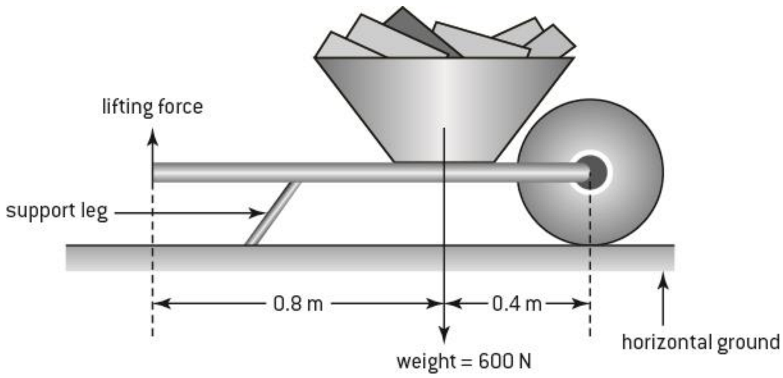
.... (2)

(ii) estimate the value of the frictional force that is acting on the trolley.

.... (1)

(Total 7 marks)

3. This question is about forces on a wheelbarrow.
Rachid is using a wheelbarrow to move some blocks. When a lifting force is applied at the handle, its support legs are lifted off the ground. The dimensions of the wheelbarrow are shown in the diagram below.



When loaded, the total weight of the wheelbarrow and the blocks is 600 N. The ground is horizontal.

a) Determine

(i) the minimum *vertical* force needed to lift the support legs off the ground.

....

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....

.... (3)

(ii) the magnitude and the direction of the force exerted by the ground on the wheel.

....

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....

....

....

.... (2)

Rachid now pushes the wheelbarrow forward at constant speed. He applies a force of 260 N to the handles at an angle of 50° to the vertical.

b) (i) Calculate the *horizontal* component of the force exerted by Rachid.

....

....

....

.... (2)

(ii) Determine the magnitude of the resultant frictional force acting on the wheelbarrow.

....

....

....

....

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.... (2)

(Total 9 marks)

4. This question is about the collision between two railway trucks (carts).

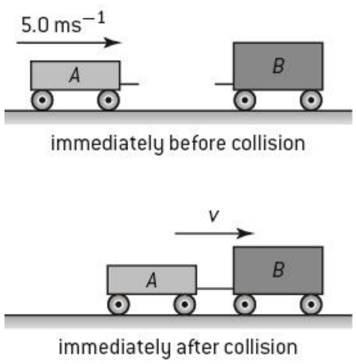
a) Define *linear momentum.*

....

....

.... (1)

In the diagram below, railway truck A is moving along a horizontal track. It collides with a stationary truck B and on collision, the two join together. Immediately before the collision, truck A is moving with speed 5.0 ms^{-1}; immediately after collision, the speed of the trucks is v.



The mass of truck A is 800 kg and the mass of truck B is 1200 kg.

b) (i) Calculate the speed v immediately after the collision.

....

....

....

.... (3)

(ii) Calculate the total kinetic energy lost during the collision.

....

.... (2)

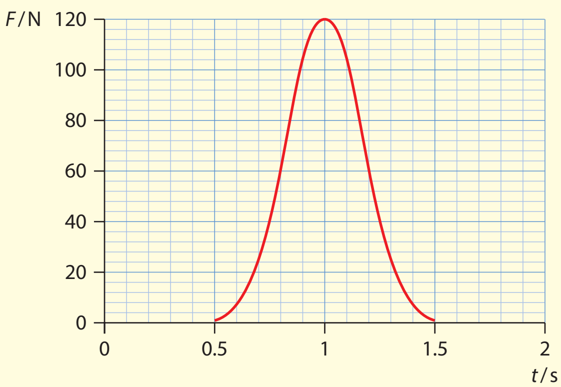
(Total 6 marks)

80 A ball of mass m moving vertically, hits a horizontal floor normally with speed v_1 and rebounds with speed v_2. The ball was in contact with the floor for a time t.

a Show that the average force F on the ball from the floor during the collision is given by:
$$F = \frac{m(v_1 + v_2)}{t} + mg$$

b Find an expression for the average net force on the ball.

81 The diagram shows the variation with time of the force exerted on a ball as the ball came into contact with a spring.



a For how long was the spring in contact with the ball?

b Estimate the magnitude of the change in momentum of the ball.

c What was the average force that was exerted on the ball?

82 Two masses of 2.0 kg and 4.0 kg are held in place, compressing a spring between them. When they are released, the 2.0 kg moves away with a speed of $3.0\,\mathrm{m\,s^{-1}}$. What was the energy stored in the spring?

83 A rocket in space where gravity is negligible has a mass (including fuel) of 5000 kg. It is desired to give the rocket an average acceleration of $15.0\,\mathrm{m\,s^{-2}}$ during the first second of firing the engine. The gases leave the rocket at a speed of $1500\,\mathrm{m\,s^{-1}}$ (relative to the rocket). Estimate how much fuel must be burnt in that second.

Exam-style questions

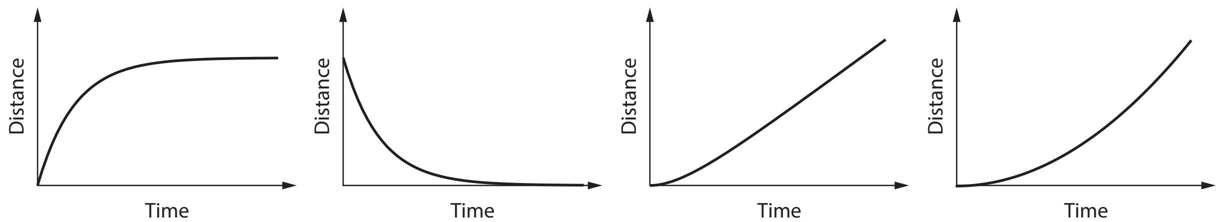
1 Four cars race along a given race track starting at the same time. The car that will reach the finishing line first is the one with the largest

A maximum speed
B acceleration
C power
D average speed

2 A body that started from rest moves with constant acceleration in a straight line. After travelling a distance d the speed of the car is v. What is the distance travelled when the speed of the car was $\frac{v}{2}$?

A $\frac{d}{2}$ **B** $\frac{d}{\sqrt{2}}$ **C** $\frac{d}{4}$ **D** $\frac{d}{2\sqrt{2}}$

3 A sphere falls trough a liquid and eventually reaches terminal speed. Which graph shows the variation with time of the distance travelled by the sphere?

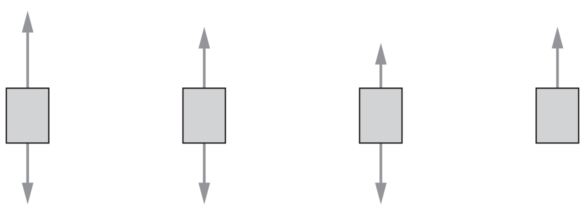


A **B** **C** **D**

4 A steel ball of mass m is thrown vertically downwards with initial speed u near the Earth's surface. The rate of change of the momentum of the ball as it falls is:

A 0 **B** mu **C** $m(u+gt)$ **D** mg

5 A lunar module is descending vertically above the lunar surface. The speed of the module is decreasing. Which is a free-body diagram of the forces on the landing module?



A **B** **C** **D**

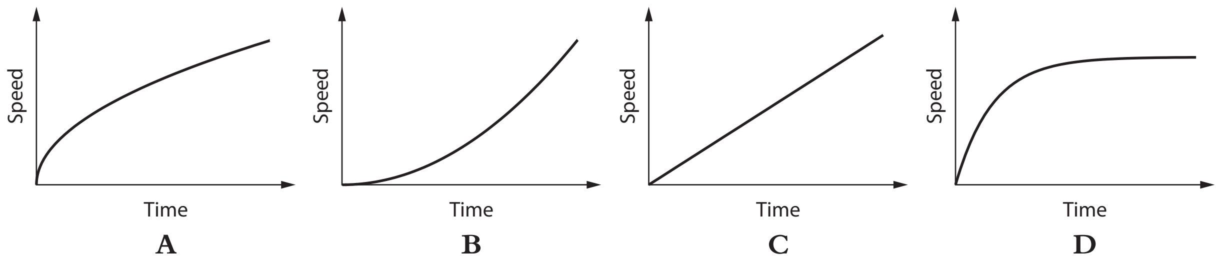
6 A person of mass m stands on weighing scales in an elevator. The elevator is accelerating upwards with acceleration a. The reaction force from the scales on the person is R. What is the reading on the scales?

A mg **B** $R+ma$ **C** $R-ma$ **D** R

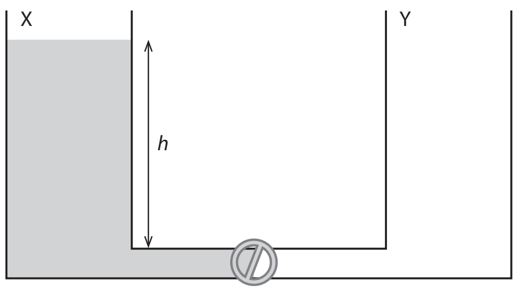
7 A body of mass $3M$ at rest explodes into two pieces of mass M and $2M$. What is the ratio of the kinetic energy of M to that of $2M$?

A $\frac{1}{4}$ **B** $\frac{1}{2}$ **C** 4 **D** 2

8 The power delivered by a car engine is constant. A car starts from rest. Resistance forces are negligible. Which graph shows the variation with time of the speed of the car?



9 The diagram shows two identical containers, X and Y, that are connected by a thin tube of negligible volume. Initially container X is filled with water of mass m up to a height h and Y is empty.



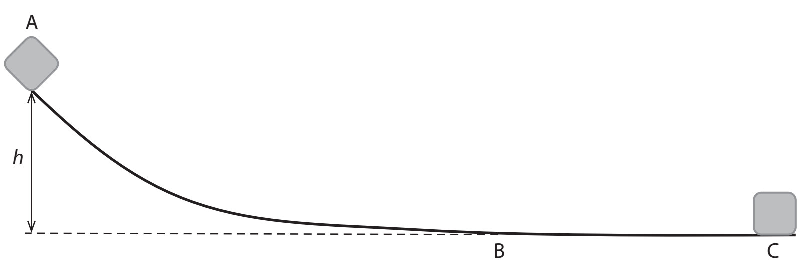
The valve is then opened and both containers contain equal quantities of water. The loss of gravitational potential energy of the water is:

A 0 **B** $\frac{mgh}{8}$ **C** $\frac{mgh}{4}$ **D** $\frac{mgh}{2}$

10 A person of mass m stands on roller skates facing a wall. After pushing against the wall with a constant force F he moves away, reaching speed v after a distance d. What is the work done by F?

A zero **B** mv^2 **C** $\frac{1}{2}mv^2$ **D** Fd

11 In a factory blocks of ice slide down a smooth curved path AB and then on to a rough horizontal path starting at B.



The length of the curved path AB is s; the block of ice takes time t to move from A to B.

a Explain why, for the motion of the block from A to B:

i the formula $s = \frac{1}{2}gt^2$ does not apply. **[1]**

ii the formula $v = \sqrt{2gh}$ does apply. **[1]**

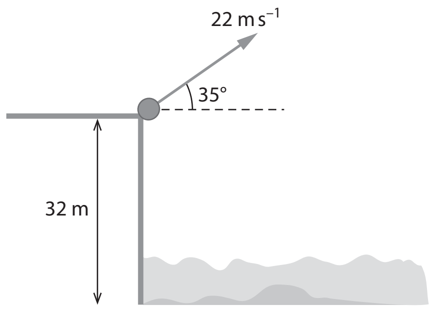
b A block of ice of mass 25 kg slides from A to B. The speed of the block at B is $v_B = 4.8\,\mathrm{m\,s^{-1}}$. Calculate the height h. **[3]**

c **i** The coefficient of dynamic friction between the block of ice and the rough surface BC is 0.45. Show that the distance BC at which the block of ice is brought to rest is 2.7 m. **[2]**

ii Calculate the time it takes the block of ice to cover the distance BC. **[2]**

d The factory also produces blocks of ice of mass 50 kg that slide down the same path starting at A. Predict, for this heavier block of ice, the speed at B and the stopping distance BC. (The coefficient of friction stays the same.) **[3]**

12 A stone of mass 0.20 kg is thrown with speed $22\,\mathrm{m\,s^{-1}}$ from the edge of a cliff that is 32 m above the sea. The initial velocity of the stone makes an angle of 35° with the horizontal. Air resistance is neglected.



a **i** Determine the horizontal and vertical components of the initial velocity. **[2]**

ii Sketch graphs showing the variation with time of the horizontal and vertical components of velocity. **[2]**

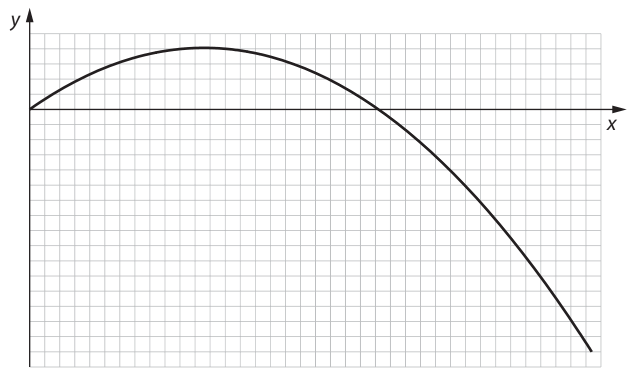
b **i** Calculate the maximum height above the cliff reached by the stone. **[3]**

ii State the net force on the stone at the highest point in its path. **[1]**

c **i** Using conservation of energy, determine the speed of the stone as it hits the sea. **[2]**

ii Hence or otherwise, determine the time it took the stone to reach the surface of the sea. **[2]**

The graph shows the path followed by this stone, until just before hitting the sea, in the absence of air resistance.



d **i** On a copy of the axes above, draw the path of the stone in the presence of an air resistance force opposite to the velocity and proportional to the speed. **[3]**

ii State and explain one difference between your graph and the graph above. **[2]**

13 A toy helicopter has mass $m = 0.30\,\text{kg}$ and blade rotors of radius $R = 0.25\,\text{m}$. It may be assumed that as the blades turn, the air exactly under the blades is pushed downwards with speed v. The density of air is $\rho = 1.2\,\text{kg}\,\text{m}^{-3}$.

a **i** Show that the force that the rotor blades exert on the air is $\rho \pi R^2 v^2$. **[3]**

ii Hence estimate the speed v when the helicopter just hovers. **[2]**

b Determine the power generated by the helicopter's motor when it just hovers as in **a**. **[2]**

c The rotor blades now move faster pushing air downwards at a speed double that found in **a**. The helicopter is raised vertically a distance of 12 m.

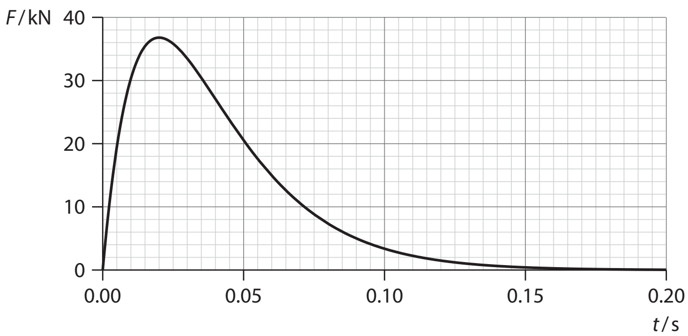
Estimate:

i the time needed to raise the helicopter. **[2]**

ii the speed of the helicopter after it is raised 12 m. **[2]**

iii the work done by the rotor in raising the helicopter. **[1]**

14 It is proposed to launch projectiles of mass 8.0 kg from satellites in space in order to destroy incoming ballistic missiles. The launcher exerts a force on the projectile that varies with time according to the graph.



The impulse delivered to the projectile is $2.0 \times 10^3\,\text{N}\,\text{s}$. The projectile leaves the launcher in 0.20 s.

a Estimate:

i the area under the curve **[1]**

ii the average acceleration of the projectile **[3]**

iii the average speed of the projectile **[2]**

iv the length of the launcher. **[2]**

b Calculate, for the projectile as it leaves the launcher:

i the speed **[2]**

ii the kinetic energy. **[2]**

c Estimate the power delivered to the projectile by the launcher. **[2]**

15 A car of weight $1.4 \times 10^4\,\text{N}$ is moving up an incline at a constant speed of $6.2\,\text{m}\,\text{s}^{-1}$. The incline makes an angle of 5.0° to the horizontal. A frictional force of 600 N acts on the car in a direction opposite to the velocity.

a **i** State the net force on the car. **[1]**

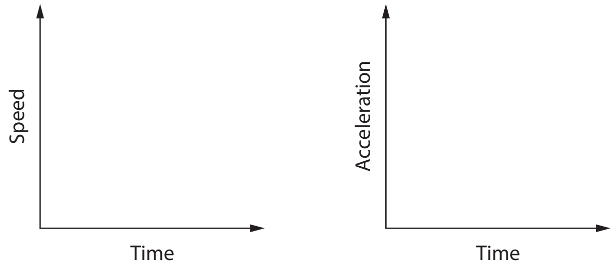
ii Calculate the force F pushing the car up the incline. **[3]**

b The power supplied by the car is 15 kW. Determine the efficiency of the car engine in pushing the car uphill. **[3]**

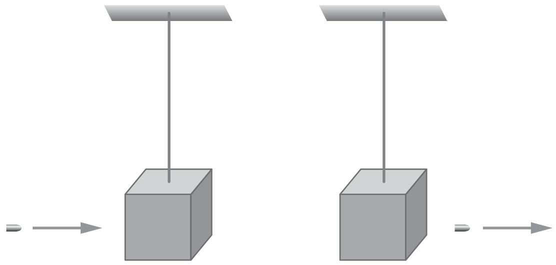
c The car is now allowed to roll down the incline from rest with the engine off. The only resistance force on the car is assumed to be proportional to speed. On a copy of the axes below, draw sketch graphs to show the variation with time of:

i the speed of the car **[2]**

ii the acceleration of the car. **[2]**



16 A bullet of mass 0.090 kg is shot at a wooden block of mass 1.20 kg that is hanging vertically at the end of a string.



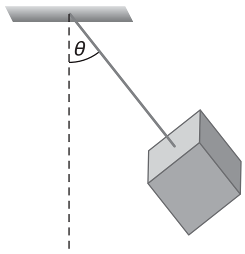
The bullet enters the block with speed $130\,\mathrm{m\,s^{-1}}$ and leaves it with speed $90\,\mathrm{m\,s^{-1}}$. The mass of the block does not change appreciably as a result of the hole made by the bullet.

a **i** Calculate the change in the momentum of the bullet. **[2]**

ii Show that the initial velocity of the block is $3.0\,\mathrm{m\,s^{-1}}$. **[1]**

iii Estimate the loss of kinetic energy in the bullet–block system. **[2]**

As a result of the impact, the block is displaced. The maximum angle that the string makes with the vertical is θ. The length of the string is 0.80 m.



b Show that $\theta \approx 65°$. **[3]**

c **i** State and explain whether the block in **b** is in equilibrium. **[2]**

ii Calculate the tension in the string in **b**. **[3]**

Topic 2.1a Kinematics Problems

Conceptual Questions

(These questions are not in an IB style but instead designed to check your understanding of the concept of this topic. You should try your best to appropriately communicate your answer using prose)

1. Can an object have zero velocity and nonzero acceleration at the same time? Give examples.

2. Can the velocity of an object be negative when its acceleration is positive? What about vice-versa?

3. Can an object be increasing in speed as its acceleration decreases? If so, give an example. If not, explain.

Topic 2.1b Kinematics Problems

Calculation-based Questions

1. A car accelerates from 13m/s to 25m/s in 6.0s. What was its acceleration? How far did it travel in this time? Assume constant acceleration.

[2 marks]

2. A car slows down from 23m/s to rest in a distance of 85m. What was the acceleration, assumed constant?

[1 mark]

3. Estimate how long it took King Kong to fall straight down from the top of the Empire State Building (380m high) and his velocity just before he touched the ground. Ignore air resistance.

[2 marks]

4. A stone is thrown vertically upward with a speed of 18.0m/s. How fast is it moving when it reaches a height of 11.0m and how long is required to reach this height? Why are there two answers?

[3 marks]

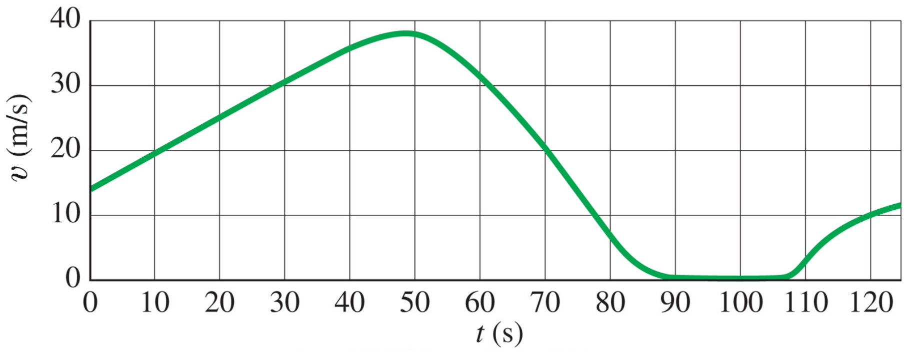
5. A stone is thrown vertically upward with a speed of 12.0m/s from the edge of a cliff 70.0m high. How long does it take to reach the bottom of the cliff and what is its speed before hitting? What was the total distance that it traveled? Ignore air resistance.

[3 marks]

Topic 2.1b Kinematics Problems

Calculation-based Questions

1. The graph below shows the velocity of a train as a function of time.



   a. At what time was its velocity the greatest?
   b. During which periods, if any, was the velocity constant?
   c. During what periods, if any, was the acceleration constant?
   d. When was the magnitude of the acceleration the greatest?

[4 marks]

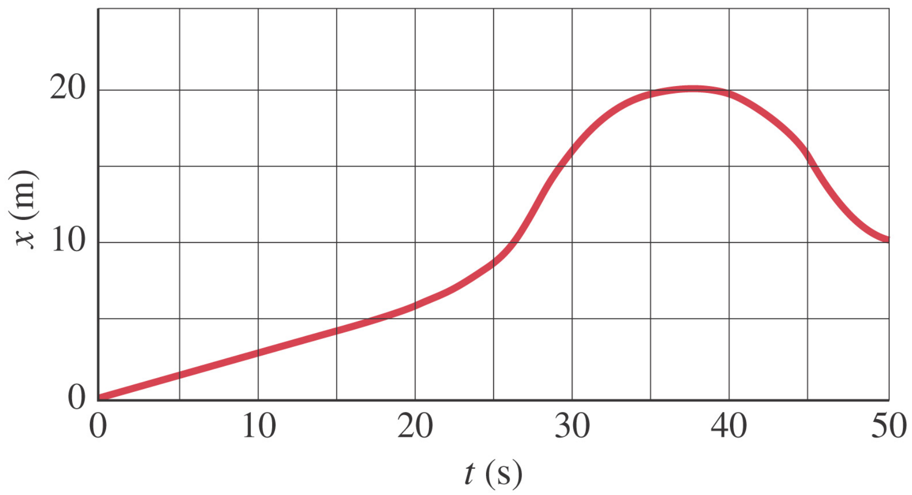
Esimtate the distance the object travelled

   e. during the first minute and;
   f. in the second minute

[2 marks]

2. The position of a rabbit along a straight tunnel as a function of time is plotted below. What is the instantaneous velocity
    a. at t = 10.0s and,
    b. at t = 30.0s?

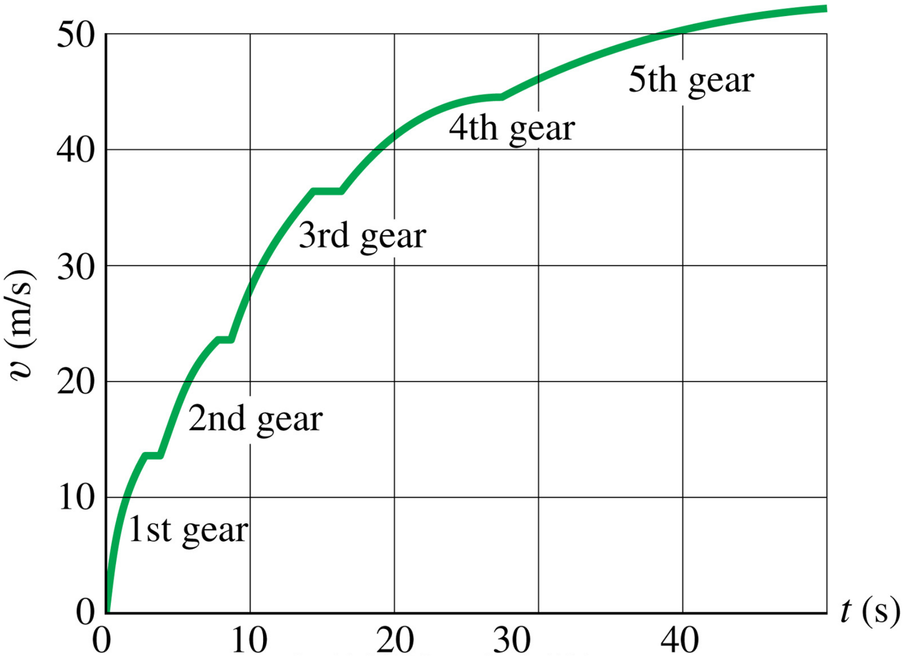
[2 marks]



What is the average velocity
    c. between t = 0 and t = 5.0s,
    d. between t = 25.0s and t = 30.0s and,
    e. between t = 40.0s and t = 50.0s?

[3 marks]

3. A certain type of automobile can accelerate approximately as shown in the velocity – time graph as shown below. (The short flat spots in the curve represent shifting of the gears.)



Estimate the average acceleration when it is in

a. first,
b. third,
c. fifth gear.
d. What is its average acceleration through the first four gears?

[4 marks]

Topic 2.1c Kinematics Problems

Calculation-based Questions

1. A car accelerates from 13m/s to 25m/s in 6.0s. What was its acceleration? How far did it travel in this time? Assume constant acceleration.

[2 marks]

2. A car slows down from 23m/s to rest in a distance of 85m. What was the acceleration, assumed constant?

[1 mark]

3. Estimate how long it took King Kong to fall straight down from the top of the Empire State Building (380m high) and his velocity just before he touched the ground. Ignore air resistance.

[2 marks]

4. A stone is thrown vertically upward with a speed of 18.0m/s. How fast is it moving when it reaches a height of 11.0m and how long is required to reach this height? Why are there two answers?

[3 marks]

5. A stone is thrown vertically upward with a speed of 12.0m/s from the edge of a cliff 70.0m high. How long does it take to reach the bottom of the cliff and what is its speed before hitting? What was the total distance that it traveled? Ignore air resistance.

[3 marks]

Topic 2.1d Projectile Motion Problems

Conceptual Questions

(These questions are not in an IB style but instead designed to check your understanding of the concept of this topic. You should try your best to appropriately communicate your answer using prose)

1. Two cannon balls A and B are fired from the ground with identical initial speeds, but with θA larger than θB. (a) Which cannonball reaches a higher elevation? (b) which stays longer in the air? (c) Which travels farther?

2. A projectile is launched at an angle of 30° to the horizontal with a speed of 30m/s. How does the horizontal component of its velocity 1.0s after launch compare with its horizontal component of velocity 2.0s after launch?

Calculation Based

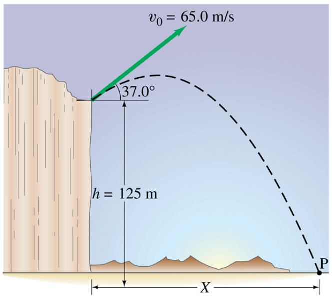
3. A tiger leaps horizontally from a 6.5m high rock with a speed of 3.5m/s. How far from the base of the rock will she land?

4. A diver running 1.8m/s dives out horizontally from the edge of a vertical cliff and 3.0s later reaches the water below. How high was the cliff and how far from its base did the diver hit the water?

5. A football is kicked at ground level with a speed of 18.0m/s at an angle of 35.0° to the horizontal. How much later does it hit the ground?

6. A projectile is fired with an initial speed of 65.2m/s at an angle of 34.5° above the horizontal on a long flat firing range. Determine (a) the maximum height reached by the projectile, (b) the total time in the air, (c) the total horizontal distance covered (that is the range), and (d) the velocity of the projectile 1.50s after firing.

7. A projectile is shot from the edge of a cliff 125m above ground level with an initial speed of 65.0m/s at an angle of 37.0° with the horizontal, as shown below. (a) Determine the time taken by the projectile to hit point P at ground level. (b) Determine the range X of the projectile as measured from the base of the cliff. At the instant just before the projectile hits point P, find (c) the horizontal and the vertical components of its velocity, (d) the magnitude of the velocity, and (e) the angle made by the velocity vector with the horizontal. (f) Find the maximum height above the cliff top reached by the projectile.



Topic 2.2a Kinematics Problems

Calculation-based Questions

1. A net force of 265N accelerates a bike and rider at 2.30m/s^2. What is the mass of the bike and the rider together?

[1 mark]

2. What is the weight of a 76kg astronaut
   a. on Earth
   b. on the Moon (g = 1.7m/s^2)
   c. on Mars (g = 3.7m/s^2)
   d. in outer space traveling with constant velocity?

[4 marks]

3. What is the average force required to stop a 1100-kg car in 8.0s if the car is travelling at 95km/h?

[3 marks]

4. What is the average force needed to accelerate a 7.00g pellet from rest to 125m/s over a distance of 0.800m along the barrel of the rifle?

[2 marks]

5. A 0.140kg baseball traveling at 35.0m/s strikes the catcher's mit, which, in bringing the ball to rest, recoils backward 11.0cm. What was the average force applied by the ball on the glove?

[2 marks]

Topic 2.2b Kinematics Problems

Conceptual Questions

(These questions are not in an IB style but instead designed to check your understanding of the concept of this topic. You should try your best to appropriately communicate your answer using prose)

1. Why does a child, sat in a toy wagon, seem to fall backward when you give the wagon a sharp pull forward?

2. If the acceleration of an object is zero, are no forces acting on it? If only one force acts on the object, can the object have zero acceleration? Can it have zero velocity? Explain.

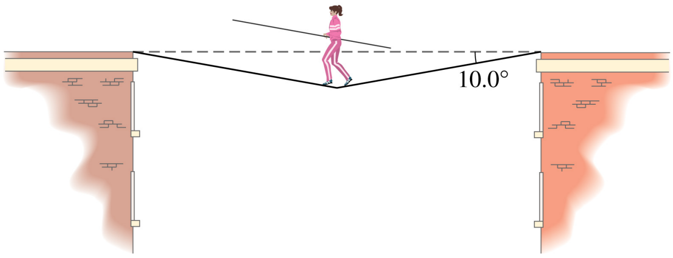
3. If you walk along a log floating on a lake, why does the log move in the opposite direction?

Topic 2.2c Kinematics Problems

Calculation-based Questions

1. Arlene is to walk across a "high-wire" strung horizontally between two buildings 10.0m apart. The sag in the rope when she is at the mid-point is 10.0° as shown. If her mass is 50.0kg, what is the tension in the rope at this point?

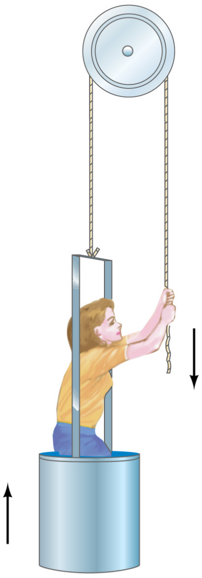
[2 marks]



2. A box weighing 77.0N rests on a table. A rope tied to the box runs vertically upward over a pulley and a weight is hung from the other end. Determine the force that the table exerts on the box if the weight hanging on the other side of the pulley weighs
    a. 30.0N
    b. 60.0N
    c. 90.0N

[4 marks]

(Hint: You should sketch a free-body diagram for the general case)

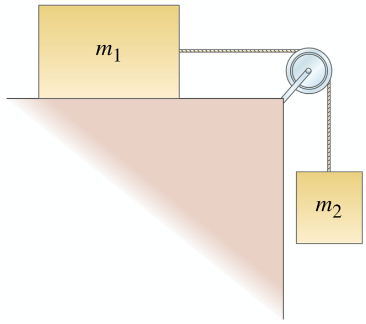


3. A window washer pulls herself upward using a bucket-pulley system as shown.
   a. Sketch a free-body diagram showing the force of gravity and the force exerted by the rope (tension).
   b. How hard must she pull downward to raise herself slowly at constant speed?
   c. If she increases this force by 15%, what will her acceleration by?

   Assume the mass of the person and the bucket is 65kg.

[4 marks]

4. The diagram below shows a block (mass m_A) on a smooth horizontal surface, connected by a thin cord that passes over a pulley to a second block (m_B), which hangs vertically.



   a. Draw a free-body diagram for each block, showing the force of gravity on each, the force (tension) exerted by the cord, and any normal force.
   b. Apply Newton's second law to find formulas for the acceleration of the system and for the tension in the cord. Ignore friction and the masses of the pulley and cord.

[3 marks]

Topic 2.3a Work and Energy

Conceptual Questions

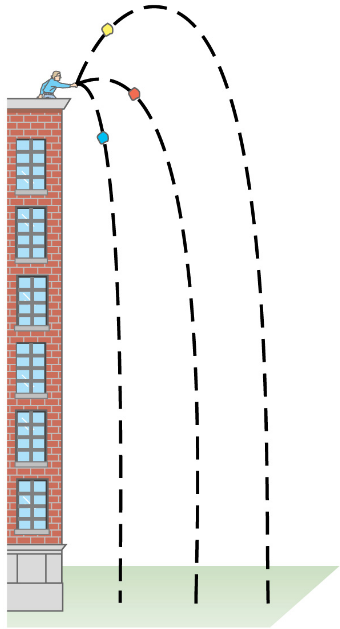
(These questions are not in an IB style but instead designed to check your understanding of the concept of this topic. You should try your best to appropriately communicate your answer using prose)

1. You have two springs that are identical except that spring 1 is stiffer than spring 2 ($k_1 > k_2$). On which spring is more work done if (a) they are stretched using the same force, (b) stretched the same distance?

2. When a rubber bouncy-ball is dropped, can it rebound to a height greater than its original height? Explain.

3. Why is it easier to climb a mountain via a zigzag trail than to climb straight up?

4. Water balloons are tossed from the roof of a building, all with the same speed but with different launch angles. Which one has the highest speed on impact? Ignore air resistance.



Topic 2.3b Work done by a constant force

Calculation-based Questions

1. How much work is done by the gravitational force when a 256kg pile driver falls 2.80m?

[1 mark]

2. A 1300-N crate rests on the floor. How much work is required to move it at a constant speed…
    a. 4.0m along the floor against a friction force of 230N, and
    b. 4.0m vertically?

[2 mark]

3. A box of mass 5.0kg is accelerated from rest across a floor at a rate of 2.0m/s2 for 7.0s. Find the net work done on the box.

[2 marks]

4. A 330-kg piano slides 3.6m down a 28° incline and is kept from accelerating by a man who is pushing back on it parallel to the incline. The effective coefficient of friction μ is 0.40 and the force due to friction can be calculated by F = μN where is the normal force.
   Calculate:
   a. the force exerted by the man.
   b. the work done by the man on the piano.
   c. the work done by the friction force.
   d. the work done by the force of gravity.
   e. the net work done on the piano.

[10 marks]

(Hint: Draw the free-body diagram. You will need to resolve forces parallel and perpendicular to the incline.)

Topic 2.3c Mechanical Energy

Calculation-based Questions

1. If the KE of an arrow is doubled, by what factor has its speed increased? If its speed is doubled, by what factor does its KE increase?

   [2 marks]

2. How much work must be done to stop a 1250-kg car travelling at 105km/h?

   [2 marks]

3. A spring has a stiffness constant of, k, of 440N/m. How much must this spring be stretched to store 25J of potential energy?

   [1 mark]

4. By how much does the gravitational potential energy of a 64kg pole-vaulter change if his centre of mass rises about 4.0m during the jump?

   [1 mark]

5. A sled is initially given a shove up a frictionless 28.0° incline. It reaches a maximum vertical height of 1.35m higher than where it started. What was the initial speed?

[2 marks]

6. Two railroad cars, each of mass 7650kg and traveling 95km/h in opposite directions, collide head-on and come to rest. How much thermal energy is produced in this collision?

[2 marks]

7. You drop a ball from a height of 2.0m, and it bounces back to a height of 1.5m.
    a. What fraction of its initial energy is lost during the bounce?
    b. What is the ball's speed just as it leaves the ground after the bounce?
    c. Where did the energy go?

[5 marks]

8. How long will it take a 1750-W motor to lift a 315kg piano to a sixth-story window 16.0m above?

9. A car generates 18hp (1hp = 746W) when travelling at a steady 88km/h, what must the average force exerted on the car due to friction and air resistance?

[2 marks]

Topic 2.4a Momentum Problems

Conceptual Questions

(These questions are not in an IB style but instead designed to check your understanding of the concept of this topic. You should try your best to appropriately communicate your answer using prose)

1. When you release an inflated but untied balloon, why does it fly across the room?

2. Cars used to be built as rigid as possible to withstand collisions. Today, though, cars are designed to have "crumple zones" that collapse upon impact. What is the advantage of this new design?

3. Is it possible for an object to receive a larger impulse from a small force than from a large force? Explain.

Calculation-based Questions

4. A constant friction force of 25N acts on a 65kg skier for 20s. What is the skier's change in velocity?

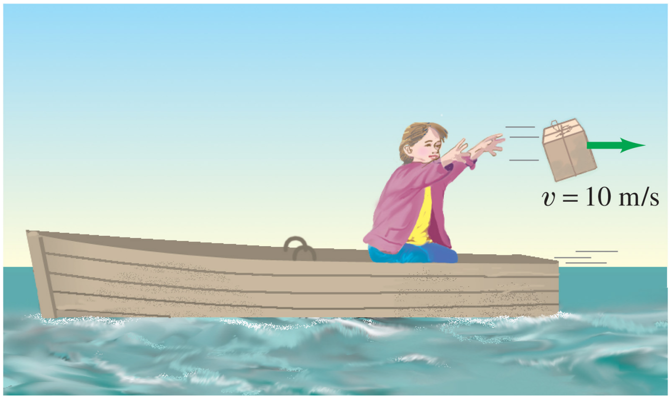
[2 marks]

5. A 0.145kg baseball pitched at 39.0m/s is hit on a horizontal line drive straight back at the pitcher at 52.0m/s. If the contact time between the bat and the ball is 3.00x10-3s, calculate the average force between the bat and the ball during contact.

[2 marks]

6. A child in a boat throws a 6.40kg package out horizontally with a speed of 10.0m/s. Calculate the velocity of the boat immediately after, assuming it was initially at rest. The mass of the child is 26.0kg and that of the boat is 45.0kg. Ignore water resistance.

[2 marks]



7. A 12,600-kg railroad car travels alone on a level frictionless track with a constant speed of 18.0m/s. A 5350-kg load, initially at rest, is dropped onto the car. What will be the car's new speed?

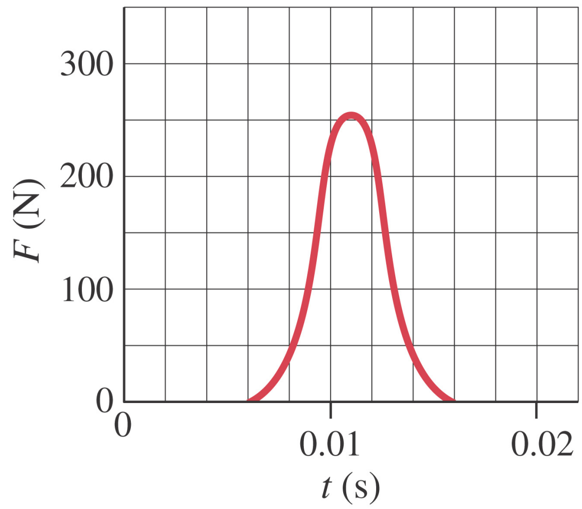
[2 marks]

8. A 9300-kg boxcar travelling at 15.0m/s strikes a second boxcar at rest. The two stick together and move off with a common speed of 6.0m/s. What is the mass of the second car?

[2 marks]

9. Suppose the force acting on a tennis ball (mass 0.060kg) points in the +x direction and is given by the graph as a function of time. Use graphical methods to estimate
   a. the total impulse given the ball, and
   b. the velocity of the ball after being struck, assuming the ball is being served so it is nearly at rest initially.

[2 marks]



Topic 2.4b Momentum and Energy Problems

Calculation-based Questions

1. A 0.450kg ice puck, moving east with a speed of 3.00m/s, has a head on collision with a 0.900kg puck initially at rest. Assuming a perfectly elastic collision, what will be the speed and direction of each object after the collision?

[4 marks]

2. Two billiard balls of equal mass undergo a perfectly elastic head-on collision. If one ball's initial speed was 2.00m/s, and the other's was 3.00m/s in the opposite direction, what will be their speeds after the collision?

[4 marks]

3. A 10,000kg railroad car, A travelling at a speed of 24.0m/s strikes an identical car, B, at rest. If the cars lock together as a result of the collision, calculate:
    a. the common speed after the collision.
    b. how much of the initial kinetic energy is transformed to thermal or other forms of energy.

[4 marks]

Topic 2: Mechanics

1. Which **one** of the following is a correct definition of *displacement*?

A. Distance from a fixed point

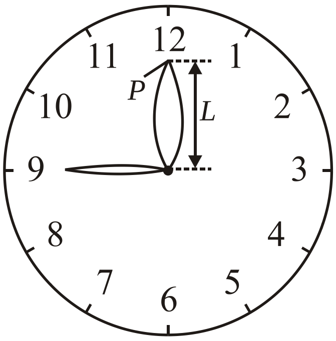
B. Distance moved from a fixed point

C. Distance from a fixed point in a given direction

D. Distance moved in a given direction

(1)

2. The minute hand of a clock hung on a vertical wall has length L.



The minute hand is observed at the time shown above and then again, 30 minutes later.

What is the displacement of, and the distance moved by, the end P of the minute hand during this time interval?

	displacement	**distance moved**
A.	$2L$ vertically downwards	πL
B.	$2L$ vertically upwards	πL
C.	$2L$ vertically downwards	$2L$
D.	$2L$ vertically upwards	$2L$

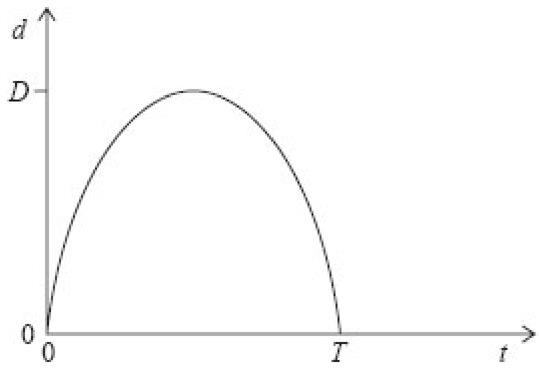
(1)

3. A particle moves from a point P to a point Q in a time T. Which **one** of the following correctly defines both the average velocity and average acceleration of the particle?

	Average velocity	**Average acceleration**
A.	$\frac{\text{displacement of Q and P}}{T}$	$\frac{\text{change in speed from Q to P}}{T}$
B.	$\frac{\text{displacement of Q and P}}{T}$	$\frac{\text{change in velocity from Q to P}}{T}$
C.	$\frac{\text{distance between Q and P}}{T}$	$\frac{\text{change in speed from Q to P}}{T}$
D.	$\frac{\text{distance between Q and P}}{T}$	$\frac{\text{change in velocity from Q to P}}{T}$

(1)

4. A ball is thrown vertically upwards from the ground. The graph shows the variation with time t of the vertical displacement d of the ball.

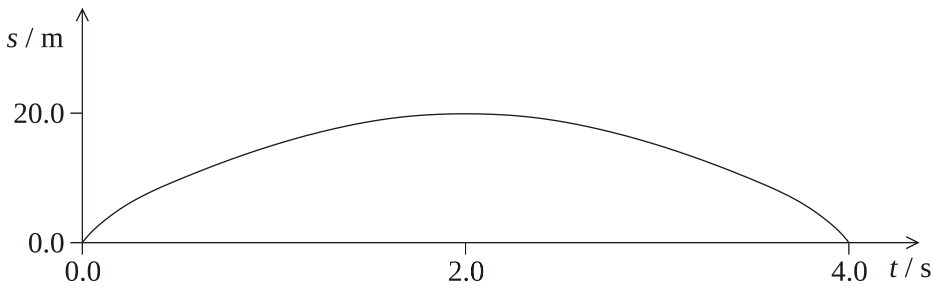


Which of the following gives the final displacement after time T and the average speed between time t = 0 m aand time t = T?

	Displacement	Average speed
A.	0	0
B.	0	$\frac{2D}{T}$
C.	$2D$	$\frac{2D}{T}$
D.	$2D$	0

(1)

5. The graph below shows the variation with time t of the displacement s of an object moving along a straight-line.



The best estimate of the instantaneous speed of the object at t = 2.0 s is

A. 0.0 ms^{-1}.

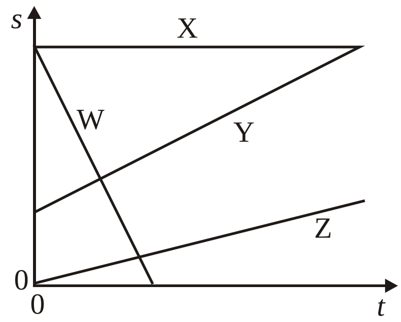
B. 0.2 ms^{-1}.

C. 5.0 ms^{-1}.

D. 10.0 ms^{-1}.

(1)

6. Four cars W, X, Y and Z are on a straight road. The graph below shows the variation with time t of the distance s of each car from a fixed point.

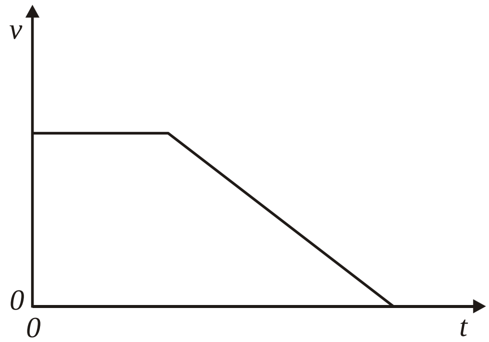


Which car has the greatest speed?

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

(1)

7. The diagram below shows the variation with time t of the velocity v of an object.



The area between the line of the graph and the time-axis represents

A. the average velocity of the object.

B. the displacement of the object.

C. the impulse acting on the object.

D. the work done on the object.

(1)

8. An object has initial speed u and acceleration a. After travelling a distance s, its final speed is v. The quantities u, v, a and s are related by the expression

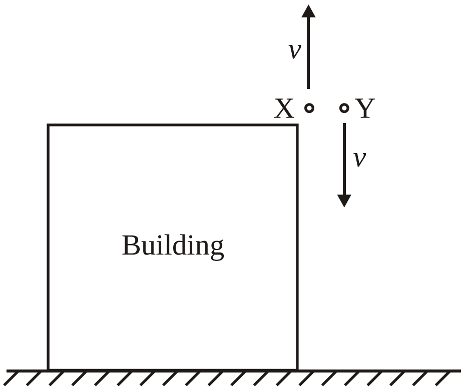
$$v^2 = u^2 + 2as.$$

Which of the following includes the **two** conditions necessary for the equation to apply?

A.	*a* has constant direction	*u* and *v* are in the same direction
B.	*a* has constant direction	*a*, *u* and *v* are in the same direction
C.	*a* has constant magnitude	*a* has constant direction
D.	*a* has constant magnitude	*u* and *v* are in the same direction

(1)

9. A stone X is thrown vertically upwards with speed *v* from the top of a building. At the same time, a second stone Y is thrown vertically downwards with the same speed *v* as shown.



Air resistance is negligible. Which **one** of the following statements is **true** about the speeds with which the stones hit the ground at the base of the building?

A. The speed of stone X is greater than that of stone Y.

B. The speed of stone Y is greater than that of stone X.

C. The speed of stone X is equal to that of stone Y.

D. Any statement about the speeds depends on the height of the building.

(1)

10. A body starting from rest moves along a straight-line under the action of a constant force. After travelling a distance *d* the speed of the body is *v*.

The speed of the body when it has travelled a distance $\frac{d}{2}$ from its initial position is

A. $\frac{v}{4}$.

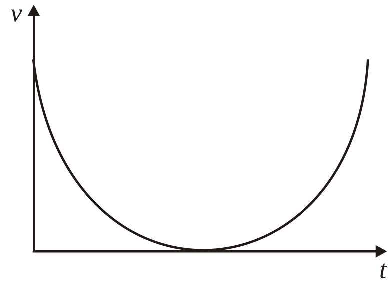
B. $\frac{v}{2}$.

C. $\frac{v}{\sqrt{2}}$.

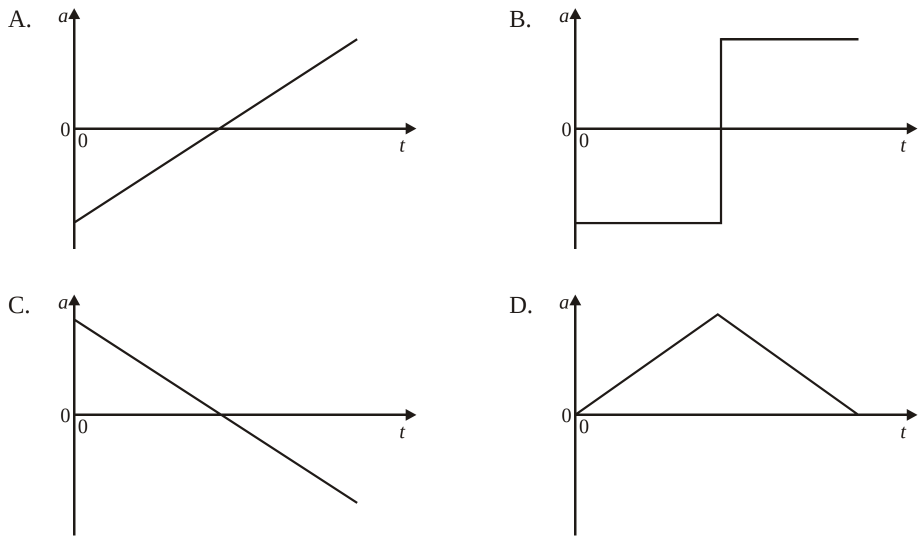
D. $\frac{v}{2\sqrt{2}}$.

(1)

11. The graph shows the variation with time *t* of the velocity *v* of an object.

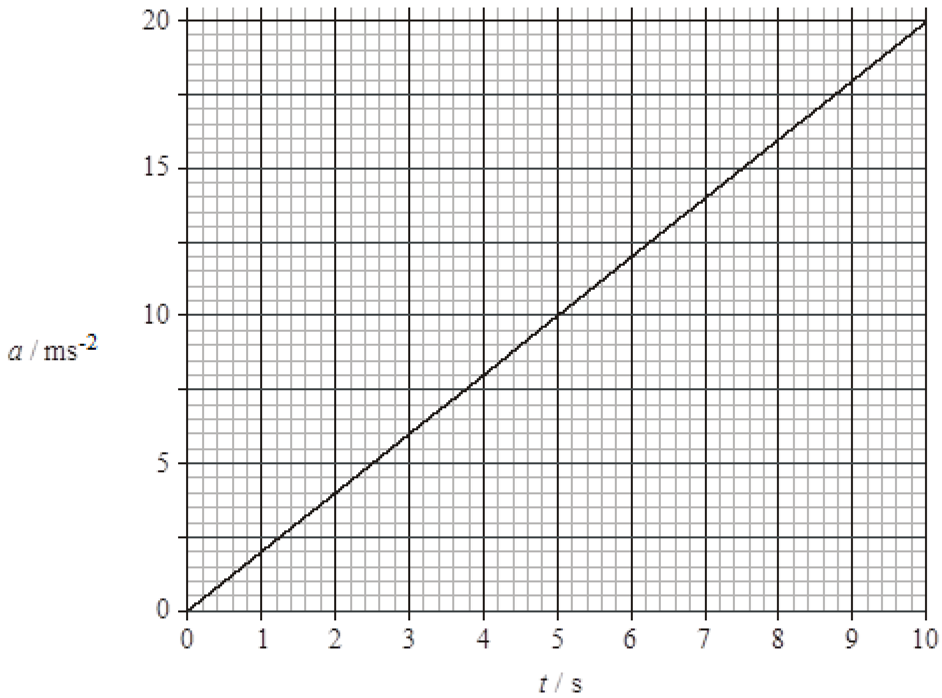


Which **one** of the following graphs best represents the variation with time *t* of the acceleration *a* of the object?



(1)

12. The graph shows the variation with time *t* of the acceleration *a* of an object.



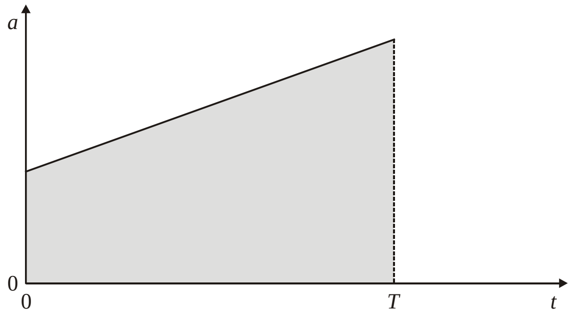
The object is at rest at time *t* = 0.

Which of the following is the velocity of the object at time *t* = 6.0 s?

A. 0.50 m s^{-1}. B. 2.0 m s^{-1}. C. 36 m s^{-1}. D. 72 m s^{-1}.

(1)

13. The graph below shows the variation with time t of the acceleration a of a spaceship.



The spaceship is at rest at $t = 0$.

The shaded area represents

A. the distance travelled by the spaceship between $t = 0$ and $t = T$.

B. the speed of the spaceship at $t = T$.

C. the rate at which the speed of the spaceship changes between $t = 0$ and $t = T$.

D. the rate at which the acceleration changes between $t = 0$ and $t = T$.

(1)

14. A raindrop falling through air reaches a terminal velocity before hitting the ground. At terminal velocity, the frictional force on the raindrop is

A. zero.

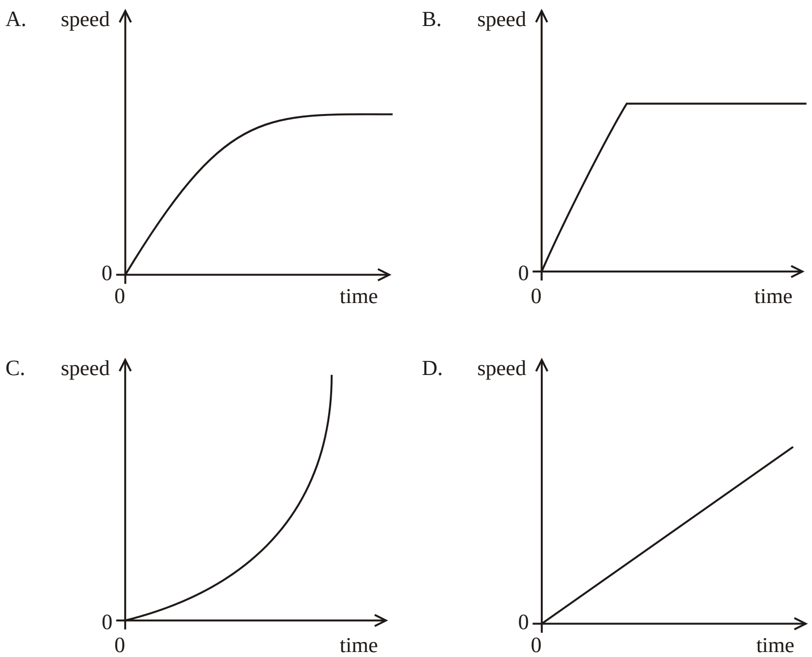
B. less than the weight of the raindrop.

C. greater than the weight of the raindrop.

D. equal to the weight of the raindrop.

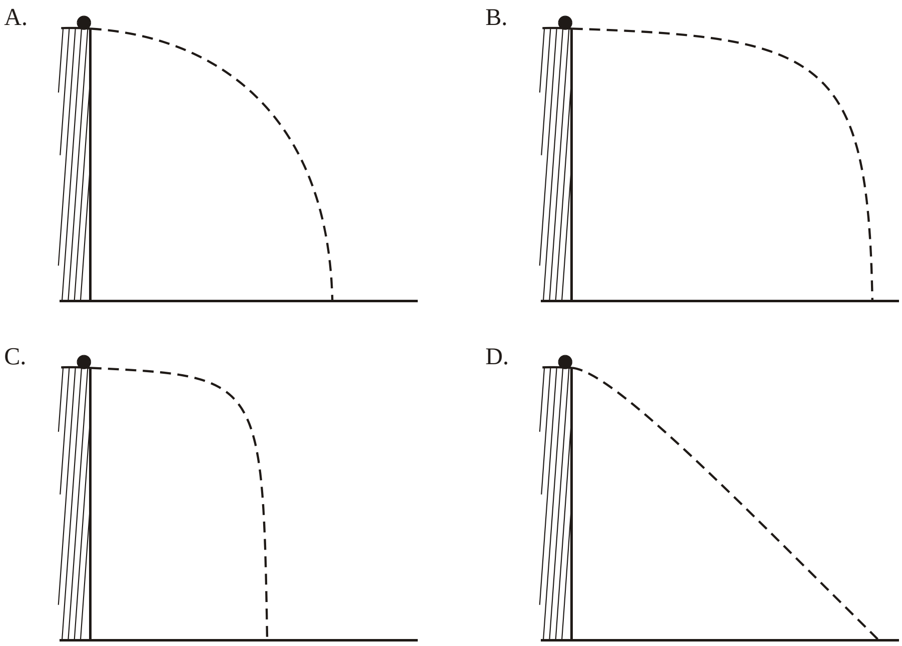
(1)

15. A steel sphere is dropped from rest in oil. Which of the following graphs best represents the variation with time of the speed of the sphere?



(1)

16. A ball is thrown horizontally from the top of a cliff. Air resistance is negligible. Which of the following diagrams best represents the subsequent path of the ball?



(1)

17. A stone is thrown at an angle to the horizontal. Ignoring air resistance, the horizontal component of the initial velocity of the stone determines the value of

A. range only.

B. maximum height only.

C. range and maximum height.

D. range and time of flight.

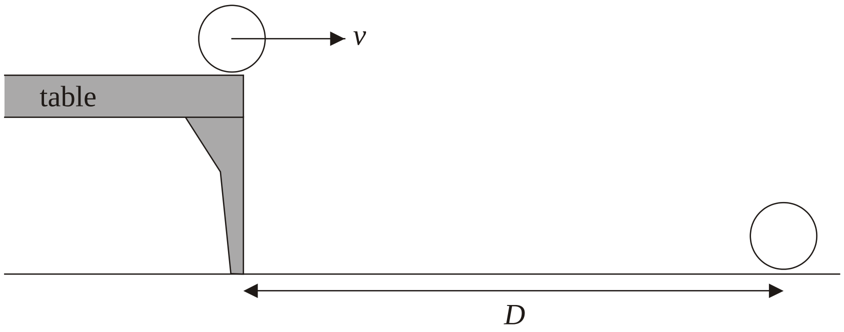
(1)

18. A stone is projected horizontally from the top of a cliff. Neglecting air resistance, which *one* of the following correctly describes what happens to the horizontal component of velocity and to the vertical component of velocity?

	Horizontal component of velocity	**Vertical component of velocity**
A.	Decreases	Increases
B.	Decreases	Constant
C.	Constant	Constant
D.	Constant	Increases

(1)

19. A ball rolls off a horizontal table with velocity *v*. It lands on the ground a time *T* later at a distance *D* from the foot of the table as shown in the diagram below. Air resistance is negligible.

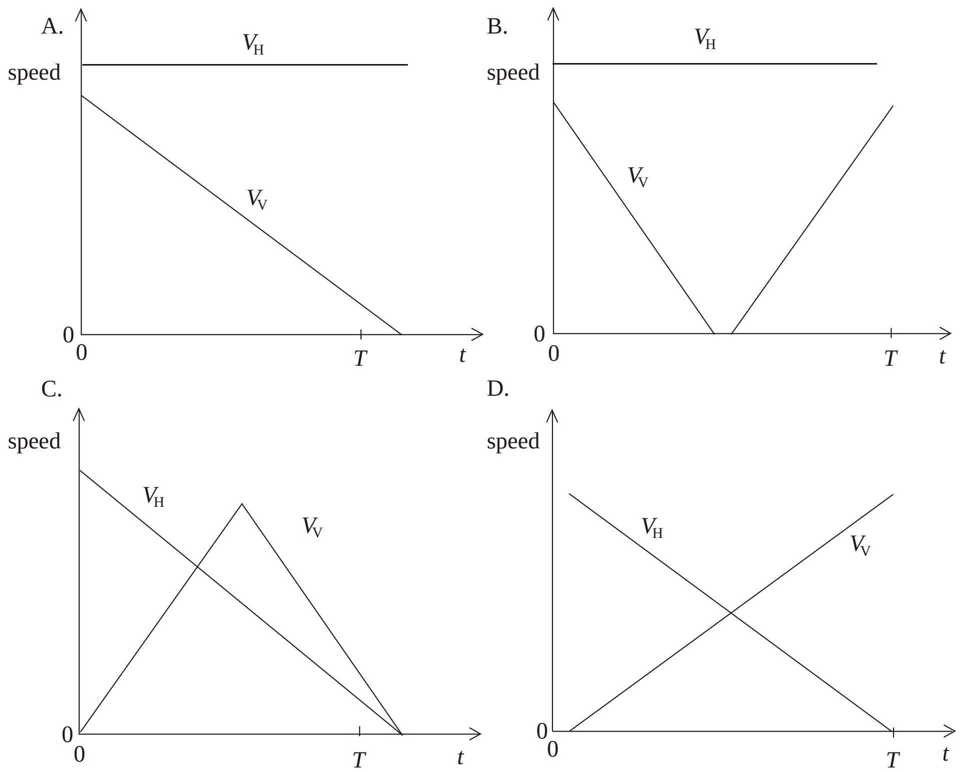


A second **heavier** ball rolls off the table with velocity *v*. Which **one** of the following is correct for the heavier ball?

	Time to land	Distance from table
A.	*T*	*D*
B.	*T*	less than *D*
C.	less than *T*	*D*
D.	less than *T*	less than *D*

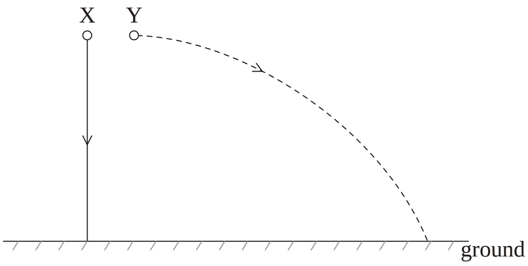
(1)

20. A projectile is fired from the ground at time $t = 0$. It lands back on the ground at time $t = T$. Which of the following sketch graphs best shows the variation with time t of the vertical speed V_V and horizontal speed V_H of the projectile? Air resistance is negligible.



(1)

21. Two identical metal spheres X and Y are released at the same time from the same height above the horizontal ground. Sphere X falls vertically from rest. Sphere Y is projected horizontally as shown below.



Air resistance is negligible.

Which of the following statements is correct?

A. Sphere X hits the ground before sphere Y because it travels a shorter distance.

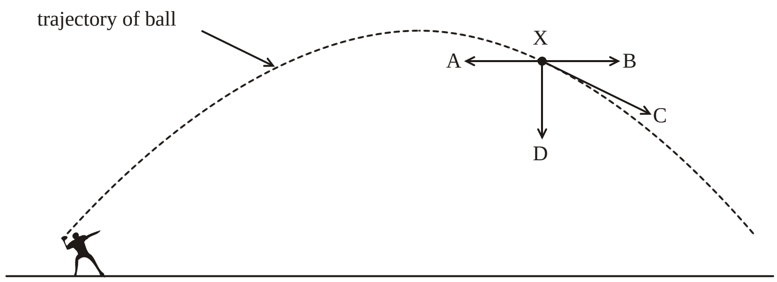
B. Sphere Y hits the ground before sphere X because its initial velocity is greater.

C. The spheres hit the ground at the same time because horizontal motion does not affect vertical motion.

D. The spheres hit the ground at the same time because they have equal weights.

(1)

22. The diagram below shows the trajectory of a ball thrown into the air. There is no air resistance.

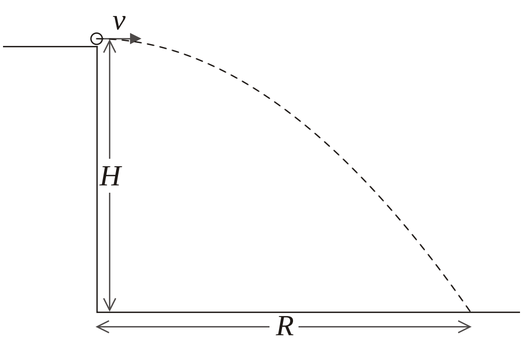


Which arrow gives the direction of the resultant force on the ball at the point X?

A. A B. B C. C D. D

(1)

23. A particle is projected horizontally with speed v from a height H. It lands a horizontal distance R from the point of launch as shown in the diagram below.



A second particle is projected horizontally from the same height with speed $2v$. Neglecting air resistance the horizontal distance travelled by this particle is

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

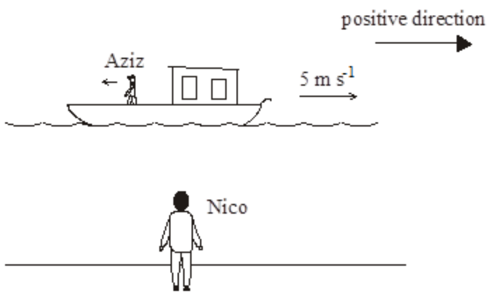
(1)

24. Which **one** of the following is a true statement concerning the vertical component of the velocity and the acceleration of a projectile when it is at its maximum height? *(The acceleration of free fall is g.)*

	Vertical component of velocity	Acceleration
A.	maximum	zero
B.	maximum	g
C.	zero	zero
D.	zero	g

(1)

25. A boat is moving in the direction shown with a speed of 5 m s^{-1} as measured by Nico who is at rest on the beach. Aziz walks along the deck of the boat in the direction shown with a speed of 2 m s^{-1} measured relative to the boat.

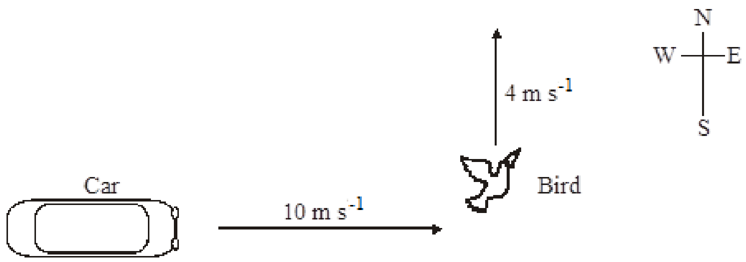


If velocity is measured as positive in the direction shown, the **velocity** of Nico relative to Aziz is

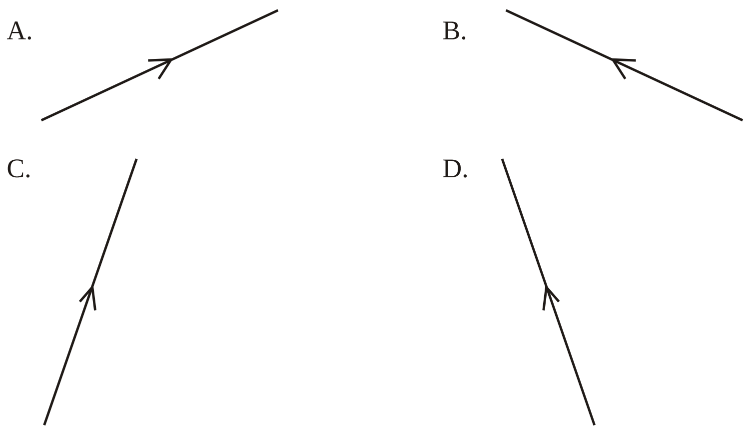
A. − 7 m s^{-1}. B. − 3 m s^{-1}. C. + 3 m s^{-1}. D. + 7 m s^{-1}.

(1)

26. A car is heading due East at a speed of 10 m s^{-1}. A bird is flying due North at a speed of 4 m s^{-1}, as shown below.



Which **one** of the following vectors represents the velocity of the bird relative to a person in the car?



(1)

27. An object is moving at constant velocity. Which **one** of the following quantities **must** have zero magnitude?

A. Weight of object

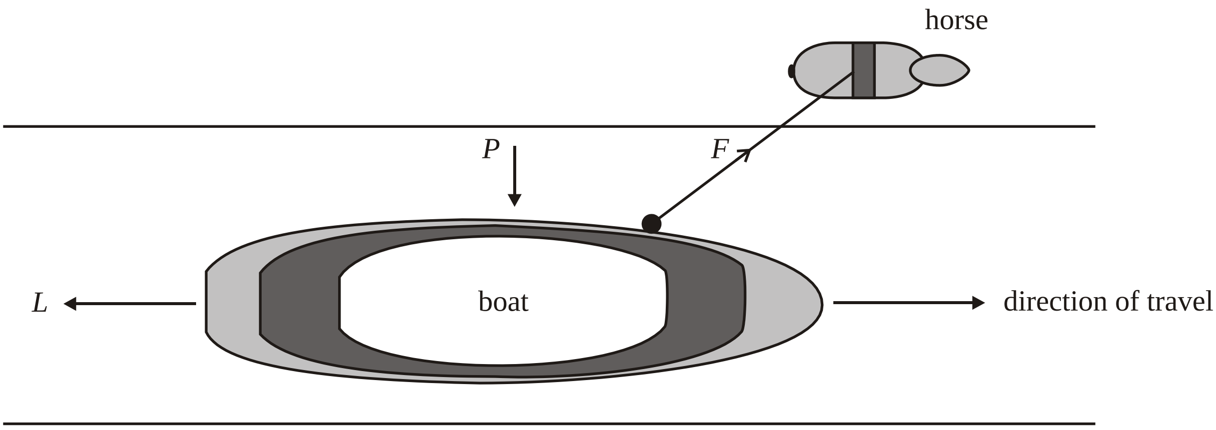
B. Momentum of object

C. Kinetic energy of object

D. Resultant force on object

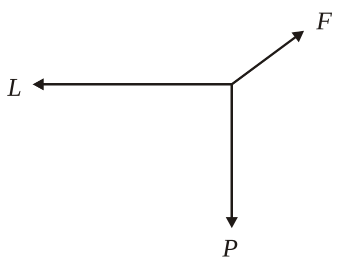
(1)

28. A horse pulls a boat along a canal at constant speed in a straight-line as shown below.

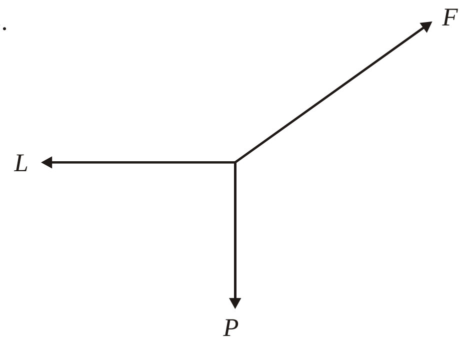


The horse exerts a constant force *F* on the boat. The water exerts a constant drag force *L* and a constant force *P* on the boat. The directions of *F*, *L* and *P* are as shown. Which **one** of the following best represents a free-body diagram for the boat?

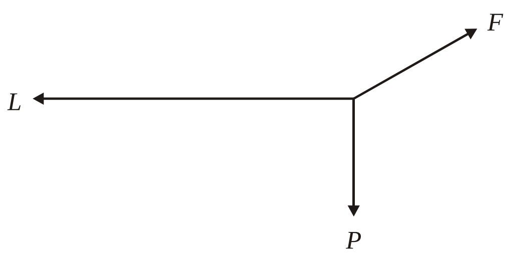
A.



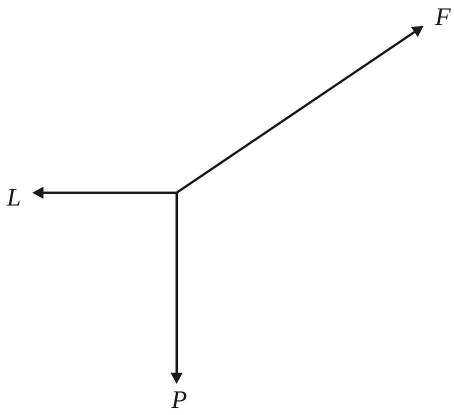
B.



C.



D.



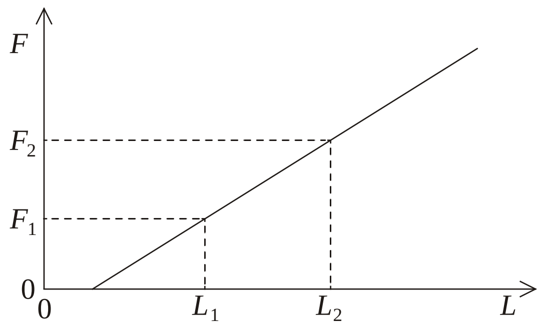
(1)

29. Three forces of magnitude F_1 = 3.0 N, F_2 = 4.0 N and F_3 = 6.0 N act at a point. The point is in equilibrium. The magnitude of the resultant of F_1 and F_2 is

A. 1.0 N. B. 5.0 N. C. 6.0 N. D. 7.0 N.

(1)

30. The graph below shows the variation with load F of the length L of a spring.

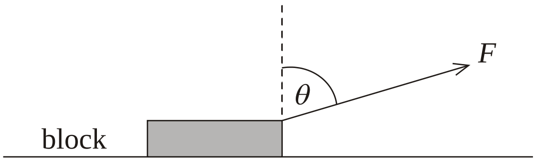


Which of the following expressions gives the force per unit extension (the spring constant) of the spring?

A. $\frac{F_1}{L_1}$ B. $\frac{F_2}{L_2}$ C. $\frac{(F_2 - F_1)}{L_2}$ D. $\frac{(F_2 - F_1)}{L_2 - L_1}$

(1)

31. A block of mass m is pulled along a horizontal, frictionless surface by a force of magnitude F. The force makes an angle θ with the vertical.

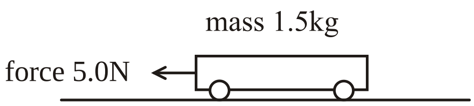


The magnitude of the acceleration of the block in the horizontal direction produced by the force F is

A. $\frac{F}{m}$. B. $\frac{F \sin\theta}{m}$. C. $\frac{F \cos\theta}{m}$. D. $\frac{F \tan\theta}{m}$.

(1)

32. A trolley of mass 1.5 kg is pulled along a horizontal table by a force of 5.0N.



The frictional force acting on the trolley is 0.50N.

The acceleration of the trolley is

A. 0.30 m s^{-2}.

B. 0.33 m s^{-2}.

C. 3.0 m s^{-2}.

D. 3.3 m s^{-2}.

(1)

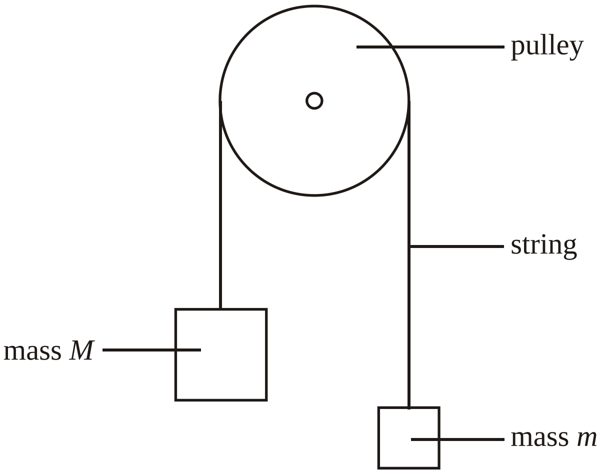
33. Two blocks having different masses slide down a frictionless slope.

Which of the following correctly compares the accelerating force acting on each block and also the accelerations of the blocks down the slope?

	Accelerating force	**Acceleration**
A.	Equal	Equal
B.	Equal	Different
C.	Different	Equal
D.	Different	Different

(1)

34. A light inextensible string has a mass attached to each end and passes over a frictionless pulley as shown.



The masses are of magnitudes *M* and *m*, where $m < M$. The acceleration of free fall is *g*. The downward acceleration of the mass *M* is

A. $\frac{(M-m)g}{(M+m)}$. B. $\frac{(M-m)g}{M}$. C. $\frac{(M+m)g}{(M-m)}$. D. $\frac{Mg}{(M+m)}$.

(1)

35. Which is an example of static friction?

A. ice skating on a frozen pond.

B. pushing a box that is at rest.

C. braking a car going down a hill.

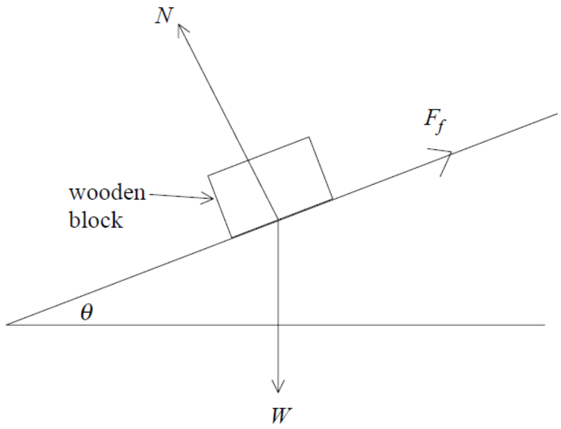
D. driving a car up a hill.

36. Using lubricants on engine parts is an example of reducing

A. force. B. friction.

C. acceleration. D. motion.

37. In the diagram a wooden block is resting on an inclined plane. The weight of the block is W and the normal reaction between the block and the plane is N and the frictional force acting on the block is F_f. Angle θ is the maximum angle of the plane before the block starts to slide down the plane. The coefficient of static friction between the block and the plane is μ.



Which **one** of the following relationships between W and N is correct?

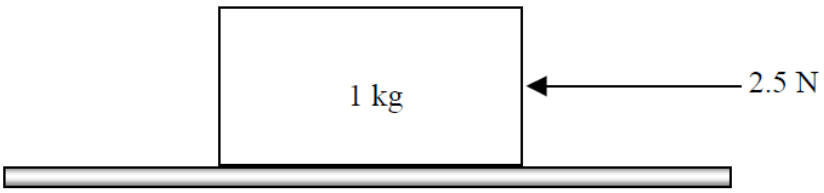
A. $W = \mu N$

B. $W \cos \theta = \mu N$

C. $W \sin \theta = \mu N$

D. $W \sin \theta = N$

38. A block of mass 1.0 kg is placed on a rough horizontal surface and a horizontal force of 2.5 N is applied to the block as shown below.



The following data is available:

Coefficient of **static** friction = 0.3

Coefficient of **dynamic** friction = 0.2

Acceleration due to gravity = 10 ms^{-2}.

Based on this data, it can be deduced that the block will

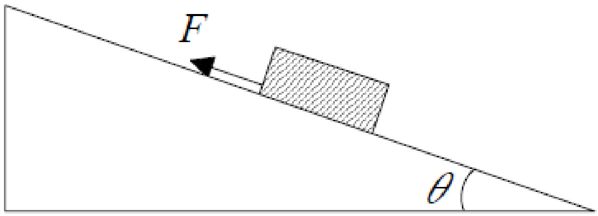
A. not move.

B. move at steady speed.

C. move with constant acceleration.

D. move with increasing acceleration.

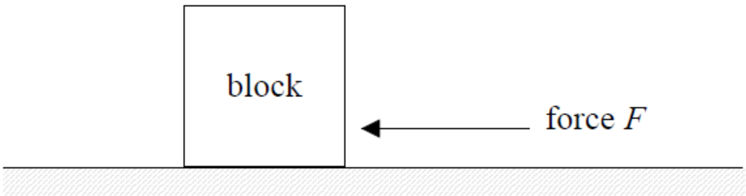
39. A block is at rest on a rough plane inclined at an angle θ relatively to the horizontal.



The angle θ is slowly reduced. Which **one** of the following correctly describes the changes, if any, in the frictional force *F* and the coefficient of static friction between the block and the plane?

	Frictional force *F*	Coefficient of static friction
A.	decreases	increases
B.	decreases	constant
C.	increases	increases
D.	increases	constant

40. A block is placed on a horizontal rough surface. A horizontal force *F* is applied to the block, as shown below.



The force required to keep the block moving at constant speed is less than the force required to make the block move from rest. The **explanation** for this observation is that

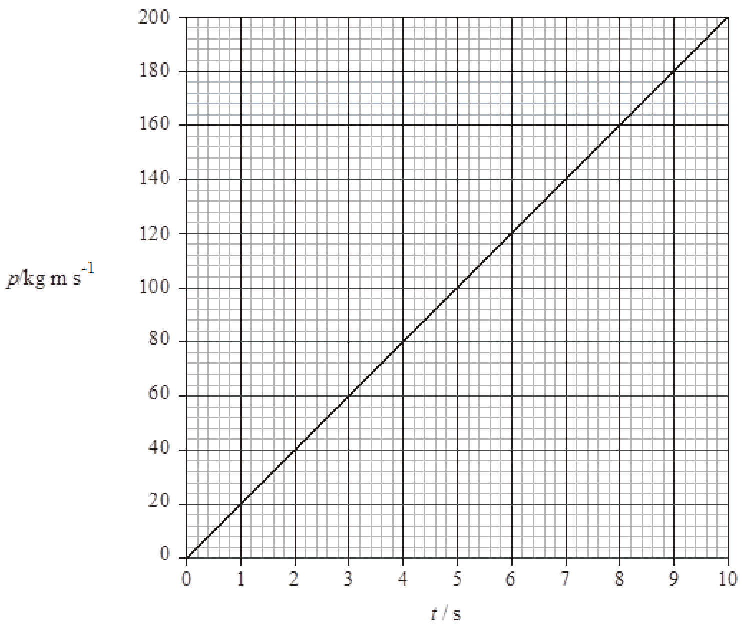
A. before the block moves, the force *F* must also produce a turning moment.

B. a force is not required to keep the block moving at constant speed.

C. friction has to be overcome to make the block move.

D. the maximum static friction forces are greater than the maximum dynamic friction forces.

41. A constant force of magnitude F acts on a body. The graph shows the variation with time t of the momentum p of the body.



The magnitude of the force F is

A. 1000 N. B. 200 N. C. 20 N. D. 0.05 N.

(1)

42. The velocity of a body of mass m changes by an amount Δv in a time Δt. The impulse given to the body is equal to

A. $m\Delta t$. B. $\frac{\Delta v}{\Delta t}$. C. $m\frac{\Delta v}{\Delta t}$. D. $m\Delta v$.

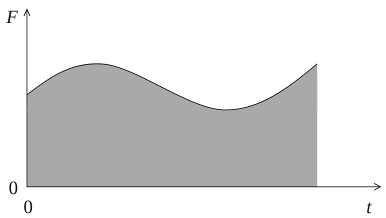
(1)

43. A net force of magnitude F acts on a body for a time Δt producing an impulse of magnitude Y. Which of the following is the magnitude of the rate of change of momentum of the body?

A. F B. $F\Delta t$ C. Y D. $Y\Delta t$

(1)

44. The graph below shows the variation with time t of the magnitude of the net force F acting on a body moving along a straight-line.



The shaded area represents

A. the total work done by F.

B. the change in the kinetic energy of the body.

C. the change in the momentum of the body.

D. the change in the velocity of the body.

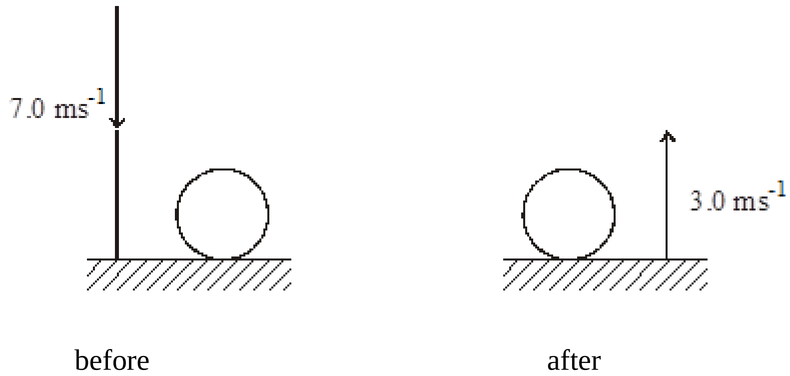
(1)

45. Which of the following quantities are conserved in an **inelastic** collision between two bodies?

	Total linear momentum of the bodies	Total kinetic energy of the bodies
A.	yes	yes
B.	yes	no
C.	no	yes
D.	no	no

(1)

46. A ball of mass 2.0 kg falls vertically and hits the ground with speed 7.0 ms^{-1} as shown below.



The ball leaves the ground with a vertical speed 3.0 ms^{-1}.

The magnitude of the change in momentum of the ball is

A. zero. B. 8.0 Ns. C. 10 Ns. D. 20 Ns.

(1)

47. A ball of mass m, travelling in a direction at right angles to a vertical wall, strikes the wall with a speed v_1. It rebounds at right angles to the wall with a speed v_2. The ball is in contact with the wall for a time Δt. The magnitude of the force that the ball exerts on the wall is

A. $\frac{m(v_1 + v_2)}{\Delta t}$. B. $m(v_1 + v_2)\Delta t$.

C. $\frac{m(v_1 - v_2)}{\Delta t}$. D. $m(v_1 - v_2)\Delta t$.

(1)

48. The momentum of a system is conserved if

A. no external forces act on the system.

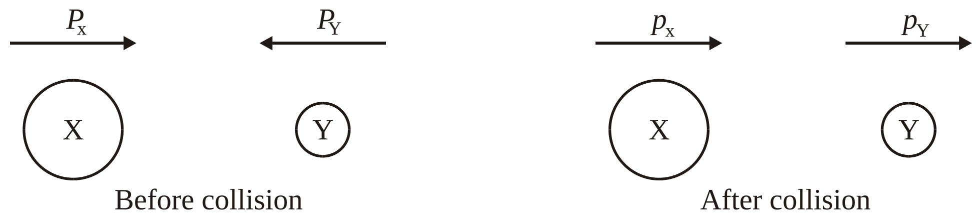
B. no friction forces act within the system.

C. no kinetic energy is lost or gained by the system.

D. the forces acting on the system are in equilibrium.

(1)

49. Two spheres X and Y are moving towards each other along the same straight line with momenta of magnitude P_X and P_Y respectively. The spheres collide and move off with momenta p_X and p_Y respectively, as illustrated below.



Which **one** of the following is a correct statement of the law of conservation of momentum for this collision?

A. $P_X + P_Y = p_X + p_Y$

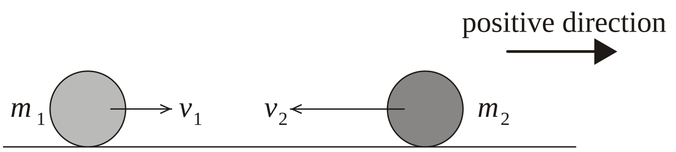
B. $P_X - P_Y = p_X + p_Y$

C. $P_X - P_Y = p_X - p_Y$

D. $P_X + P_Y = p_X - p_Y$

(1)

50. Two spheres of masses m_1 and m_2 are moving towards each other along the same straight-line with speeds v_1 and v_2 as shown.



The spheres collide. Which of the following gives the total change in linear momentum of the spheres as a result of the collision?

A. 0

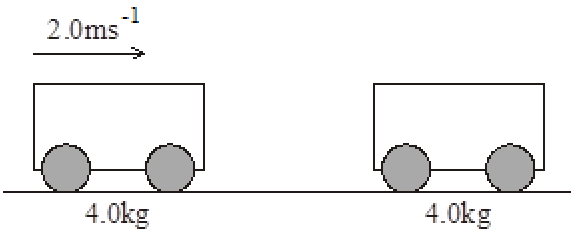
B. $m_1v_1 + m_2v_2$

C. $m_1v_1 - m_2v_2$

D. $m_2v_2 - m_1v_1$

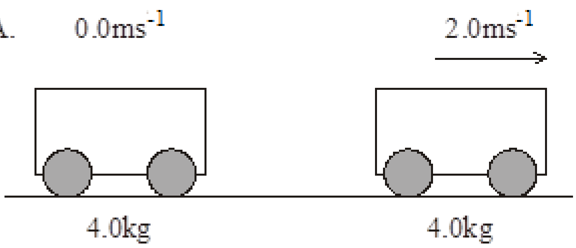
(1)

51. The diagram below shows a trolley of mass 4.0 kg moving on a frictionless horizontal table with a speed of 2.0 m s^{-1}. It collides with a stationary trolley also of mass 4.0 kg.

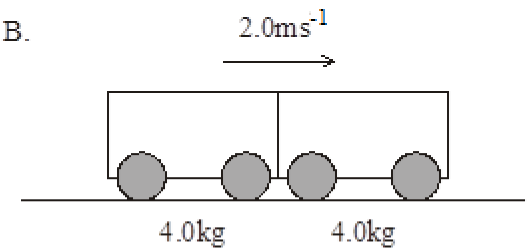


Which of the following diagrams shows a possible outcome?

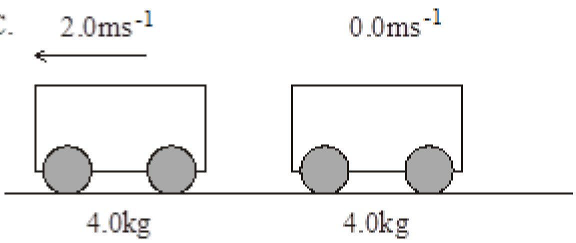
A.



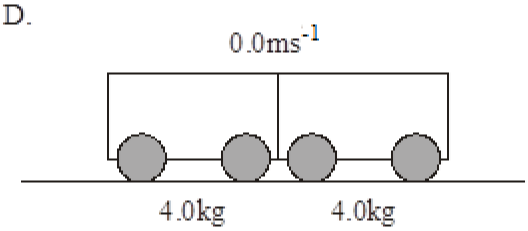
B.



C.



D.



(1)

52. A truck collides head on with a less massive car moving in the opposite direction to the truck. During the collision, the average force exerted by the truck on the car is F_T and the average force exerted by the car on the truck is F_C. Which **one** of the following statements is correct?

A. F_T will always be greater in magnitude than F_C.

B. F_T will always be equal in magnitude to F_C.

C. F_T will be greater in magnitude than F_C only when the speed of the car is less than the speed of the truck.

D. F_T will be equal in magnitude to F_C only when the speed of the truck is equal to the speed of the car.

(1)

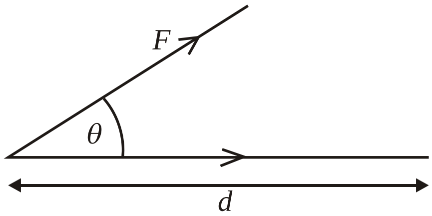
53. A box of mass *m* is moved horizontally against a constant frictional force *f* through a distance *s* at constant speed *v*. The work done on the box is

A. 0. B. *mgs*.

C. $\frac{1}{2}mv^2$. D. *fs*.

(1)

54. The point of action of a constant force F is displaced a distance d. The angle between the force and the direction of the displacement is θ, as shown below.



Which **one** of the following is the correct expression for the work done by the force?

A. Fd

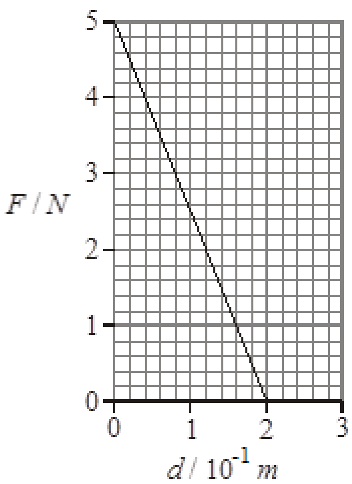
B. $Fd \sin \theta$

C. $Fd \cos \theta$

D. $Fd \tan \theta$

(1)

55. The graph below shows the variation with displacement d of the force F applied by a spring on a cart.



The work done by the force in moving the cart through a distance of 2 cm is

A. 10×10^{-2}J.

B. 7×10^{-2}J.

C. 5×10^{-2}J.

D. 2.5×10^{-2}J.

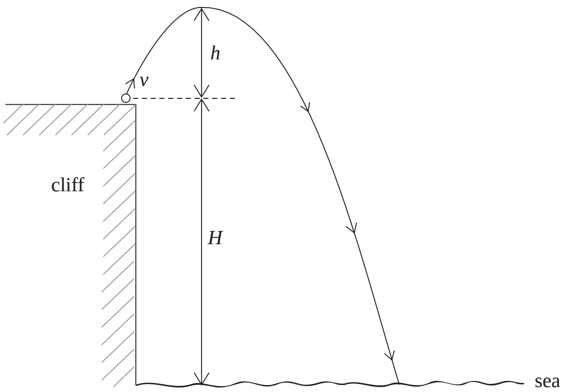
(1)

56. A body of mass m and speed v has kinetic energy E_K. A second body of mass $\frac{m}{2}$ moves at speed $2v$.
The kinetic energy of this second body is

A. $\frac{E_K}{2}$. B. E_K. C. $2E_K$. D. $4E_K$.

(1)

57. A stone is thrown with speed *v* from the top of a cliff of height *H*, as shown below.



The stone is thrown at an angle to the horizontal so that it rises to a height *h* above the top of the cliff before falling into the sea. The acceleration of free fall is *g*. Air resistance is negligible.

Which **one** of the following expressions gives correctly the speed of the stone as it hits the sea?

A. $v+\sqrt{(2gh)}$ B. $v+\sqrt{(2gH)}$

C. $\sqrt{(2g\{h+H\})}$ D. $\sqrt{(v^2+2gH)}$

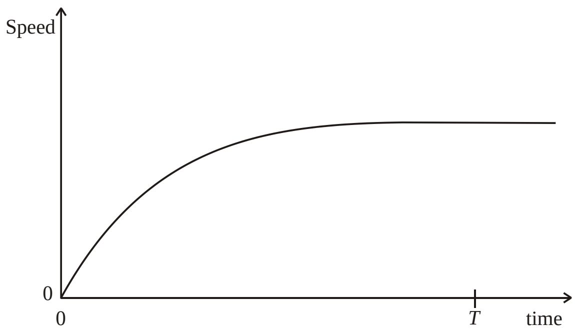
(1)

58. An object of mass m_1 has a kinetic energy K_1. Another object of mass m_2 has a kinetic energy K_2. If the momentum of both objects is the same, the ratio $\frac{K_1}{K_2}$ is equal to

A. $\frac{m_2}{m_1}$. B. $\frac{m_1}{m_2}$. C. $\sqrt{\frac{m_2}{m_1}}$. D. $\sqrt{\frac{m_1}{m_2}}$.

(1)

59. The variation with time of the vertical speed of a ball falling in air is shown below.



During the time from 0 to *T*, the ball gains kinetic energy and loses gravitational potential energy ΔE_p. Which of the following statements is true?

A. ΔE_p is equal to the gain in kinetic energy.

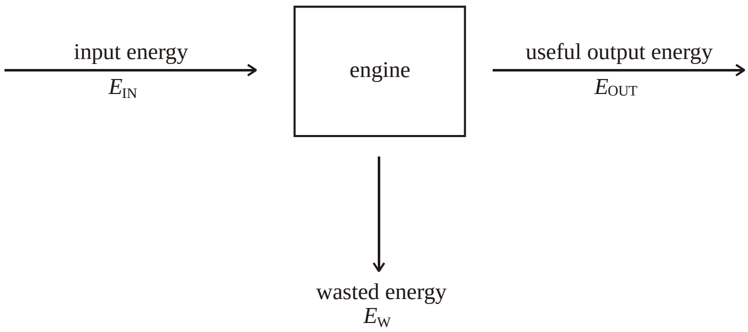
B. ΔE_p is greater than the gain in kinetic energy.

C. ΔE_p is equal to the work done against air resistance.

D. ΔE_p is less than the work done against air resistance.

(1)

60. The diagram below represents energy transfers in an engine.



The efficiency of the engine is given by the expression

A. $\frac{E_W}{E_{IN}}$. B. $\frac{E_W}{E_{OUT}}$. C. $\frac{E_{OUT}}{E_{IN}}$. D. $\frac{E_{OUT}}{E_W}$.

(1)

61. An engine takes in an amount *E* of thermal energy and, as a result, does an amount *W* of useful work. An amount *H* of thermal energy is ejected. The law of conservation of energy and the efficiency of the engine are given by which of the following?

	Law of conservation of energy	Efficiency
A.	$E = W + H$	W
B.	$E = W + H$	$\frac{W}{E}$
C.	$E + H = W$	$\frac{W}{H}$
D.	$E + H = W$	$\frac{W}{E - H}$

(1)

62. An electric train develops a power of 1.0 MW when travelling at a constant speed of 50 ms^{-1}. The net resistive force acting on the train is

A. 50 MN.

B. 200 kN.

C. 20 kN.

D. 200 N.

(1)

Short answer questions

1. Linear motion

(a) Define the term *acceleration*.

....

.... **(2)**

(b) An object has an initial speed u and an acceleration a. After time t, its speed is v and it has moved through a distance s.

The motion of the object may be summarized by the equations

$$v = u + at,$$

$$s = \tfrac{1}{2}(v+u)t.$$

(i) State the assumption made in these equations about the acceleration a.

.... **(1)**

(ii) Derive, using these equations, an expression for v in terms of u, s and a.

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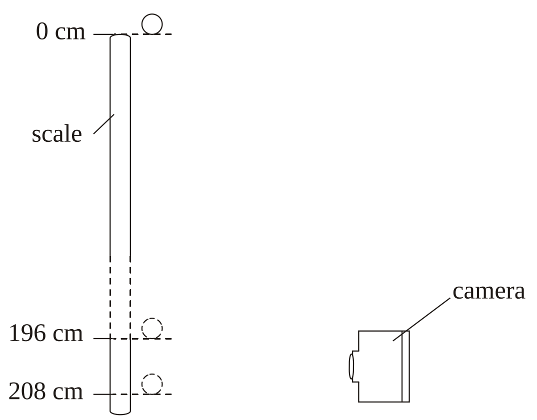
.... **(2)**

(c) The shutter speed of a camera is the time that the film is exposed to light. In order to determine the shutter speed of a camera, a metal ball is held at rest at the zero mark of a vertical scale, as shown below. The ball is released. The shutter of a camera is opened as the ball falls.



The photograph of the ball shows that the shutter opened as the ball reached the 196 cm mark on the scale and closed as it reached the 208 cm mark. Air resistance is negligible and the acceleration of free fall is 9.81 m s^{-2}.

(i) Calculate the time for the ball to fall from rest to the 196 cm mark.

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.... **(2)**

(ii) Determine the time for which the shutter was open. That is, the time for the ball to fall from the 196 cm mark to the 208 cm mark.

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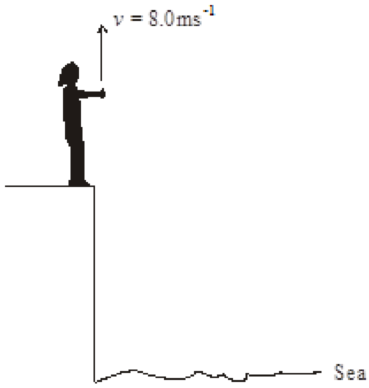
(2)
(Total 9 marks)

2. This question is about throwing a stone from a cliff.

Antonia stands at the edge of a vertical cliff and throws a stone vertically upwards.



The stone leaves Antonia's hand with a speed $v = 8.0\text{ms}^{-1}$.

The acceleration of free fall g is 10 m s^{-2} and all distance measurements are taken from the point where the stone leaves Antonia's hand.

(a) Ignoring air resistance calculate

(i) the maximum height reached by the stone.

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(2)

(ii) the time taken by the stone to reach its maximum height.

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(1)

The time between the stone leaving Antonia's hand and hitting the sea is 3.0 s.

(b) Determine the height of the cliff.

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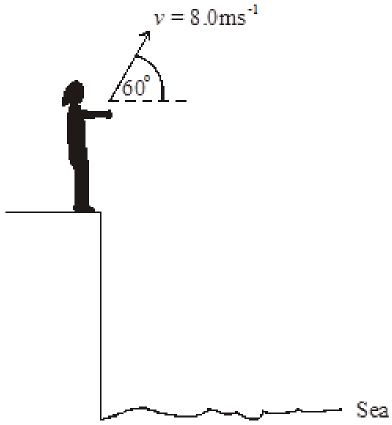
(3)
(Total 6 marks)

3. This question is about trajectory motion.

Antonia stands at the edge of a vertical cliff and throws a stone upwards at an angle of 60° to the horizontal.



The stone leaves Antonia's hand with a speed $v = 8.0 \text{ m s}^{-1}$. The time between the stone leaving Antonia's hand and hitting the sea is 3.0 s.

The acceleration of free fall g is 10 m s^{-2} and all distance measurements are taken from the point where the stone leaves Antonia's hand.

Ignoring air resistance calculate

(a) the maximum height reached by the stone.

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(3)

(b) the horizontal distance travelled by the stone.

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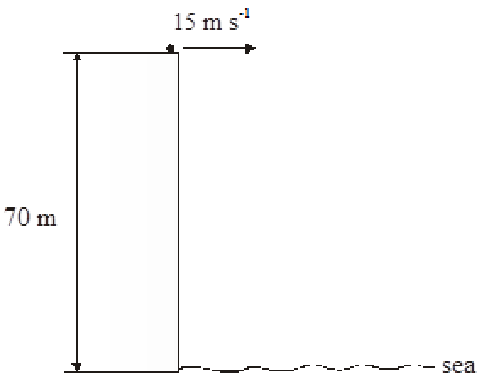
(2)
(Total 5 marks)

4. This question is about projectile motion.

A stone is projected horizontally from the top of a cliff with a speed 15 m s^{-1}.



The height of the cliff is 70 m and the acceleration of free fall is 10 m s^{-2}. The stone strikes the surface of the sea at velocity *V*.

(a) Ignoring air resistance, deduce that the stone strikes the sea at a speed of 40 m s^{-1}.

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(2)

(b) Use your answer in (a) to calculate the angle that the velocity *V* makes with the surface of the sea.

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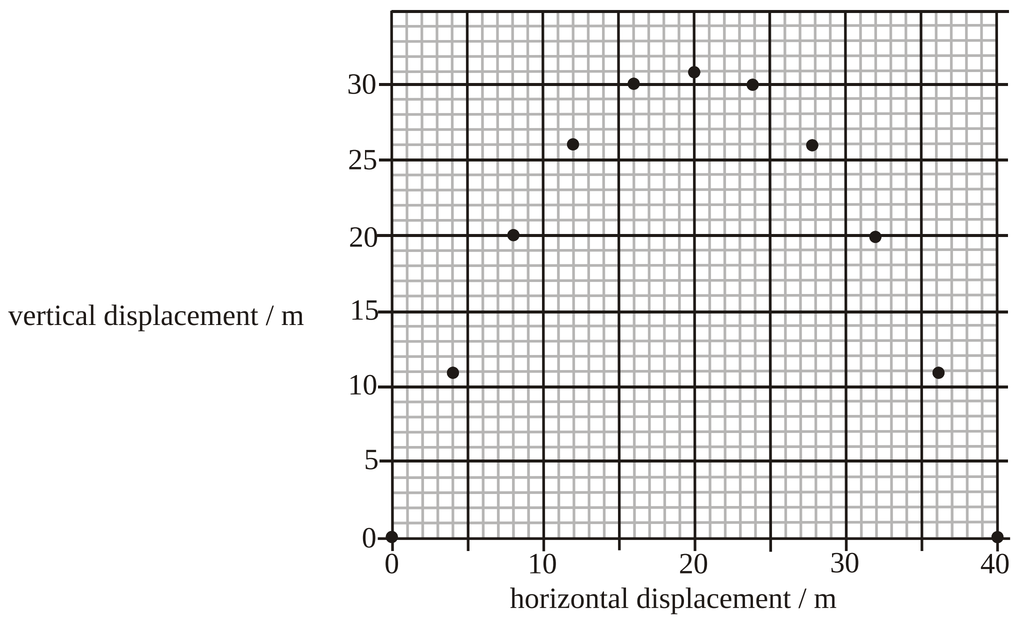
(2)
(Total 4 marks)

5. This question is about projectile motion.

A ball is kicked at an angle to the horizontal. The diagram below shows the position of the ball every 0.50 s.



The acceleration of free fall is g = 10 m s^{-2}. Air resistance may be neglected.

(a) Using the diagram determine, for the ball

(i) the horizontal component of the initial velocity.

....

....

(1)

(ii) the vertical component of the initial velocity.

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....

(2)

(iii) the magnitude of the displacement after 3.0 s.

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....

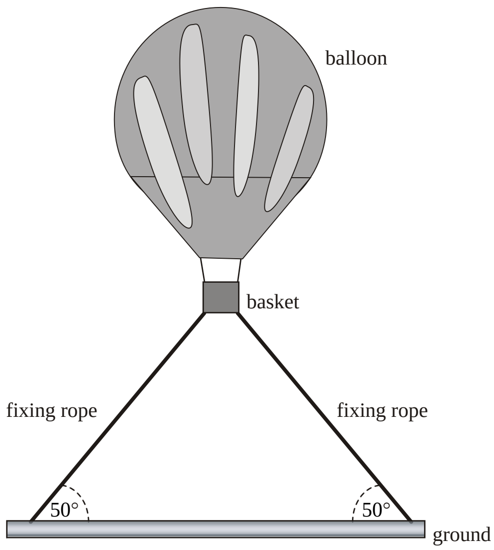
(2)

(b) On the diagram above draw a line to indicate a possible path for the ball if air resistance were not negligible.

(2)
(Total 7 marks)

6. This question is about a balloon used to carry scientific equipment.

The diagram below represents a balloon just before take-off. The balloon's basket is attached to the ground by two fixing ropes.



There is a force F vertically upwards of 2.15×10^3 N on the balloon. The total mass of the balloon and its basket is 1.95×10^2 kg.

(a) State the magnitude of the resultant force on the balloon when it is attached to the ground.

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(1)

(b) Calculate the tension in **either** of the fixing ropes.

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(3)

(c) The fixing ropes are released and the balloon accelerates upwards. Calculate the magnitude of this initial acceleration.

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(2)

(d) The balloon reaches a terminal speed 10 seconds after take-off. The upward force *F* remains constant. Describe how the magnitude of air friction on the balloon varies during the first 10 seconds of its flight.

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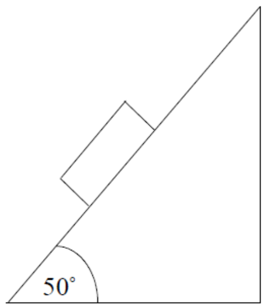
(2)
(Total 8 marks)

7. This question is about measuring the coefficient of dynamic (kinetic) sliding friction.

A student releases a block of mass *M* placed at the top of an inclined plane and measures the time it takes the block to travel a measured distance down the plane. The diagram below shows the block whilst it is still sliding.



(a) On the diagram, draw and name the forces acting on the block. *[3]*

(b) The angle of incline of the plane is 50^0 and the block takes 1.80 s to travel 4.00 m down the plane. The acceleration due to gravity is $9.81 ms^{-2}$.

Calculate

(i) the acceleration of the block down the plane.

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.... *[2]*

(ii) the component of weight down the plane in terms of *M*.

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.... *[2]*

(c) If the coefficient of dynamic sliding friction between the plane and the block is μ_k , what is the value of the frictional force expressed in terms of μ_k and M?

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....*[2]*

(d) Calculate the value of $\mu_{k.}$

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....*[3]*

(e) If the angle of incline of the plane is changed to 40^0 the block will only start to slide down the plane if it is given a slight push. Estimate the value of the coefficient of static friction between the block and the plane.

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.... *[2]*

(Total 14 marks)

8. Friction

(a) State **two** factors that affect the frictional force between surfaces in contact.

1. . . . .

2. . . . . *[2]*

(b) Distinguish between *static friction* and *dynamic (sliding) friction*.

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.... *[3]*

(c) A block of wood of weight 12 N is at rest on a flat, horizontal surface. The minimum horizontal force required to move the block is 7.2 N. Calculate the coefficient of static friction between the block and the surface.

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.... *[1]*

(d) The force of 7.2 N is applied continuously to the block. Explain whether the block will accelerate **or** move with constant speed.

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....*[3]*

(Total 9 marks)

9. This question is about the collision between two railway trucks (carts).

(a) Define *linear momentum*.

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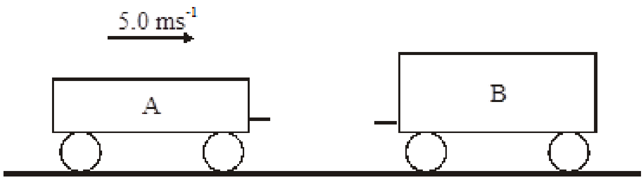
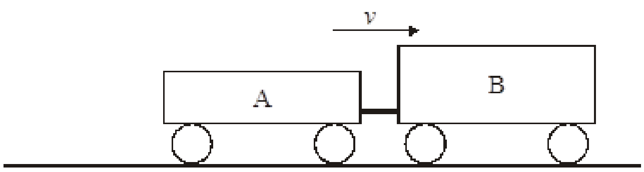
(1)

In the diagram below, railway truck A is moving along a horizontal track. It collides with a stationary truck B and on collision, the two join together. Immediately before the collision, truck A is moving with speed 5.0 ms^{-1}. Immediately after collision, the speed of the trucks is *v*.



Immediately before collision



Immediately after collision

The mass of truck A is 800 kg and the mass of truck B is 1200 kg.

(b) (i) Calculate the speed v immediately after the collision.

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(3)

(ii) Calculate the total kinetic energy lost during the collision.

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(2)

(c) Suggest what has happened to the lost kinetic energy.

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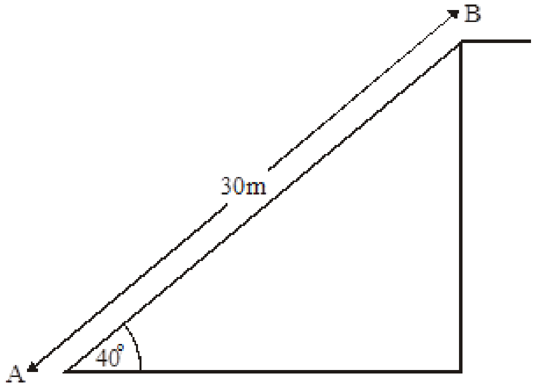
(2)
(Total 8 marks)

10. This question is about estimating energy changes for an escalator (moving staircase).

The diagram below represents an escalator. People step on to it at point A and step off at point B.



(a) The escalator is 30 m long and makes an angle of 40° with the horizontal. At full capacity, 48 people step on at point A and step off at point B every minute.

(i) Calculate the potential energy gained by a person of weight 7.0×10^2 N in moving from A to B.

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(2)

(ii) Estimate the energy supplied by the escalator motor to the people every minute when the escalator is working at full capacity.

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(1)

(iii) State **one** assumption that you have made to obtain your answer to (ii).

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(1)

The escalator is driven by an electric motor that has an efficiency of 70%.

(b) Using your answer to (a) (ii), calculate the minimum input power required by the motor to drive the escalator.

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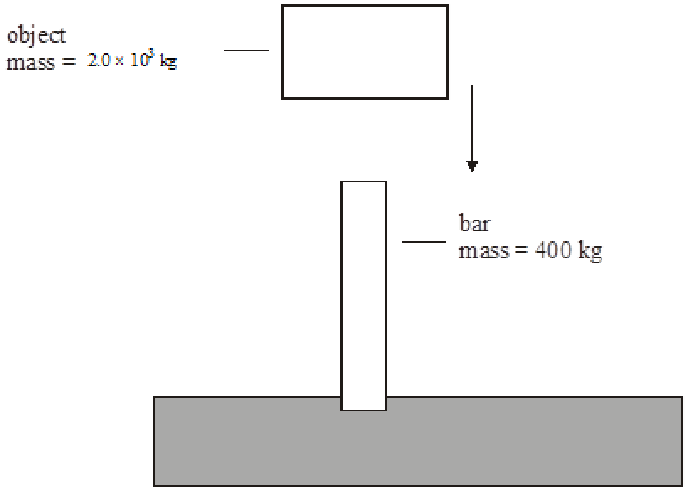
(3)
(Total 7 marks)

11. This question is about driving a metal bar into the ground.

Large metal bars can be driven into the ground using a heavy falling object.



In the situation shown, the object has a mass 2.0×10^3 kg and the metal bar has a mass of 400 kg.

The object strikes the bar at a speed of 6.0 m s^{-1}. It comes to rest on the bar without bouncing. As a result of the collision, the bar is driven into the ground to a depth of 0.75 m.

(a) Determine the speed of the bar immediately after the object strikes it.

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(4)

(b) Determine the average frictional force exerted by the ground on the bar.

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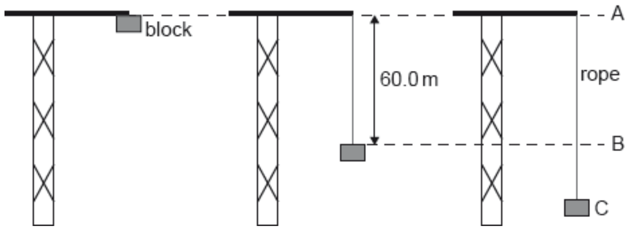
(3)
(Total 7 marks)

Topic 2 (New) *[90 marks]*

An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.



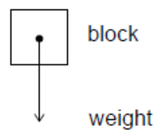
The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

1a. At position B the rope starts to extend. Calculate the speed of the block at position B. *[2 marks]*

At position C the speed of the block reaches zero. The time taken for the block to fall between B and C is 0.759 s. The mass of the block is 80.0 kg.

1b. Determine the magnitude of the average resultant force acting on the block between B and C. *[2 marks]*

1c. Sketch on the diagram the average resultant force acting on the block between B and C. The arrow on the diagram represents the weight of the block. *[2 marks]*



1d. Calculate the magnitude of the average force exerted by the rope on the block between B and C. *[2 marks]*

For the rope and block, describe the energy changes that take place

1e. between A and B. *[1 mark]*

1f. between B and C. *[1 mark]*

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1g. The length reached by the rope at C is 77.4 m. Suggest how energy considerations could be used to determine the elastic constant of the rope. *[2 marks]*

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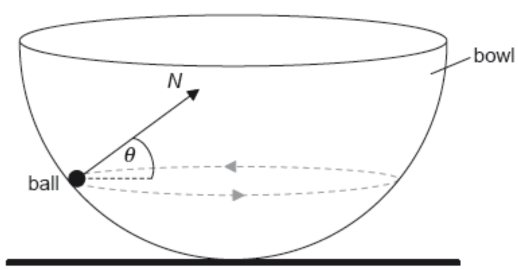
A small ball of mass m is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.



The normal reaction force N makes an angle θ to the horizontal.

2a. State the direction of the resultant force on the ball. *[1 mark]*

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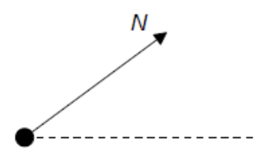
2b. On the diagram, construct an arrow of the correct length to represent the weight of the ball. *[2 marks]*



2c. Show that the magnitude of the net force *F* on the ball is given by the following equation. *[3 marks]*

$$F = \frac{mg}{\tan\theta}$$

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2d. The radius of the bowl is 8.0 m and $\theta = 22°$. Determine the speed of the ball. *[4 marks]*

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2e. Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. *[2 marks]*

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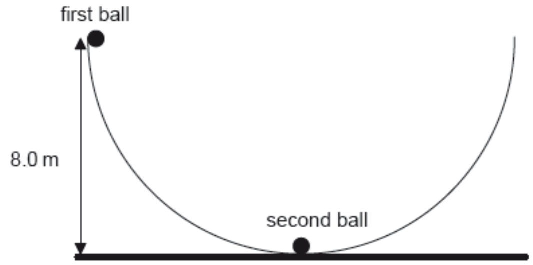
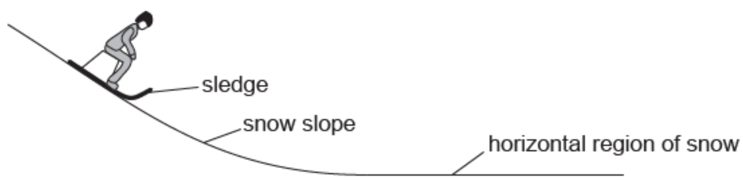
2f. A second identical ball is placed at the bottom of the bowl and the first ball is displaced so that its height from the horizontal is equal to 8.0 m. *[3 marks]*



The first ball is released and eventually strikes the second ball. The two balls remain in contact. Determine, in m, the maximum height reached by the two balls.

A girl on a sledge is moving down a snow slope at a uniform speed.



3a. Draw the free-body diagram for the sledge at the position shown on the snow slope. *[2 marks]*

3b. After leaving the snow slope, the girl on the sledge moves over a horizontal region *[3 marks]*

of snow. Explain, with reference to the physical origin of the forces, why the vertical forces on the girl must be in equilibrium as she moves over the horizontal region.

3c. When the sledge is moving on the horizontal region of the snow, the girl jumps off the sledge. The girl has no horizontal velocity after the jump. The velocity of the sledge immediately after the girl jumps off is 4.2 m s^{-1}. The mass of the girl is 55 kg and the mass of the sledge is 5.5 kg. Calculate the speed of the sledge immediately before the girl jumps from it. *[2 marks]*

3d. The girl chooses to jump so that she lands on loosely-packed snow rather than frozen ice. Outline why she chooses to land on the snow. *[3 marks]*

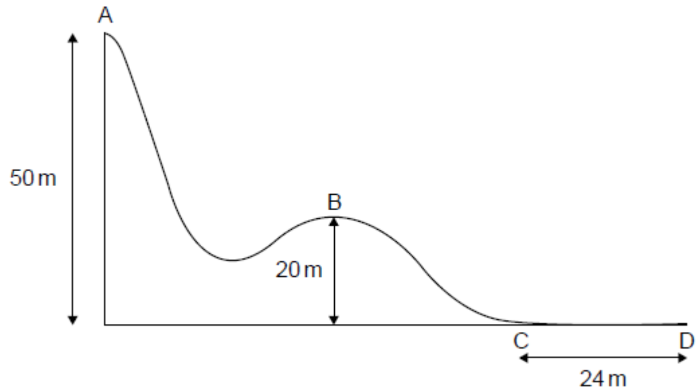
The sledge, without the girl on it, now travels up a snow slope that makes an angle of 6.5˚ to the horizontal. At the start of the slope, the speed of the sledge is 4.2 m s^{-1}. The coefficient of dynamic friction of the sledge on the snow is 0.11.

3e. Show that the acceleration of the sledge is about –2 m s^{-2}. *[3 marks]*

3f. Calculate the distance along the slope at which the sledge stops moving. Assume that the coefficient of dynamic friction is constant. *[2 marks]*

3g. The coefficient of static friction between the sledge and the snow is 0.14. Outline, with a calculation, the subsequent motion of the sledge. *[2 marks]*

The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.



A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

4a. From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is 12 m s^{-1}. *[2 marks]*

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4b. Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. *[2 marks]*

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4c. The dot on the following diagram represents the skier as she passes point B. Draw and label the vertical forces acting on the skier. *[2 marks]*

4d. The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. *[3 marks]*

4e. The skier reaches point C with a speed of 8.2 m s^{-1}. She stops after a distance of 24 m at point D. *[3 marks]*

Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected.

At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed 9.6 m s^{-1}.

4f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. *[2 marks]*

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4g. Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. *[2 marks]*

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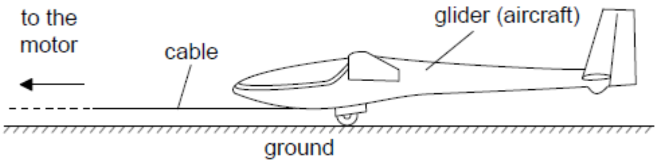
A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.



5a. The glider reaches its launch speed of 27.0 m s^{-1} after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. *[2 marks]*

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5b. The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates. *[3 marks]*

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5c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. *[3 marks]*

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5d. The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s^{-1}. Include an appropriate unit for your answer. *[2 marks]*

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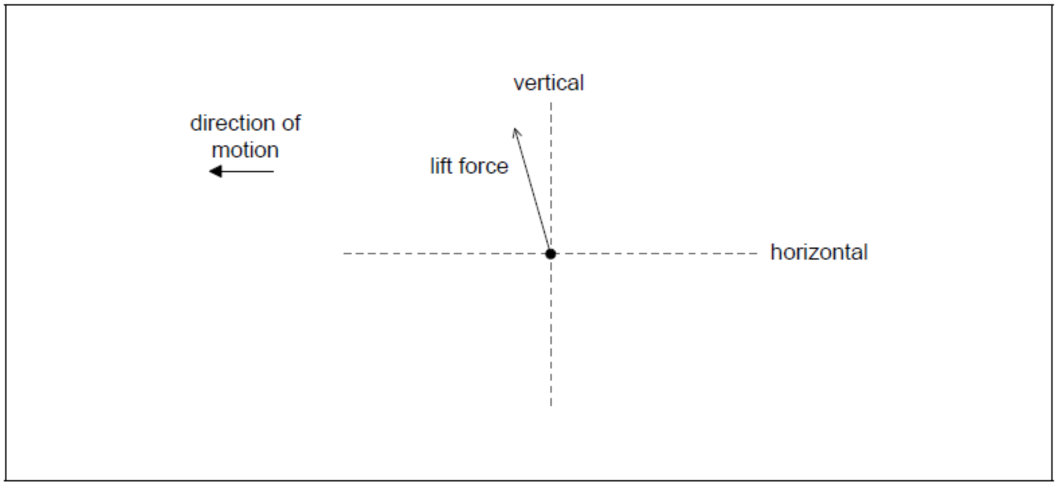
5e. After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider. *[2 marks]*

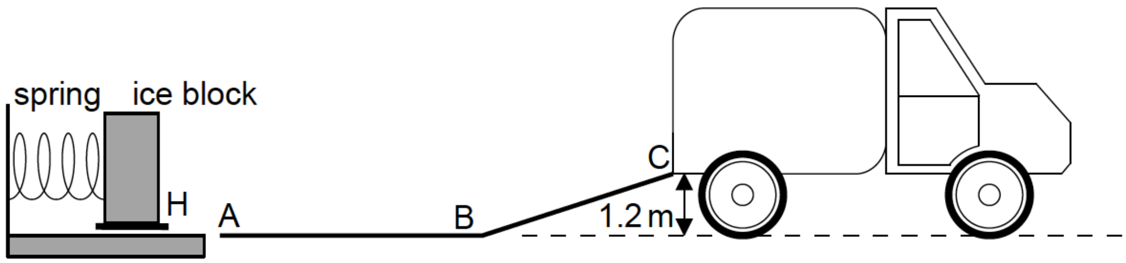


Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.

5f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. *[2 marks]*

5g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s^{-1}. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. *[3 marks]*

A company designs a spring system for loading ice blocks onto a truck. The ice block is placed in a holder H in front of the spring and an electric motor compresses the spring by pushing H to the left. When the spring is released the ice block is accelerated towards a ramp ABC. When the spring is fully decompressed, the ice block loses contact with the spring at A. The mass of the ice block is 55 kg.



Assume that the surface of the ramp is frictionless and that the masses of the spring and the holder are negligible compared to the mass of the ice block.

6a. (i) The block arrives at C with a speed of $0.90 ms^{-1}$. Show that the elastic energy stored in the spring is 670J. *[4 marks]*

(ii) Calculate the speed of the block at A.

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6b. Describe the motion of the block *[3 marks]*

(i) from A to B with reference to Newton's first law.

(ii) from B to C with reference to Newton's second law.

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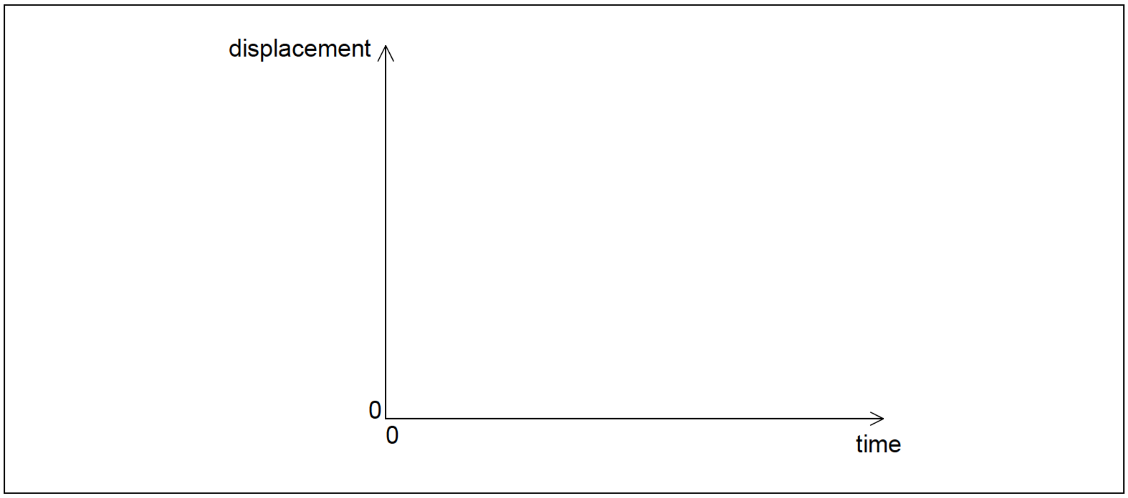
6c. On the axes, sketch a graph to show how the displacement of the block varies with time from A to C. (You do not have to put numbers on the axes.) *[2 marks]*



6d. The spring decompression takes 0.42s. Determine the average force that the spring exerts on the block. *[2 marks]*

. . . .

. . . .

. . . .

6e. The electric motor is connected to a source of potential difference 120V and draws a current of 6.8A. The motor takes 1.5s to compress the spring. *[2 marks]*

Estimate the efficiency of the motor.

. . . .

. . . .

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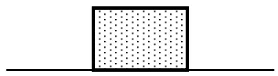
free-body diagram (FBD) worksheet:

Draw and label the forces acting on the object.

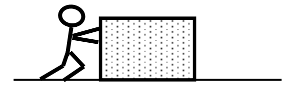
Newton's 2nd Law tells us that the vector sum of all of the forces acting on a body equals its mass x acceleration. We can look at the FBD to see how a body's motion will change AND we can look at how a body's motion is changing and make assumptions about the forces that must be acting on it.

Draw a FBD for a block at rest on a horizontal surface



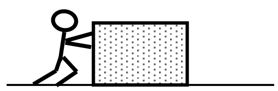
Label the magnitude of the forces for a 10-kg block

Draw a FBD for a block being pushed on a horizontal, frictionless surface



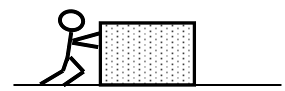
Label the magnitude of the forces and find the acceleration for a 10-kg block with a push of 50N.

Draw a FBD for a block being pushed on a rough, horizontal surface



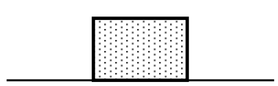
Label the magnitude of the forces and find the acceleration for a 10-kg block with a push of 50N & a 30N friction force.

Draw a FBD for a block being pushed on a horizontal surface at a constant velocity.



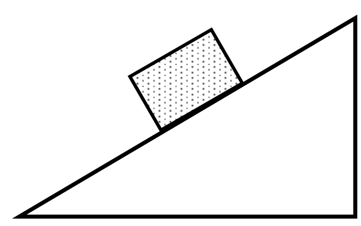
Find the acceleration & label the magnitude of the forces for a 10-kg block with a push of 50N & a constant velocity of 30m/s.

Draw a FBD for a block sliding to a stop.



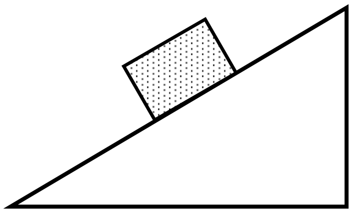
Label the magnitude of the forces for a 5 kg block that is initially traveling at 30 m/s and slows to a stop in 5 s.

Draw a FBD for a block on a frictionless incline.



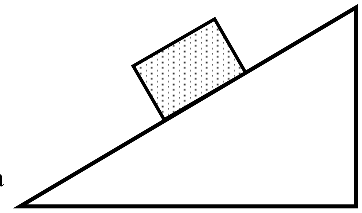
Find the acceleration of a 10-kg block on a 30° incline.

Draw a FBD for a block at rest on an incline.



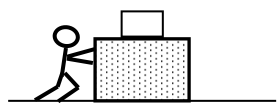
Find the friction force for a 10-kg block on a 30º incline.

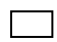
Draw a FBD for a block accelerating down a rough incline.

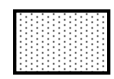


Find the friction force acting on a 10-kg block on a 30º incline that accelerates at 2 m/s^2

The floor is frictionless. The top block moves with the bottom block. Draw a FBD for the two blocks together & for the individual blocks.

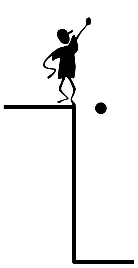


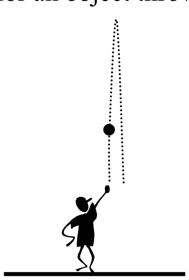


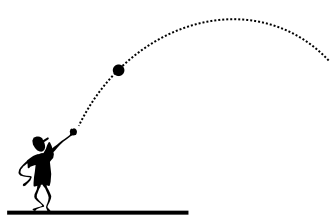


The big block is 10 kg. Find the magnitude of all of the forces present if the applied force = 36N and the system accelerates at 3 m/s^2

Ignoring air resistance, draw a FBD…
…for an object dropped from rest.
…for an object thrown straight upwards.
…for an object thrown at an angle to the horizontal.





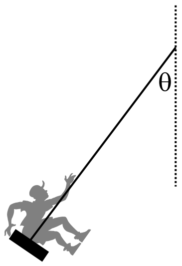


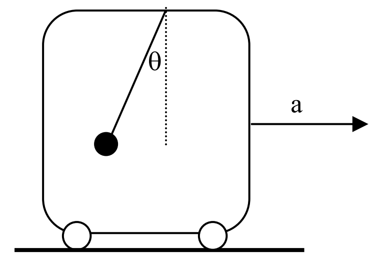
Ponder these…
What is the definition of freefall?

How can such different motions result from these FBDs?

IF we chose to think about air resistance, in which direction would F_{air} be in each of these?

Draw FBDs for these situations.
How do we find F_{net}?

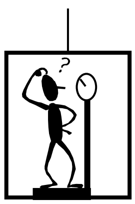




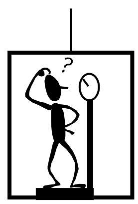
If the mass is 5 kg and a = 2 m/s^2, what angle does the string make with the vertical?

Draw a FBD for a person in an elevator when the elevator is…

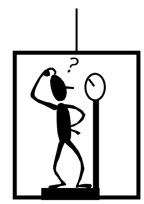
…moving at constant speed.



…accelerating upwards.



…accelerating downwards.



His mass is 80 kg. What does the scale read when the speed in the 1st diagram is 5 m/s and the acceleration in the other two is 2 m/s^2?
Which way is the elevator moving in each case?

Draw a FBD for the 500-kg jet. If the thrust is 10,000 N and the plane accelerates horizontally at 8m/s^2, what is the drag force?

Draw a FBD for the 100-kg rocket. If the thrust is 10,000 N, what is the acceleration of the rocket?