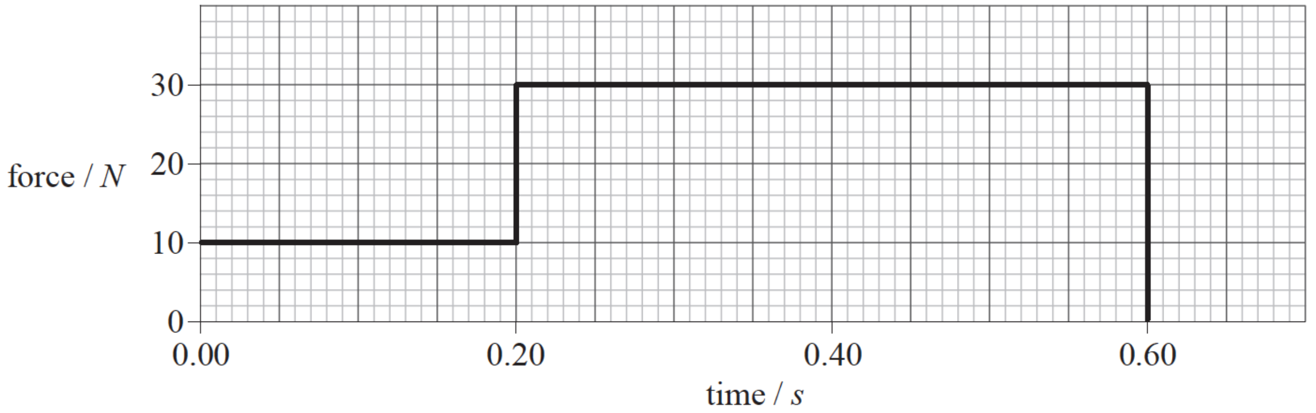
T2-2 *[195 marks]*

1. The graph shows how an external force applied to an object of mass 2.0 kg varies with time. The object is initially at rest. *[1 mark]*



What is the speed of the object after 0.60 s?

A. 7.0 ms^{-1}
B. 14 ms^{-1}
C. 18 ms^{-1}
D. 28 ms^{-1}

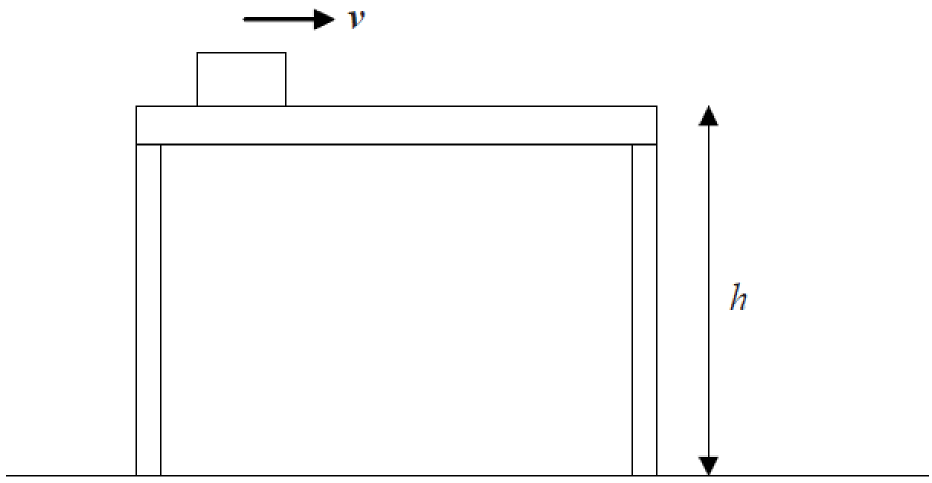
2. A stone is thrown vertically upwards from the surface of Earth. Which of the following quantities will **not** become zero while the stone is in the air? *[1 mark]*

A. Speed
B. Velocity
C. Momentum
D. Acceleration

3. An ice-hockey puck is slid along ice in a straight line. The puck travels at a steady speed of 20 ms^{-1} and experiences no frictional force. How far does the puck travel in 2.5 s? *[1 mark]*

A. 5 m
B. 8 m
C. 25 m
D. 50 m

4. A block of mass m is moving at constant velocity v along a frictionless surface that is height h above the ground. *[1 mark]*



Which expression gives the work necessary to maintain the constant velocity?

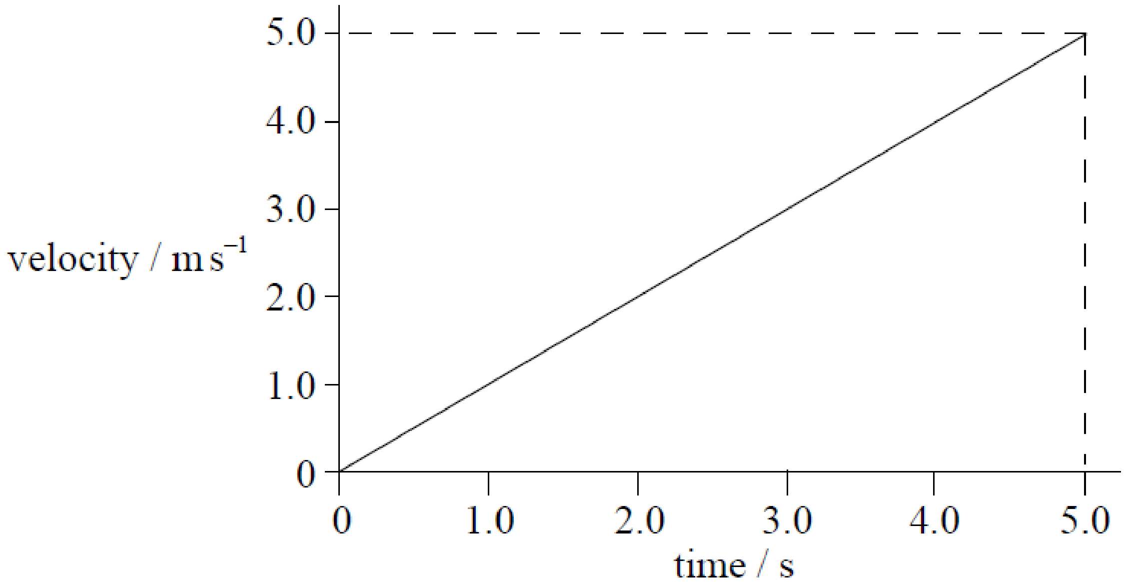
A. mgh

B. $\frac{1}{2}mv^2$

C. $mgh+\frac{1}{2}mv^2$

D. zero

5. The velocity–time graph for an accelerating object that is traveling in a straight line is shown below. *[1 mark]*

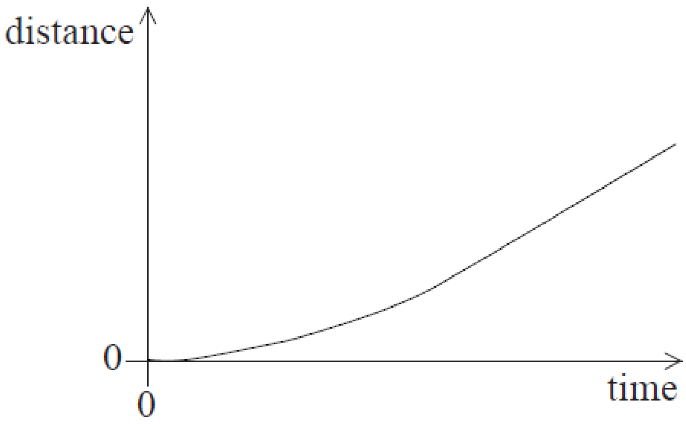


Which of the following is the change in displacement of the object in the first 5.0 seconds?

A. 25.0 m
B. 12.5 m
C. 5.0 m
D. 1.0 m

6. An object falls vertically from rest. Air resistance acts on the object and it reaches a terminal speed. Which of the following is the distance–time graph for its motion? *[1 mark]*

A.



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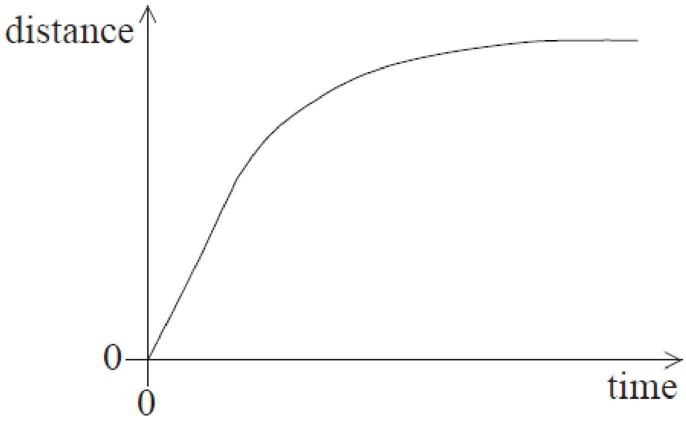

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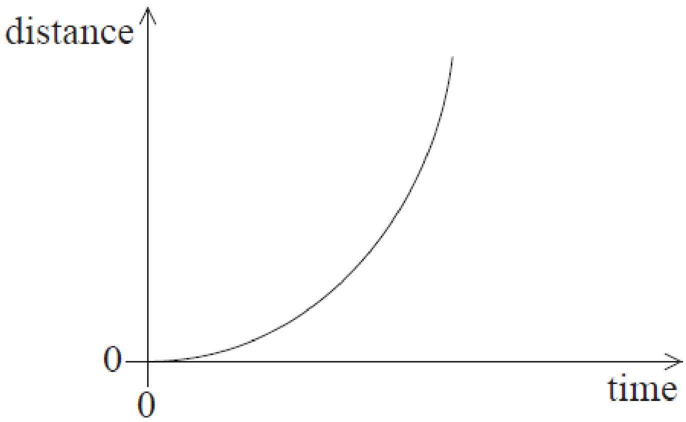

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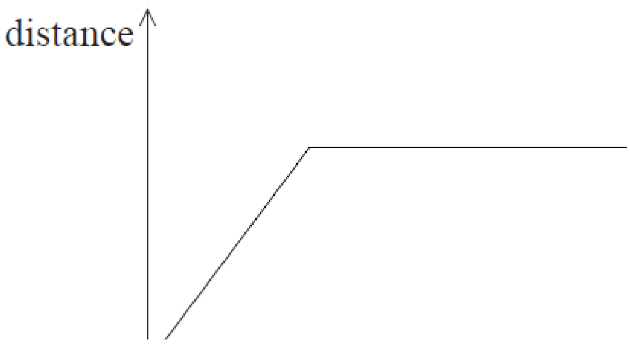
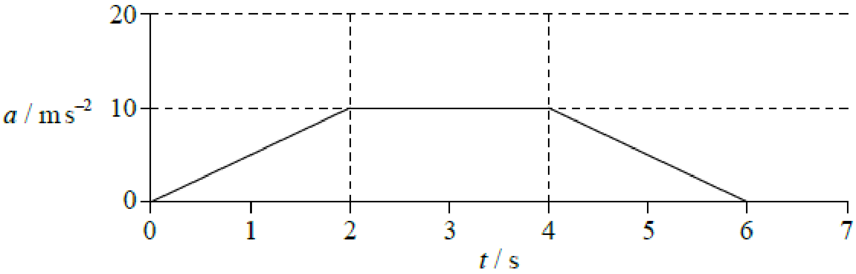


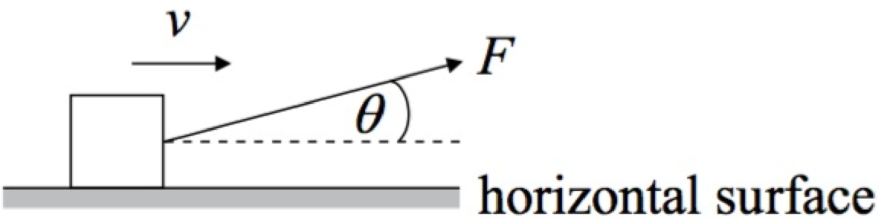
7. The graph shows the acceleration *a* of an object as time *t* varies. *[1 mark]*



What is the magnitude of the change in the velocity of the object between 0 and 3 seconds?

A. 5 ms^{-1}
B. 10 ms^{-1}
C. 20 ms^{-1}
D. 30 ms^{-1}

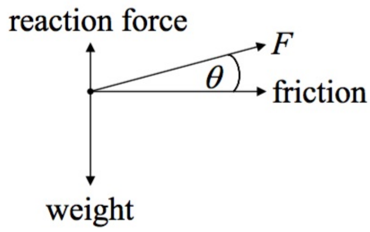
8. A force *F* acts on a block at an angle *θ* with respect to a horizontal surface. *[1 mark]*



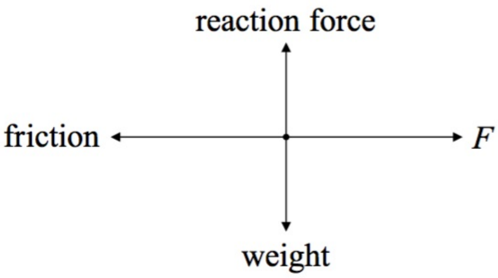
The block is moving with a constant velocity *v* along the surface. A resistive force acts on the block.

Which of the following correctly represents the forces acting on the block?

A.



B.



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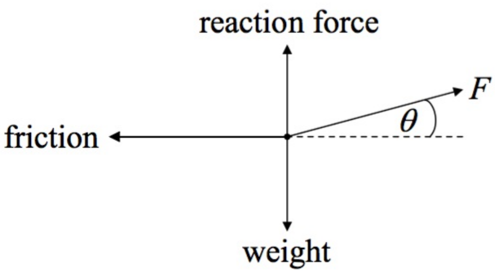

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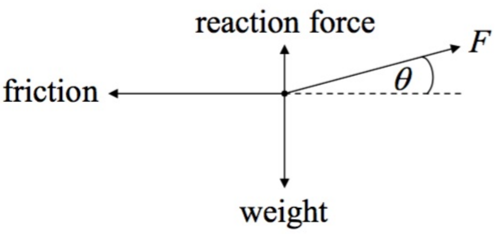


9. The momentum of a particle stays constant provided that *[1 mark]*

A. it moves in a circle with constant speed.
B. its acceleration is uniform.
C. the net internal force acting on it is zero.
D. the net external force acting on it is zero.

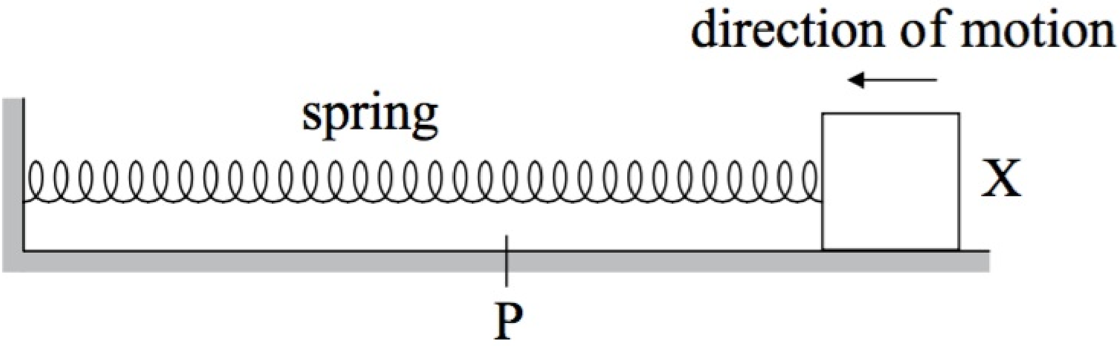
10. A student makes three statements about situations in which no work is done on an object. *[1 mark]*

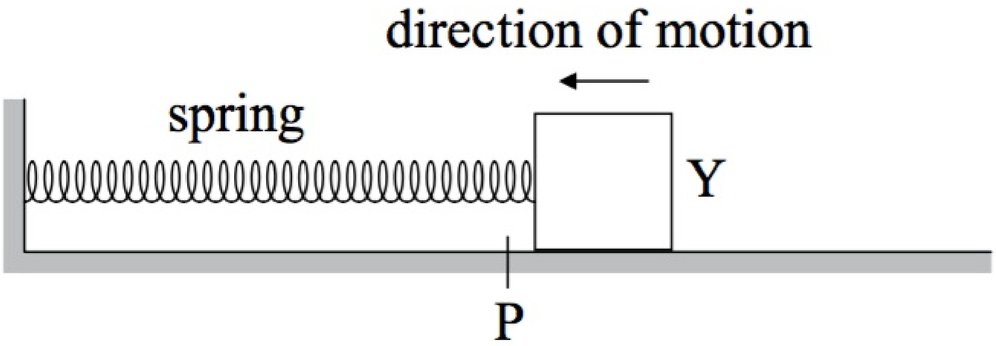
I. The object is moving with uniform circular motion.
II. A force is applied to the object in the direction of its velocity.
III. A force is applied to the object in a direction opposite to its motion.

Which of the above statements is/are correct?

A. I only
B. I and II only
C. I and III only
D. III only.

11. A block is attached to a stretched spring and then released. It moves from X to Y along a horizontal frictionless surface in the direction shown. The mass of the spring is negligible. *[1 mark]*





The equilibrium position of the system is P.

Which of the following is correct with respect to the changes in kinetic energy and potential energy of the block and of the spring as the block moves from X to Y?

	Block	Spring
A.	kinetic energy decreases	potential energy increases
B.	kinetic energy increases	potential energy decreases
C.	potential energy decreases	kinetic energy increases
D.	potential energy increases	kinetic energy decreases

12. Which of the following is an elastic collision? *[1 mark]*

A. Two railway trucks collide and they link together.

B. Two railway trucks collide and they do not link together.

C. Two gas molecules collide and each changes direction.

D. Two gas molecules collide and a bond is formed between them.

13. The momentum of an object changes by Δp in a time Δt. What is the impulse acting on the object during this change? *[1 mark]*

A. Δp

B. $\Delta p\ \Delta t$

C. $\frac{\Delta p}{\Delta t}$

D. zero

14. A gun fires a bullet of mass m at a horizontal velocity of v. Air resistance on the bullet is negligible. A change in which of the following will affect the time for the bullet to hit the ground? *[1 mark]*

A. m only

B. v only

C. m and v

D. neither m nor v

This question is about kinematics.

15a. State the difference between average speed and instantaneous speed. *[2 marks]*

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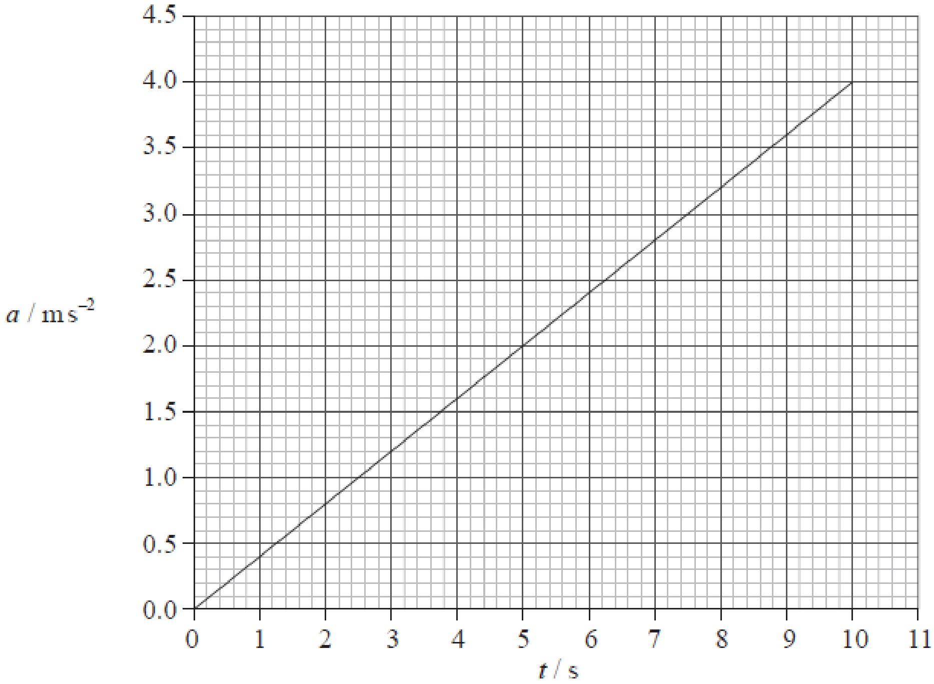
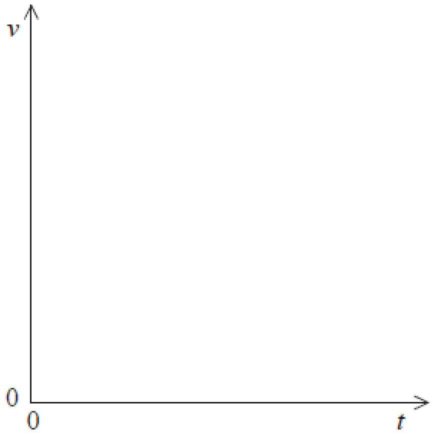
15b. The graph shows how the acceleration *a* of a particle varies with time *t*. *[3 marks]*



At time $t = 0$ the instantaneous speed of the particle is zero.

(i) Calculate the instantaneous speed of the particle at $t = 7.5$ s.

(ii) Using the axes below, sketch a graph to show how the instantaneous speed *v* of the particle varies with *t*.



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This question is in **two** parts. **Part 1** is about kinematics and mechanics. **Part 2** is about electric potential difference and electric circuits.

Part 1 Kinematics and mechanics

16a. Define *linear momentum*. *[1 mark]*

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16b. State, in terms of momentum, Newton's second law of motion. *[1 mark]*

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16c. Show, using your answer to (b), how the impulse of a force F is related to the change in momentum Δp that it produces. *[1 mark]*

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16d. Show, using your answer to (b), how the impulse of a force F is related to the change in momentum Δp that it produces. *[1 mark]*

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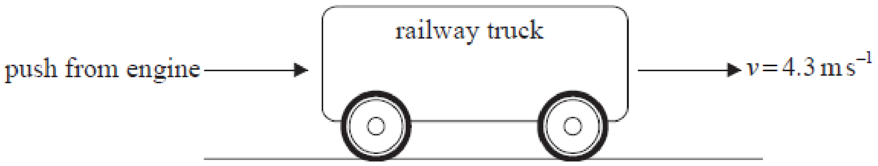
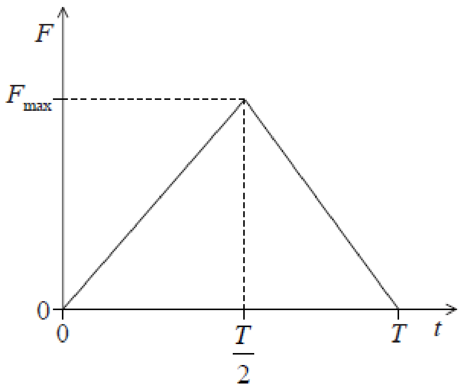
16e. A railway truck on a level, straight track is initially at rest. The truck is given a quick, horizontal push by an engine so that it now rolls along the track. *[12 marks]*



The engine is in contact with the truck for a time T = 0.54 s and the initial speed of the truck after the push is 4.3 ms^{-1}. The mass of the truck is 2.2×10^{3} kg.

Due to the push, a force of magnitude F is exerted by the engine on the truck. The sketch shows how F varies with contact time t.



(i) Determine the magnitude of the maximum force F_{max} exerted by the engine on the truck.

(ii) After contact with the engine (t = 0.54 s) the truck moves a distance 15 m along the track. After travelling this distance the speed of the truck is 2.8 ms^{-1}. Assuming a uniform acceleration, calculate the time it takes the truck to travel 15 m.

(iii) Calculate the average rate at which the kinetic energy of the truck is dissipated as it moves along the track.

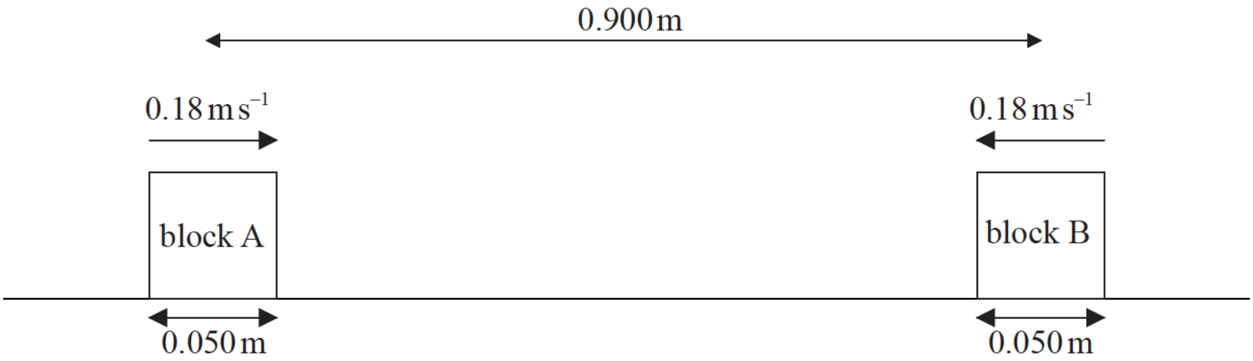
(iv) When the speed of the truck is 2.8ms^{-1} it collides with a stationary truck of mass 3.0×10^{3}kg. The two trucks move off together with a speed V. Show that the speed V=1.2ms^{-1}.

(v) Outline the energy transformations that take place during the collision of the two trucks.

This question is in **two** parts. **Part 1** is about a collision. **Part 2** is about electric current and resistance.

Part 1 A collision

Two identical blocks of mass 0.17kg and length 0.050m are travelling towards each other along a straight line through their centres as shown below. Assume that the surface is frictionless.



The initial distance between the centres of the blocks is 0.900m and both blocks are moving at a speed of $0.18 ms^{-1}$ relative to the surface.

17a. Determine the time taken for the blocks to come into contact with each other. *[3 marks]*

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17b. As a result of the collision, the blocks reverse their direction of motion and travel at the same speed as each other. During the collision, 20% of the kinetic energy of the blocks is given off as thermal energy to the surroundings. *[5 marks]*

(i) State and explain whether the collision is elastic or inelastic.

(ii) Show that the final speed of the blocks relative to the surface is 0.16 m s^{-1}.

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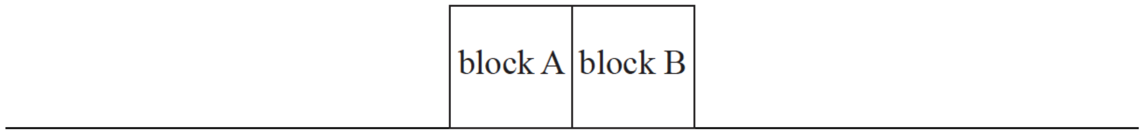
17c. (i) State Newton's third law of motion. *[7 marks]*

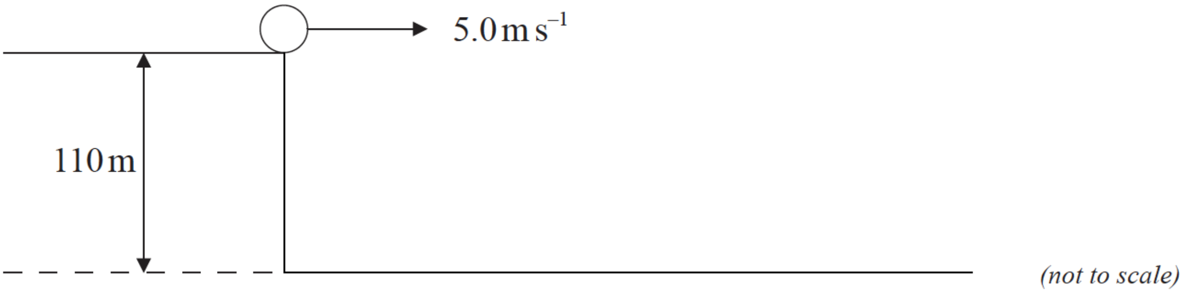
(ii) During the collision of the blocks, the magnitude of the force that block A exerts on block B is F_{AB} and the magnitude of the force that block B exerts on block A is F_{BA}. On the diagram below, draw labelled arrows to represent the magnitude and direction of the forces F_{AB} and F_{BA}.



(iii) The duration of the collision between the blocks is 0.070 s. Determine the average force one block exerted on the other.

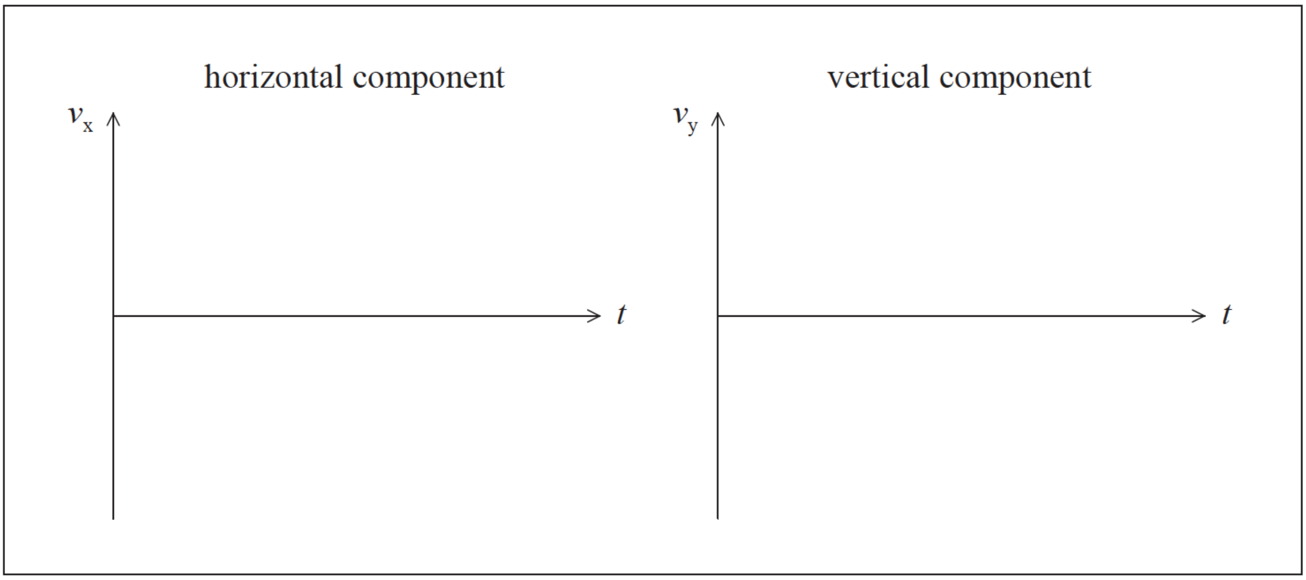
Part 2 Projectile motion

A ball is projected horizontally at 5.0ms^{-1} from a vertical cliff of height 110m. Assume that air resistance is negligible and use g=10ms^{-2}.



18a. (i) State the magnitude of the horizontal component of acceleration of the ball after it leaves the cliff. *[3 marks]*

(ii) On the axes below, sketch graphs to show how the horizontal and vertical components of the velocity of the ball, v_x and v_y , change with time t until just before the ball hits the ground. It is not necessary to calculate any values.



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18b. (i) Calculate the time taken for the ball to reach the ground. *[4 marks]*

(ii) Calculate the horizontal distance travelled by the ball until just before it reaches the ground.

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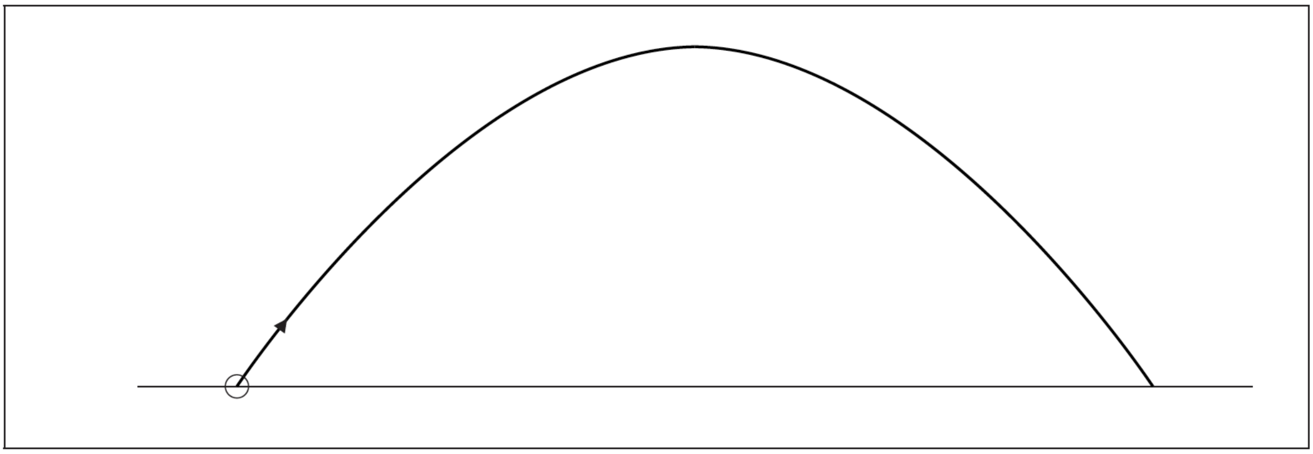
18c. Another projectile is launched at an angle to the ground. In the absence of air resistance it follows the parabolic path shown below. *[3 marks]*



On the diagram above, sketch the path that the projectile would follow if air resistance were not negligible.

This question is in **two** parts. **Part 1** is about momentum change. **Part 2** is about an oscillating water column (OWC) energy converter.

Part 1 Momentum change

19a. State the law of conservation of linear momentum. *[2 marks]*

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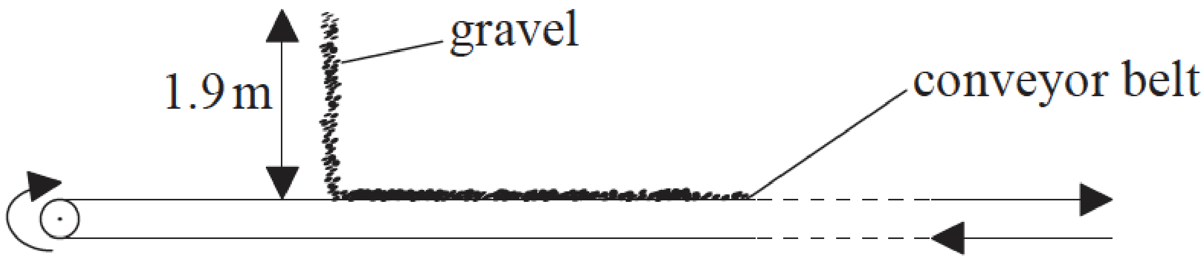
19b. Gravel falls vertically onto a moving horizontal conveyor belt. *[7 marks]*



(i) The gravel falls at a constant rate of 13 kg s^{-1} through a height of 1.9 m. Show that the vertical speed of the gravel as it lands on the conveyor belt is about 6 m s^{-1}.

(ii) The gravel lands on the conveyor belt without rebounding. Calculate the rate of change of the vertical momentum of the gravel.

(iii) Gravel first reaches the belt at t = 0.0 s and continues to fall. Determine the total vertical force that the gravel exerts on the conveyor belt at t = 5.0 s.

19c. The conveyor belt moves with a constant horizontal speed of 1.5 m s^{-1}. As the gravel lands on the belt, it has no horizontal speed. *[4 marks]*

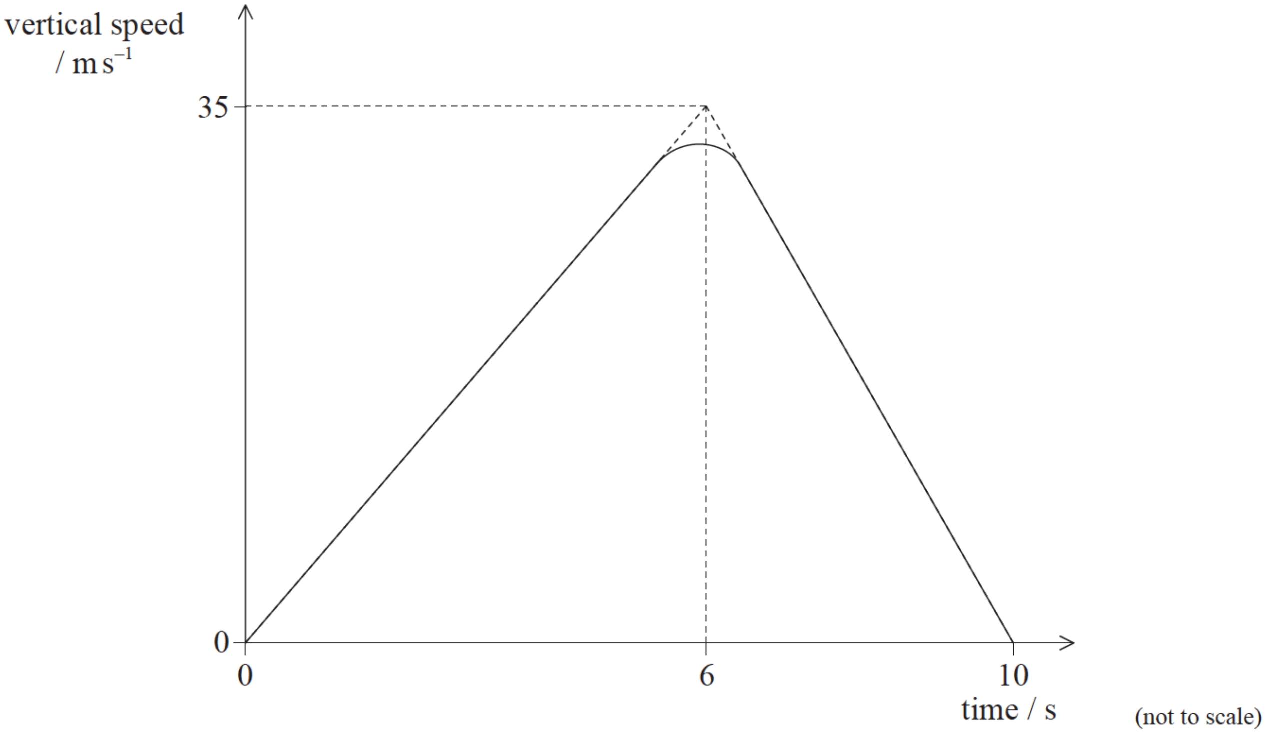
(i) Calculate the rate of change of the kinetic energy of the gravel due to its change in horizontal speed.

(ii) Determine the power required to move the conveyor belt at constant speed.

(iii) Outline why the answers to (c)(i) and (ii) are different.

Part 2 Rocket motion

A test model of a two-stage rocket is fired vertically upwards from the surface of Earth. The sketch graph shows how the vertical speed of the rocket varies with time from take-off until the first stage of the rocket reaches its maximum height.



20a. (i) Show that the maximum height reached by the first stage of the rocket is about 170 m. *[7 marks]*

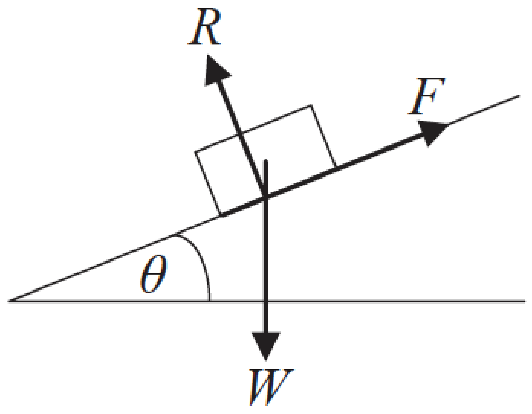
(ii) On reaching its maximum height, the first stage of the rocket falls away and the second stage fires so that the rocket acquires a constant horizontal velocity of 56 m s^{-1}. Calculate the velocity at the instant when the second stage of the rocket returns to the surface of the Earth. Ignore air resistance.

20b. A full-scale version of the rocket reaches a height of 260km when the first stage falls away. Using the data below, calculate the speed at which the second stage of the rocket will orbit the Earth at a height of 260km. *[3 marks]*

Mass of Earth = 6.0×10^{24} kg

Radius of Earth = 6.4×10^{6} m

21. A block of weight W slides down an inclined plane at a constant speed. *[1 mark]*



The normal reaction acting between the block and the plane is R and the frictional force between the block and the plane is F. The incline is at an angle θ to the horizontal. What is the magnitude of F?

A. $R \cos\theta$
B. $R \sin\theta$
C. $W \cos\theta$
D. $W \sin\theta$

22. An egg dropped on the floor is likely to break. However, when it is wrapped in a cloth it is less likely to break. This is because the cloth *[1 mark]*

A. increases the time for which the force of the ground acts on the egg.
B. reduces the momentum of the egg.
C. reduces the change of momentum of the egg.
D. reduces the impulse acting on the egg.

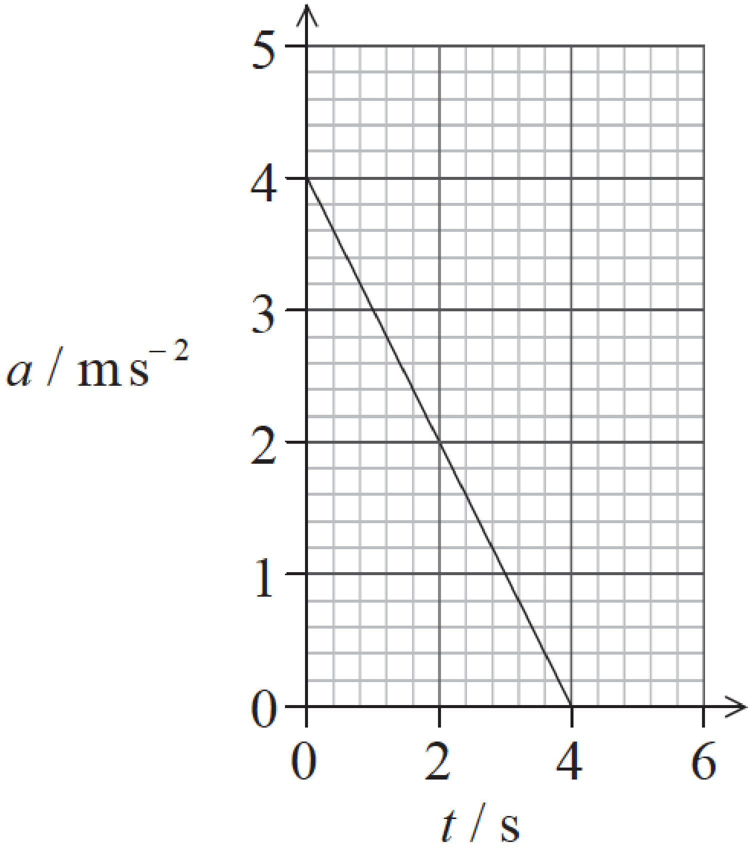
23. A ball is thrown horizontally from the top of a high cliff. Air resistance is negligible. *[1 mark]*

Which of the following correctly describes the changes, if any, to the ball’s vertical speed and horizontal speed?

	Vertical speed	Horizontal speed
A.	no change	increases
B.	increases	no change
C.	no change	decreases
D.	decreases	no change

24. *[1 mark]*

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

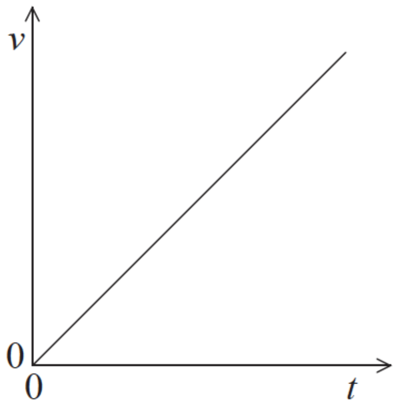


Which of the following is the change in velocity of the object in the time interval 0 to 4s?

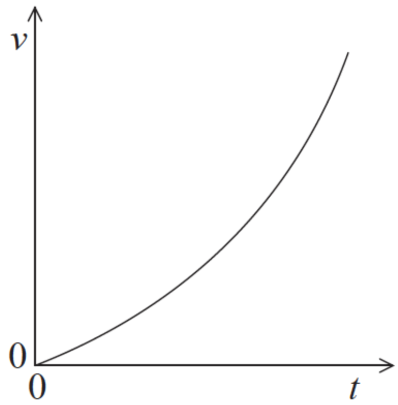
A. $-8ms^{-1}$
B. $-4ms^{-1}$
C. $+4ms^{-1}$
D. $+8ms^{-1}$

25. A car accelerates from rest. The acceleration increases with time. Which graph shows the variation with time *t* of the speed *v* of the car? *[1 mark]*

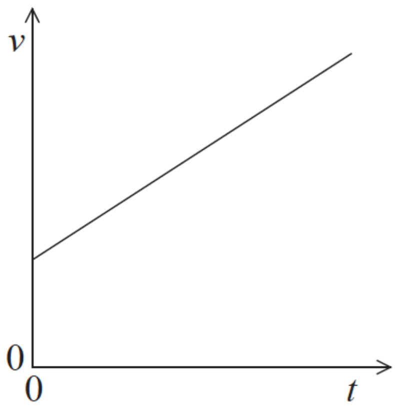
A.



B.



C.



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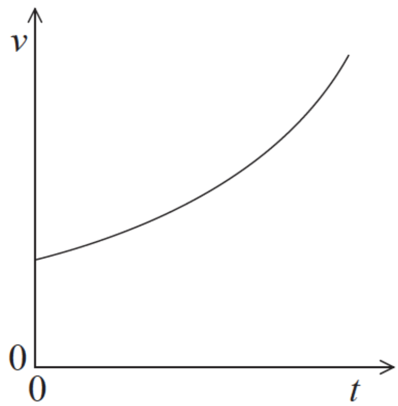


26. Which of the following is the condition for a body to be in translational equilibrium? *[1 mark]*

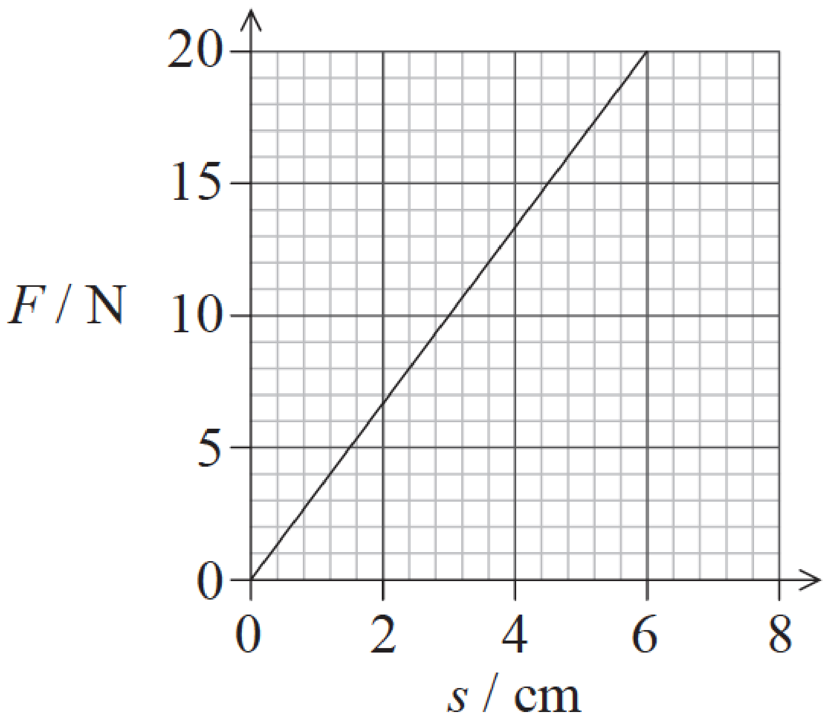
A. The resultant force on the body in any direction is zero.

B. The velocity of the body in any direction is zero.

C. No external force is acting on the body.

D. No work is done on the body.

27. The graph shows the variation with force F of the extension s of a spring. *[1 mark]*



The work done in changing the extension of the spring from 3.0 cm to 6.0 cm is

A. 15 N cm.
B. 30 N cm.
C. 45 N cm.
D. 60 N cm.

28. A body is moving in a straight line. A force F acts on the body in the direction of the body's motion. A resistive force f acts on the body. Both forces act along the same straight line as the motion of the body. The rate of change of momentum of the body is equal to *[1 mark]*

A. $F–f$.

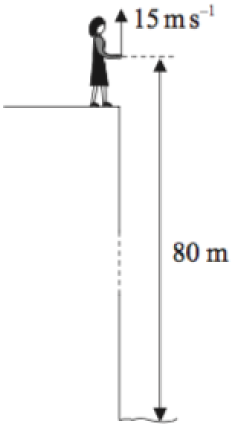
B. F.

C. $F+f$.

D. f.

This question is about kinematics.

Lucy stands on the edge of a vertical cliff and throws a stone vertically upwards.



The stone leaves her hand with a speed of $15 ms^{-1}$ at the instant her hand is 80m above the surface of the sea. Air resistance is negligible and the acceleration of free fall is $10 ms^{-2}$.

29a. Calculate the maximum height reached by the stone as measured from the point where it is thrown. *[2 marks]*

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29b. Determine the time for the stone to reach the surface of the sea after leaving Lucy’s hand. *[3 marks]*

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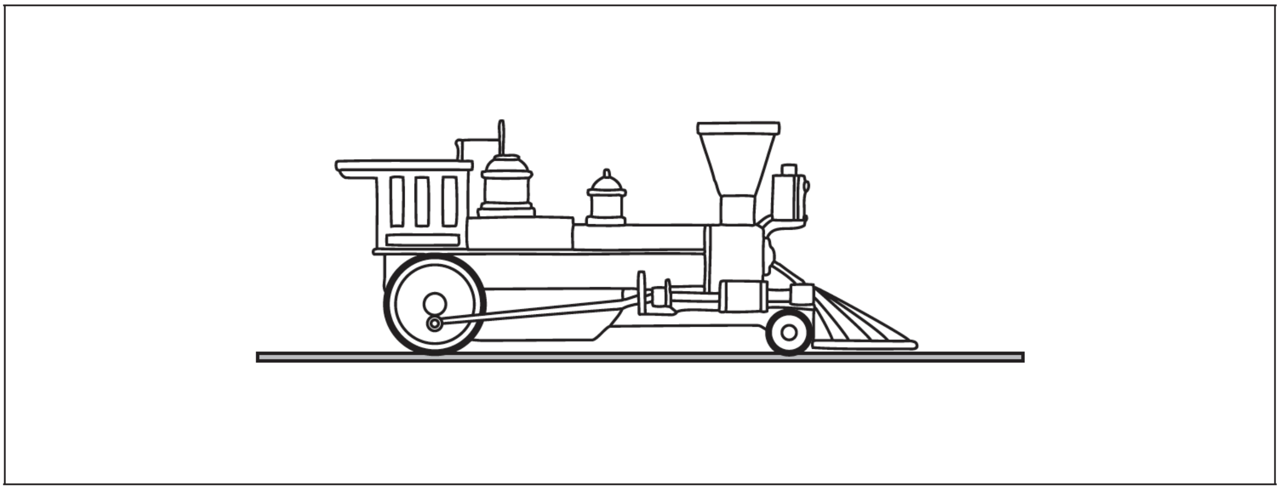
This question is in two parts. **Part 1** is about forces. **Part 2** is about internal energy.

Part 1 Forces

A railway engine is travelling along a horizontal track at a constant velocity.



30a. On the diagram above, draw labelled arrows to represent the vertical forces that act on the railway engine. *[3 marks]*

30b. Explain, with reference to Newton's laws of motion, why the velocity of the railway engine is constant. *[2 marks]*

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30c. The constant horizontal velocity of the railway engine is 16 ms^{-1}. A total horizontal resistive force of 76 kN acts on the railway engine. *[2 marks]*

Calculate the useful power output of the railway engine.

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30d. The power driving the railway engine is switched off. The railway engine stops, from its speed of 16 ms^{-1}, without braking in a distance of 1.1 km. A student hypothesizes that the horizontal resistive force is constant. *[2 marks]*

Based on this hypothesis, calculate the mass of the railway engine.

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30e. Another hypothesis is that the horizontal force in (c) consists of two components. One component is a constant frictional force of 19 kN. The other component is a resistive force F that varies with speed v where F is proportional to v^3. *[5 marks]*

(i) State the value of the magnitude of F when the railway engine is travelling at 16 ms^{-1}.

(ii) Determine the **total** horizontal resistive force when the railway engine is travelling at 8.0 ms^{-1}.

30f. On its journey, the railway engine now travels around a curved track at constant speed. Explain whether or not the railway engine is accelerating. *[3 marks]*

Part 2 Electric motor

An electric motor is used to raise a load.

31a. Whilst being raised, the load accelerates uniformly upwards. The weight of the cable is negligible compared to the weight of the load. *[6 marks]*

(i) Draw a labelled free-body force diagram of the forces acting on the accelerating load. The dot below represents the load.

(ii) The load has a mass of 350 kg and it takes 6.5 s to raise it from rest through a height of 8.0 m.

Determine the tension in the cable as the load is being raised.

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31b. The electric motor can be adjusted such that, after an initial acceleration, the load moves at constant speed. *[4 marks]*
The motor is connected to a 450 V supply and with the load moving at constant speed, it takes the motor 15 s to raise the load through 7.0 m.

(i) Calculate the power delivered to the load by the motor.

(ii) The current in the motor is 30 A. Estimate the efficiency of the motor.

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This question is about escape speed and gravitational effects.

32a. Explain what is meant by escape speed. *[2 marks]*

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32b. Titania is a moon that orbits the planet Uranus. The mass of Titania is 3.5×10^{21}kg. The radius of Titania is 800 km. *[5 marks]*

(i) Use the data to calculate the gravitational potential at the surface of Titania.

(ii) Use your answer to (b)(i) to determine the escape speed for Titania.

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32c. An astronaut visiting Titania throws an object away from him with an initial horizontal velocity of 1.8 m s^{-1}. The object is 1.5 m above the moon's surface when it is thrown. The gravitational field strength at the surface of Titania is 0.37 N kg^{-1}. *[3 marks]*

Calculate the distance from the astronaut at which the object first strikes the surface.

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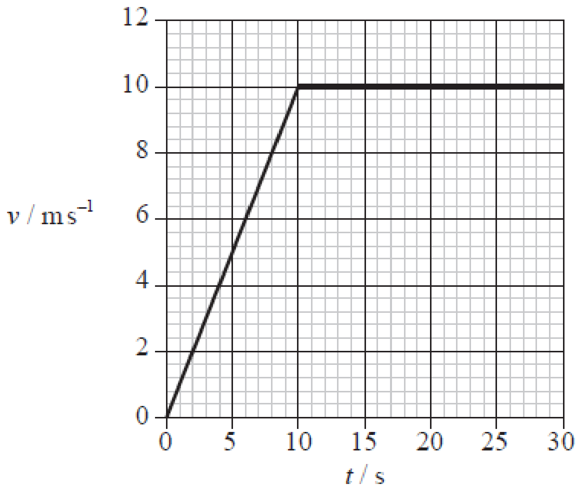
33. A skydiver of mass 80 kg falls vertically with a constant speed of 50 m s^{-1}. The upward force acting on the skydiver is approximately *[1 mark]*

A. 0 N.
B. 80 N.
C. 800 N.
D. 4000 N.

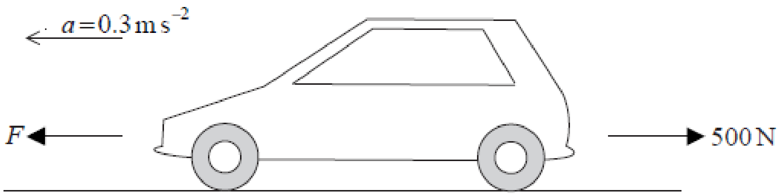
34. Joseph runs along a long straight track. The variation of his speed v with time t is shown below. *[1 mark]*



After 25 seconds Joseph has run 200 m. Which of the following is correct at 25 seconds?

	Instantaneous speed / $m\,s^{-1}$	Average speed / $m\,s^{-1}$
A.	$8\,m\,s^{-1}$	$8\,m\,s^{-1}$
B.	$8\,m\,s^{-1}$	$10\,m\,s^{-1}$
C.	$10\,m\,s^{-1}$	$8\,m\,s^{-1}$
D.	$10\,m\,s^{-1}$	$10\,m\,s^{-1}$

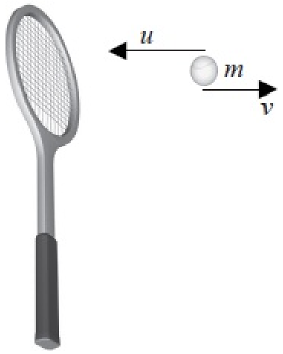
35. A car of mass 1000 kg accelerates on a straight, flat, horizontal road with an acceleration a = 0.3 m s^{-2}. The driving force F on the car is opposed by a resistive force of 500 N. *[1 mark]*



The net (resultant) force on the car is

A. 200 N.
B. 300 N.
C. 500 N.
D. 800 N.

36. A tennis ball of mass *m* moving horizontally with speed *u* strikes a vertical tennis racket. The ball bounces back with a horizontal speed *v*. *[1 mark]*



The magnitude of the change in momentum of the ball is

A. $m\ (u + v)$.
B. $m\ (u - v)$.
C. $m\ (v - u)$.
D. zero.

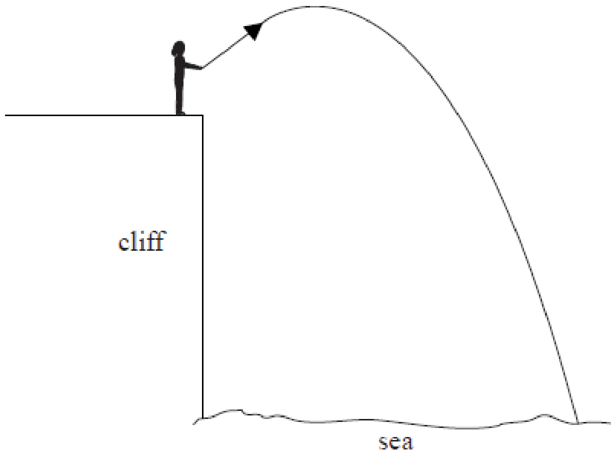
37. A brother and sister take the same time to run up a set of steps. The sister has a greater mass than her brother. Which of the following is correct? *[1 mark]*

	Has done the most work	Has developed the greatest power
A.	brother	brother
B.	brother	sister
C.	sister	brother
D.	sister	sister

38. A nuclear power station produces 10 GW of electrical power. The power generated by the nuclear reactions in the core of the reactor is 25 GW. The efficiency of the power station is *[1 mark]*

A. 15 %.
B. 35 %.
C. 40 %.
D. 60 %.

39. A stone is thrown from a cliff and it lands in the sea as shown below. Air resistance is negligible. *[1 mark]*

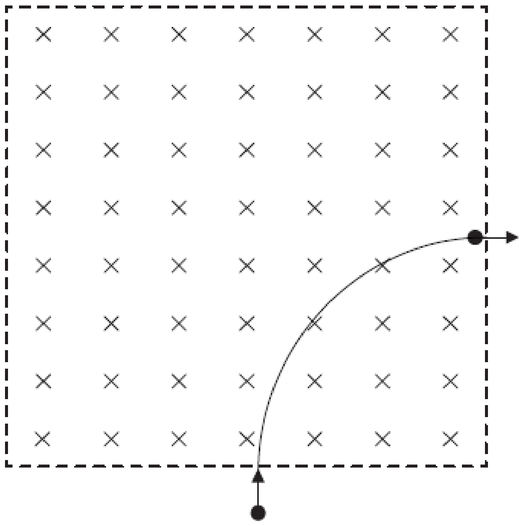


Which of the following statements is correct whilst the stone is in motion?

A. The vertical component of the stone's displacement is constant.
B. The horizontal component of the stone's displacement is constant.
C. The vertical component of the stone's velocity is constant.
D. The horizontal component of the stone's velocity is constant.

This question is about motion in a magnetic field.

An electron, that has been accelerated from rest by a potential difference of 250 V, enters a region of magnetic field of strength 0.12 T that is directed into the plane of the page.



40a. The electron's path while in the region of magnetic field is a quarter circle. Show that the *[4 marks]*

(i) speed of the electron after acceleration is $9.4\times10^{6}\mathrm{ms}^{-1}$.

(ii) radius of the path is $4.5\times10^{-4}\mathrm{m}$.

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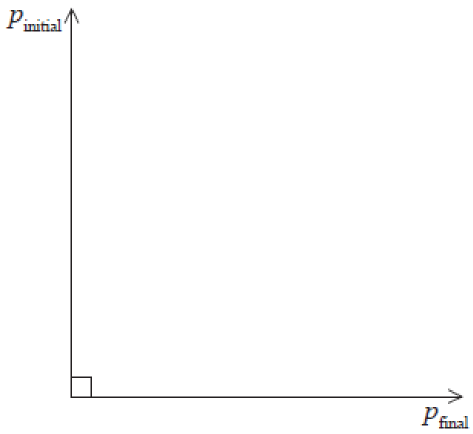
40b. The diagram below shows the momentum of the electron as it enters and leaves the region of magnetic field. *[3 marks]*
The magnitude of the initial momentum and of the final momentum is 8.6×10^{-24}Ns.



(i) On the diagram above, draw an arrow to indicate the vector representing the change in the momentum of the electron.

(ii) Show that the magnitude of the change in the momentum of the electron is 1.2×10^{-23}Ns.

(iii) The time the electron spends in the region of magnetic field is 7.5×10^{-11}s. Estimate the magnitude of the average force on the electron.

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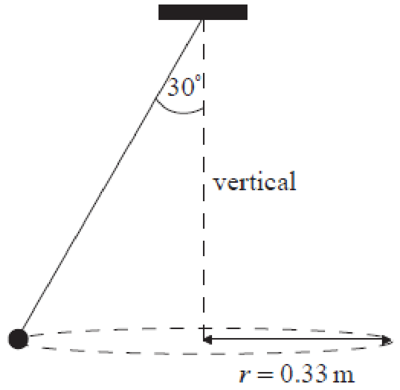
This question is about circular motion.

A ball of mass 0.25 kg is attached to a string and is made to rotate with constant speed *v* along a horizontal circle of radius *r* = 0.33m. The string is attached to the ceiling and makes an angle of 30° with the vertical.



41a. (i) On the diagram above, draw and label arrows to represent the forces on the ball in the position shown. *[4 marks]*

(ii) State and explain whether the ball is in equilibrium.

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41b. Determine the speed of rotation of the ball. *[3 marks]*

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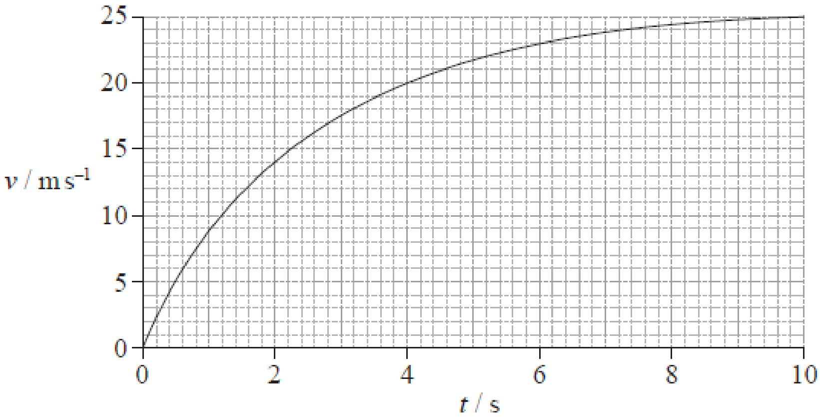
This question is in **two** parts. **Part 1** is about mechanics and thermal physics. **Part 2** is about nuclear physics.

Part 1 Mechanics and thermal physics

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. Assume that the acceleration of free fall is $g = 9.81 \text{ms}^{-2}$.

42a. State, without any calculations, how the graph could be used to determine the distance fallen. *[1 mark]*

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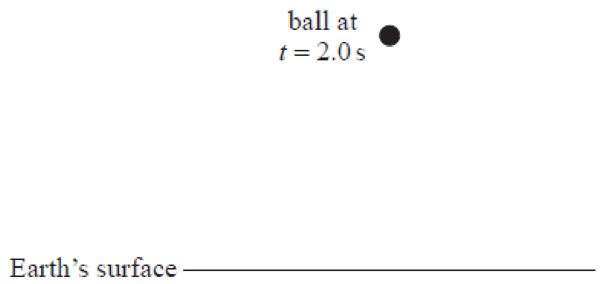
42b. (i) In the space below, draw and label arrows to represent the forces on the ball at 2.0 s. *[7 marks]*



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

42c. After 10 s the ball has fallen 190 m. *[6 marks]*

(i) Show that the sum of the potential and kinetic energies of the ball has decreased by 780 J.

(ii) The specific heat capacity of the ball is 480 J kg^{-1} K^{-1}. Estimate the increase in the temperature of the ball.

(iii) State an assumption made in the estimate in (c)(ii).

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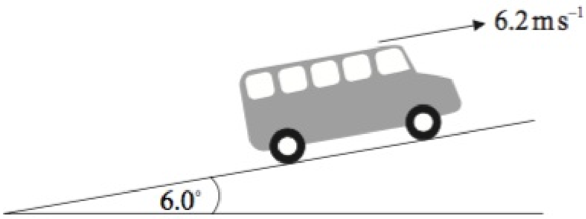
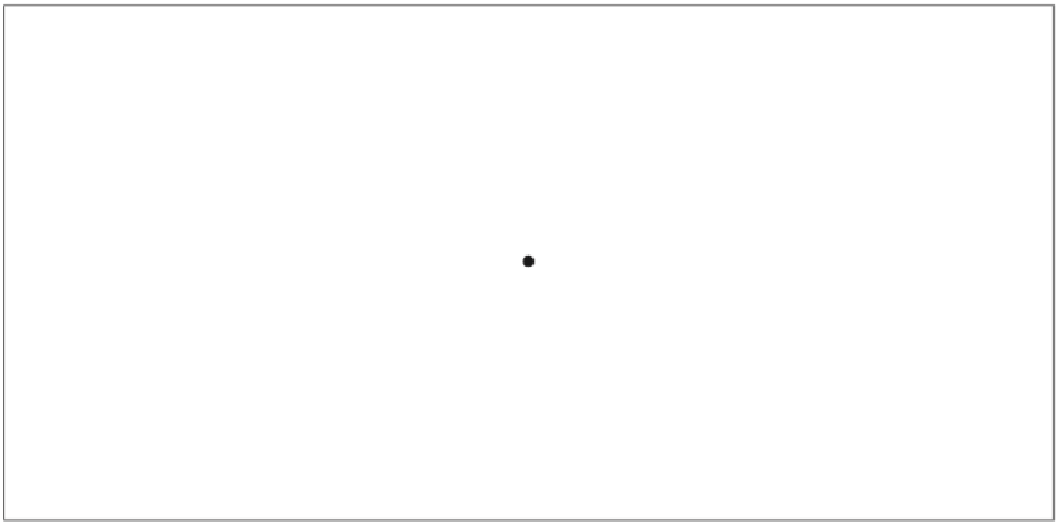
This question is in **two** parts. **Part 1** is about power and efficiency. **Part 2** is about electrical resistance.

Part 1 Power and efficiency

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.



43a. (i) The bus is represented by the black dot shown below. Draw a labelled sketch to represent the forces acting on the bus. *[5 marks]*



(ii) State the value of the rate of change of momentum of the bus.

43b. The mass of the bus is 8.5×10^3 kg. Determine the rate of increase of gravitational potential energy of the bus. *[3 marks]*

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43c. Using your answer to (c) and the data in (b), estimate the magnitude of the resistive forces acting on the bus. *[3 marks]*

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43d. The engine of the bus suddenly stops working. *[4 marks]*

(i) Determine the magnitude of the net force opposing the motion of the bus at the instant at which the engine stops.

(ii) Discuss, with reference to the air resistance, the change in the net force as the bus slows down.

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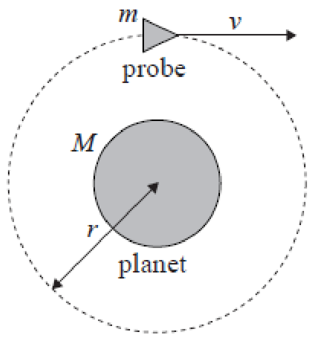
This question is about a probe in orbit.

A probe of mass *m* is in a circular orbit of radius *r* around a spherical planet of mass *M*.



(diagram not to scale)

44a. State why the work done by the gravitational force during one full revolution of the probe is zero. *[1 mark]*

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44b. Deduce for the probe in orbit that its *[4 marks]*

(i) speed is $v = \sqrt{\frac{GM}{r}}$.

(ii) total energy is $E = -\frac{GMm}{2r}$.

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44c. It is now required to place the probe in another circular orbit further away from the planet. To do this, the probe's engines will be fired for a very short time. *[2 marks]*

State and explain whether the work done on the probe by the engines is positive, negative **or** zero.

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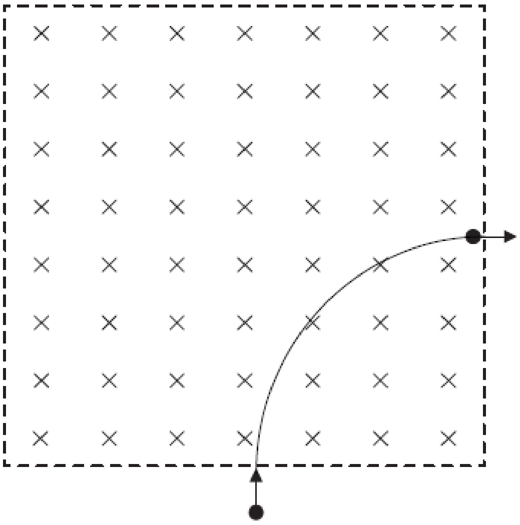
This question is about motion in a magnetic field.

An electron, that has been accelerated from rest by a potential difference of 250 V, enters a region of magnetic field of strength 0.12 T that is directed into the plane of the page.



45a. The electron's path while in the region of magnetic field is a quarter circle. Show that the time the electron spends in the region of magnetic field is 7.5×10^{-11} s. *[1 mark]*

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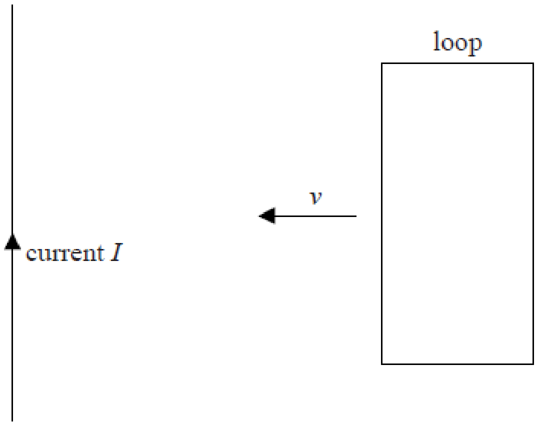
45b. A square loop of conducting wire is placed near a straight wire carrying a constant current *I*. The wire is in the same plane as the loop. *[4 marks]*



The loop is made to move with constant speed *v* towards the wire.

(i) Explain, by reference to Faraday’s and Lenz’s laws of electromagnetic induction, why work must be done on the loop.

(ii) Suggest what becomes of the work done on the loop.

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