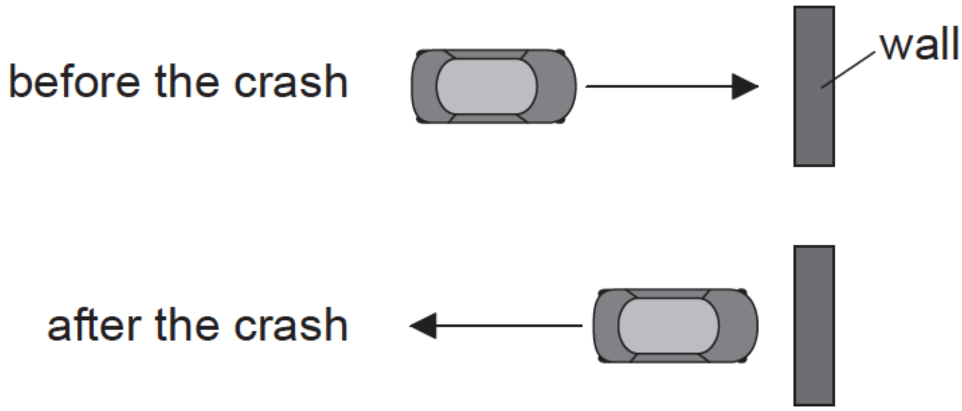
Review Chapter 1 and 2 *[184 marks]*

This question is in two parts. **Part 1** is about momentum. **Part 2** is about electric point charges.

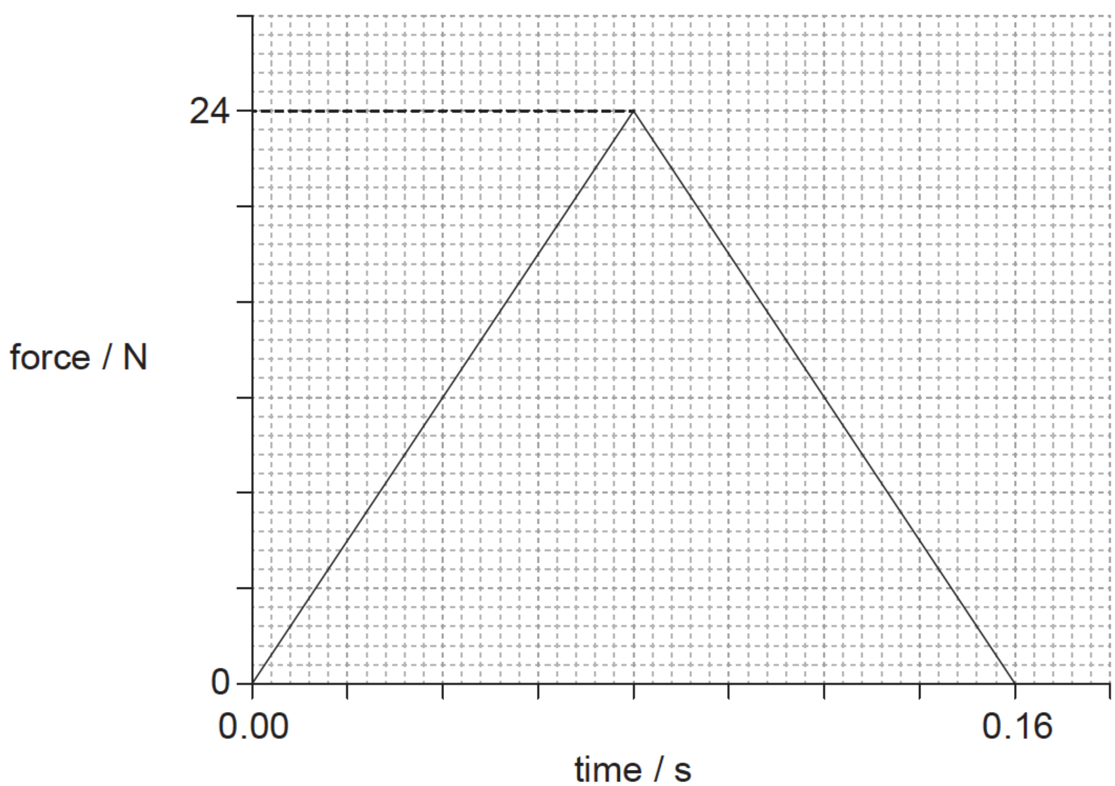
Part 1 Momentum

1a. State the law of conservation of linear momentum. *[2 marks]*

1b. A toy car crashes into a wall and rebounds at right angles to the wall, as shown in the plan view. *[9 marks]*



The graph shows the variation with time of the force acting on the car due to the wall during the collision.

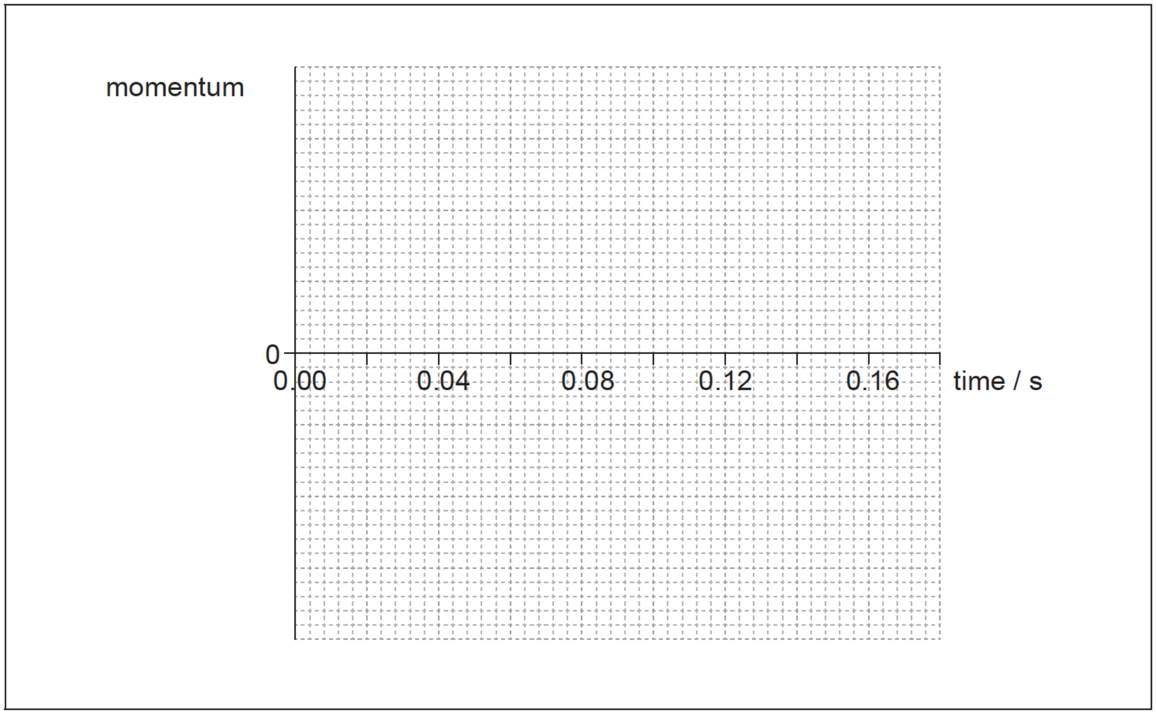


The kinetic energy of the car is unchanged after the collision. The mass of the car is 0.80 kg.

(i) Determine the initial momentum of the car.

(ii) Estimate the average acceleration of the car before it rebounds.

(iii) On the axes, draw a graph to show how the momentum of the car varies during the impact. You are not required to give values on the y-axis.

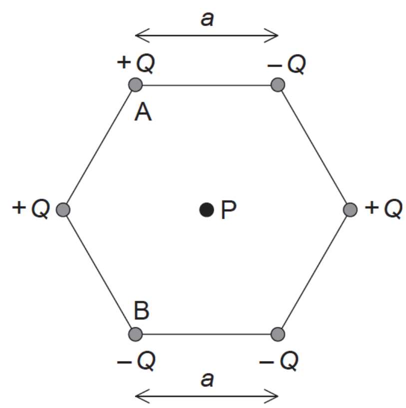


1c. Two identical toy cars, A and B are dropped from the same height onto a solid floor without rebounding. Car A is unprotected whilst car B is in a box with protective packaging around the toy. Explain why car B is less likely to be damaged when dropped. *[4 marks]*

Part 2 Electric point charges

1d. Define *electric field strength* at a point in an electric field. *[2 marks]*

1e. Six point charges of equal magnitude *Q* are held at the corners of a hexagon with the signs of the charges as shown. Each side of the hexagon has a length *a*. *[8 marks]*



P is at the centre of the hexagon.

(i) Show, using Coulomb's law, that the magnitude of the electric field strength at point P due to **one** of the point charges is

$$\frac{kQ}{a^2}$$

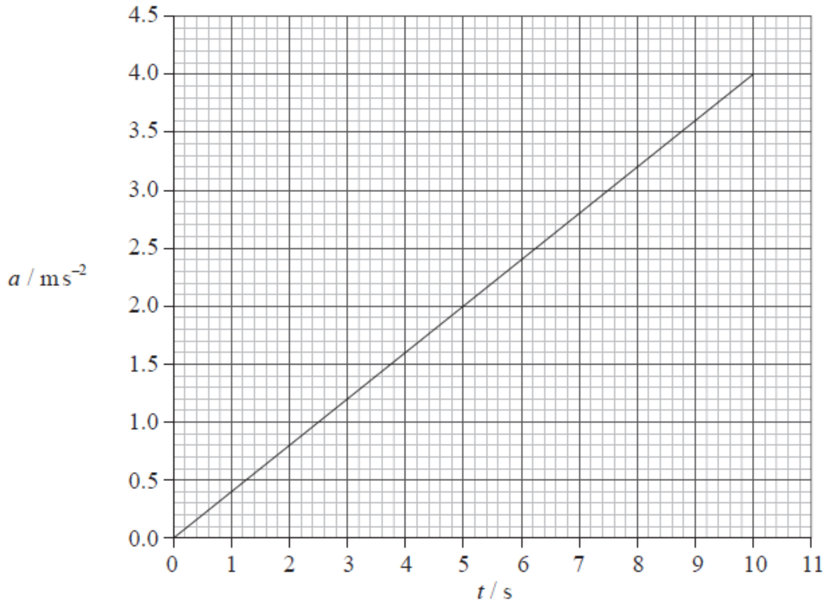
(ii) On the diagram, draw arrows to represent the direction of the field at P due to point charge A (label this direction A) and point charge B (label this direction B).

(iii) The magnitude of *Q* is 3.2 µC and length *a* is 0.15 m. Determine the magnitude and the direction of the electric field strength at point P due to all six charges.

This question is about kinematics.

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

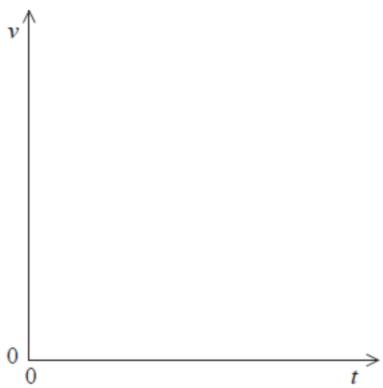
2b. The graph shows how the acceleration *a* of a particle varies with time *t*. *[3 marks]*



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

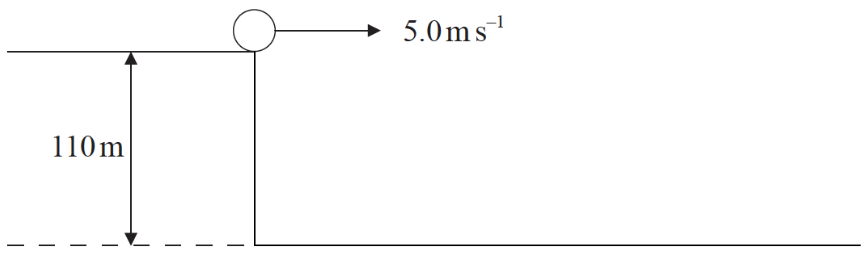
(i) Calculate the instantaneous speed of the particle at *t* = 7.5 s.

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



Part 2 Projectile motion

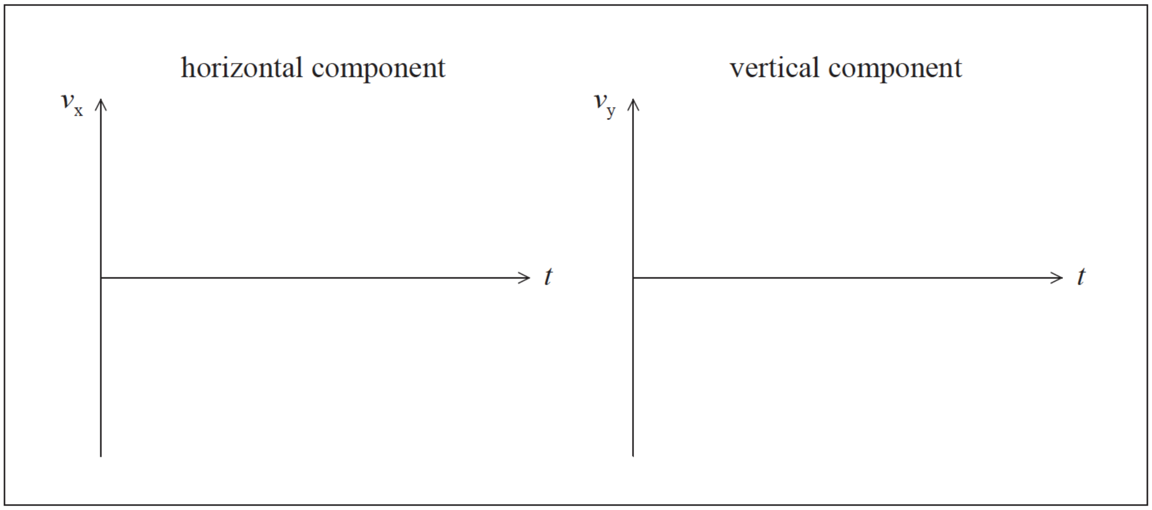
A ball is projected horizontally at 5.0ms^{-1} from a vertical cliff of height 110m. Assume that air resistance is negligible and use g=10ms^{-2}.



(not to scale)

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

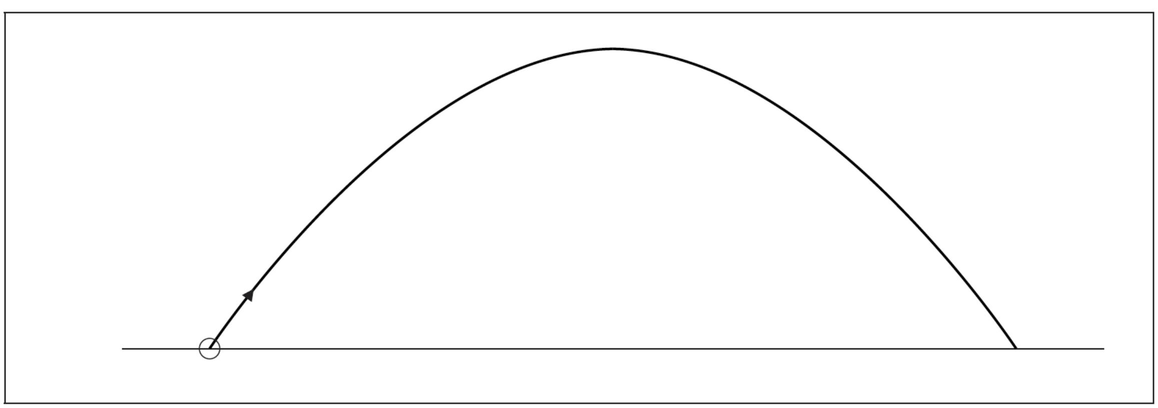
(ii) On the axes below, sketch graphs to show how the horizontal and vertical components of the velocity of the ball, v_x and v_y , change with time *t* until just before the ball hits the ground. It is not necessary to calculate any values.



3b. (i) Calculate the time taken for the ball to reach the ground. *[4 marks]*

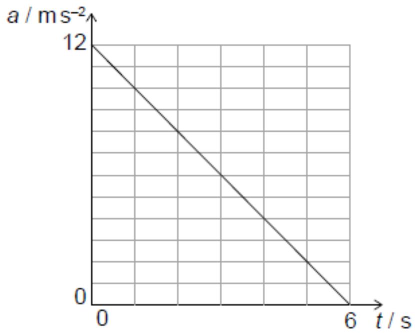
(ii) Calculate the horizontal distance travelled by the ball until just before it reaches the ground.

3c. 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.

4. The graph shows the variation of the acceleration a of an object with time *t*. *[1 mark]*



What is the change in speed of the object shown by the graph?

A. 0.5 m s^{-1}

B. 2.0 m s^{-1}

C. 36 m s^{-1}

D. 72 m s^{-1}

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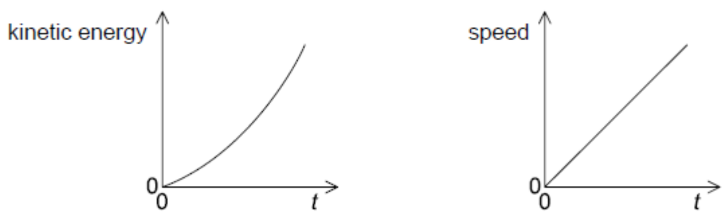
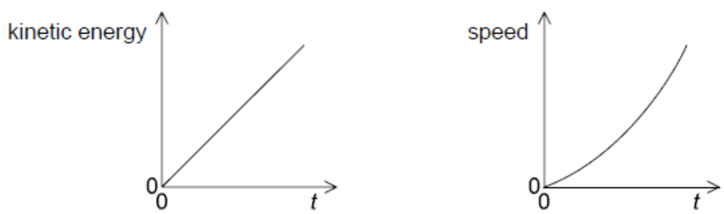
5. An object, initially at rest, is accelerated by a constant force. Which graphs show the variation with time *t* of the kinetic energy and the variation with time *t* of the speed of the object? *[1 mark]*

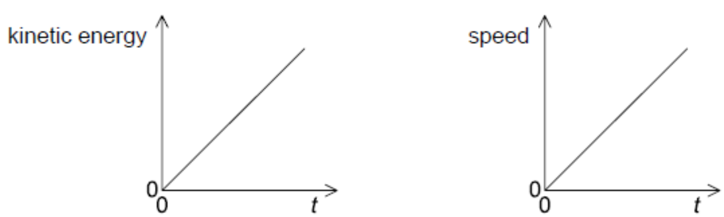
A.



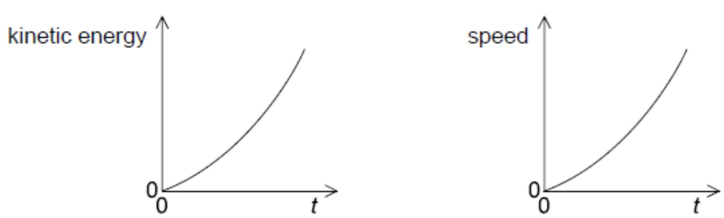
B.



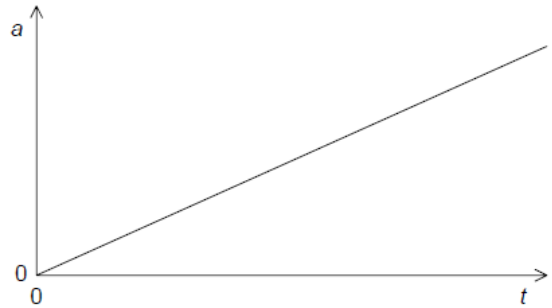
C.



D.



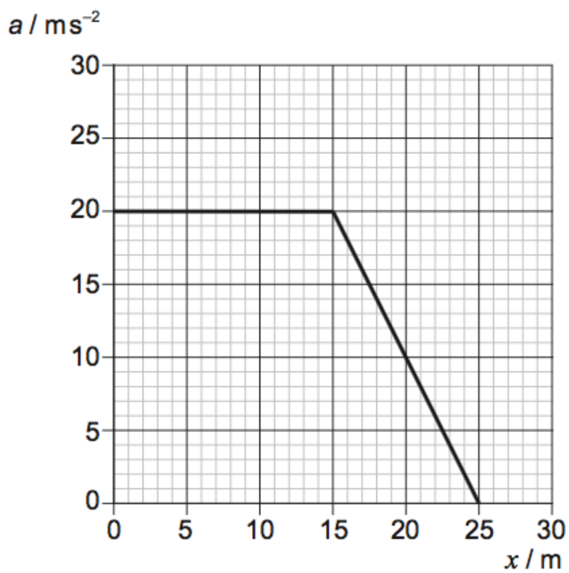
6. A student draws a graph to show the variation with time *t* of the acceleration *a* of an object. *[1 mark]*



What can the student deduce from this graph only, and what quantity from the graph is used to make this deduction?

	Deduction	Quantity used
A.	change in velocity	gradient of graph
B.	change in velocity	area under line
C.	change in displacement	gradient of graph
D.	change in displacement	area under line

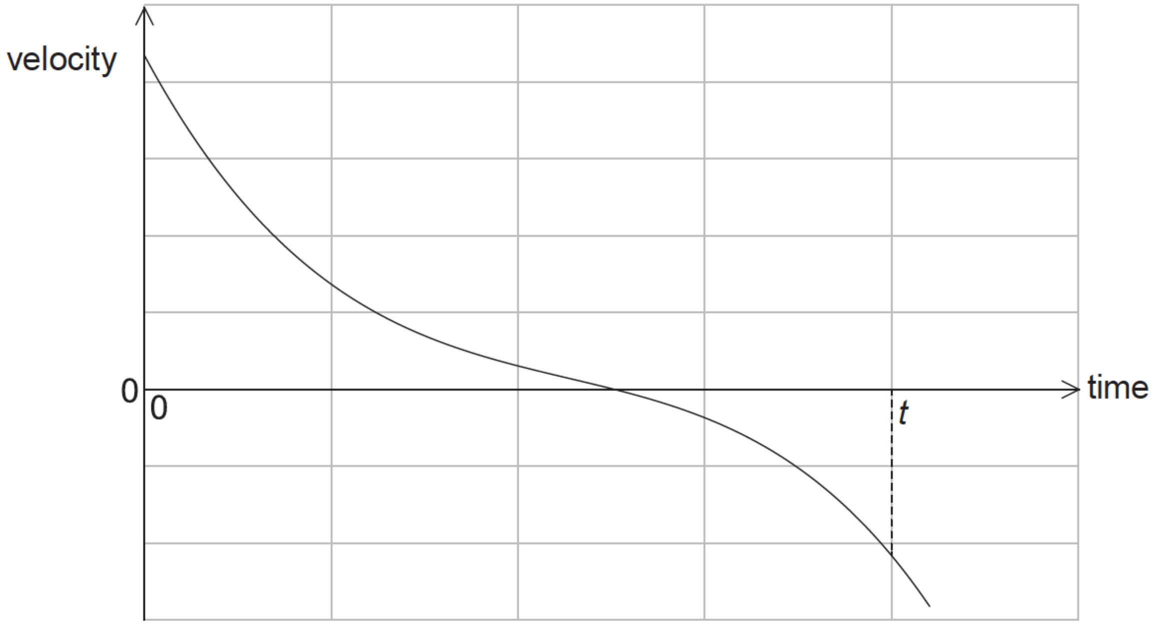
7. The graph shows how the acceleration *a* of an object varies with distance travelled *x*. *[1 mark]*



The mass of the object is 3.0 kg. What is the total work done on the object?

1. 300 J
2. 400 J
3. 1200 J
4. 1500 J

8. The graph shows the variation with time of the velocity of a truck of fixed mass. *[1 mark]*



What can be deduced from the graph?

A. The truck is always accelerating.

B. The truck is always moving.

C. The truck is always moving in one direction.

D. The displacement of the truck after time *t* is zero.

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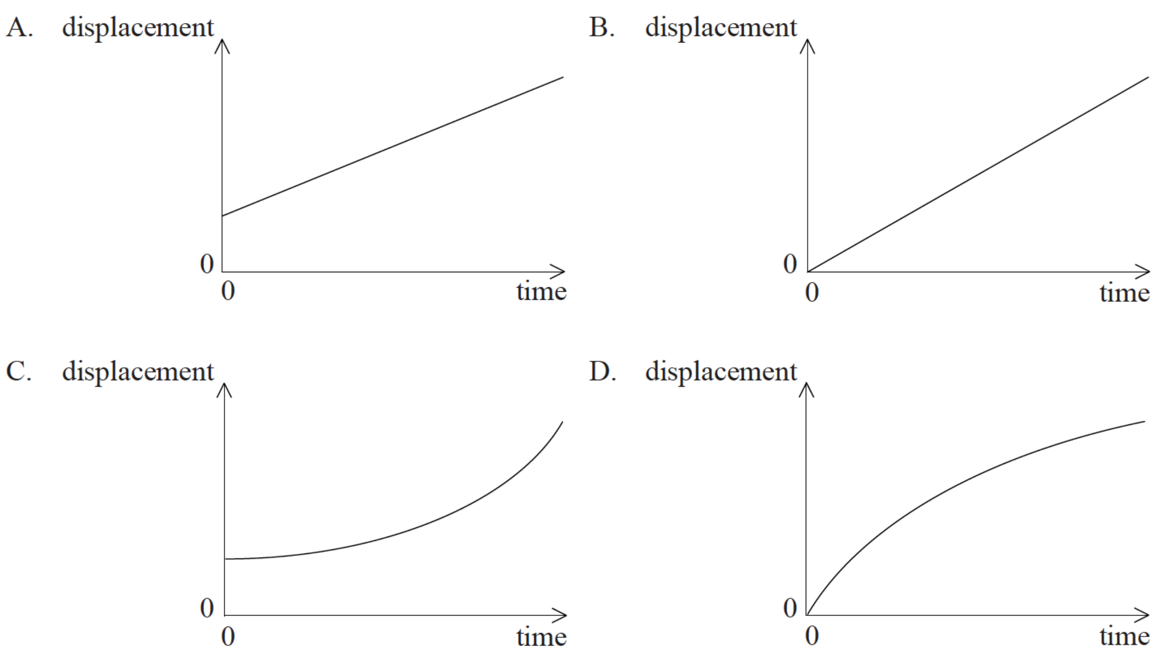
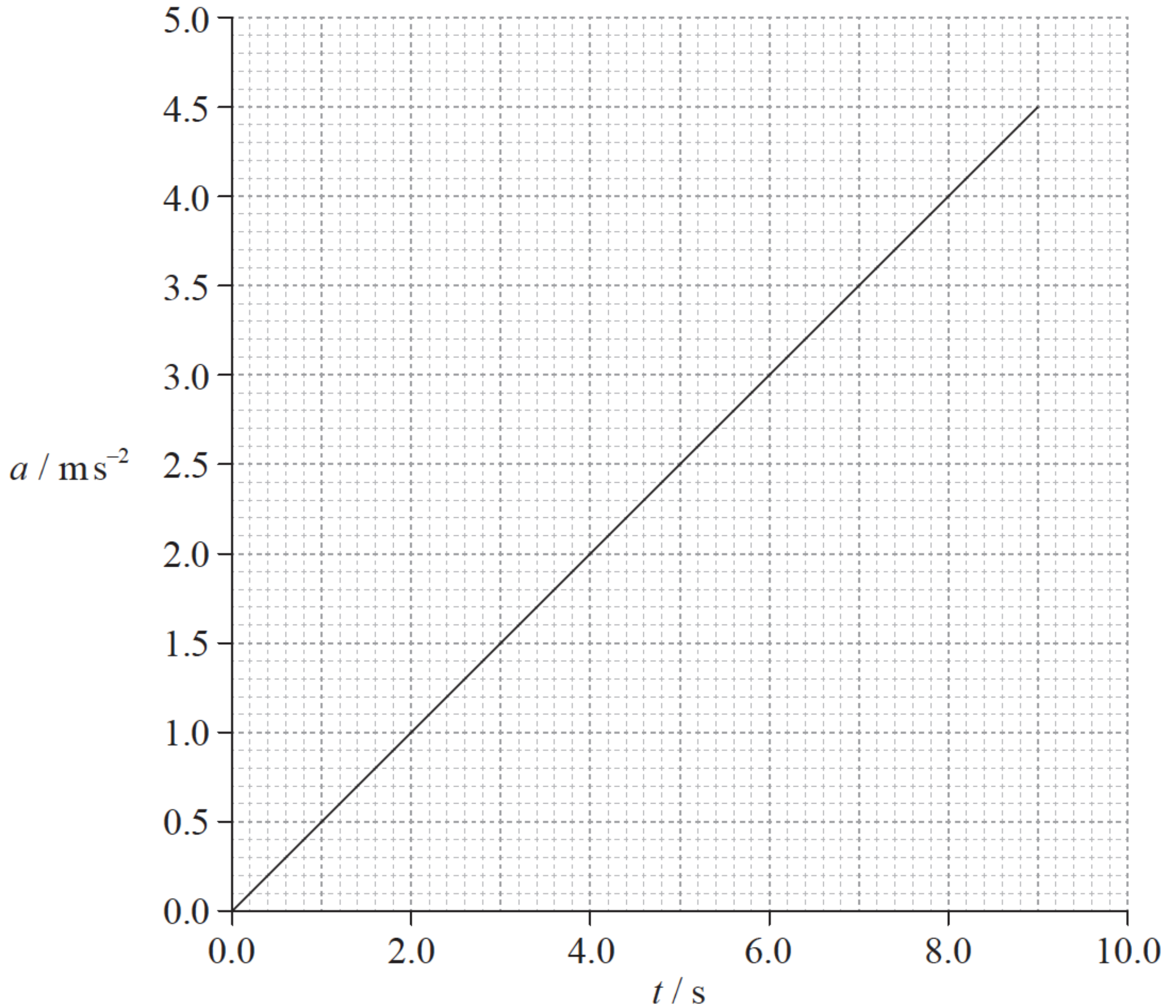
9. A body moves on a straight line. The graphs show the variation of displacement with time. Which graph shows motion with negative acceleration? *[1 mark]*



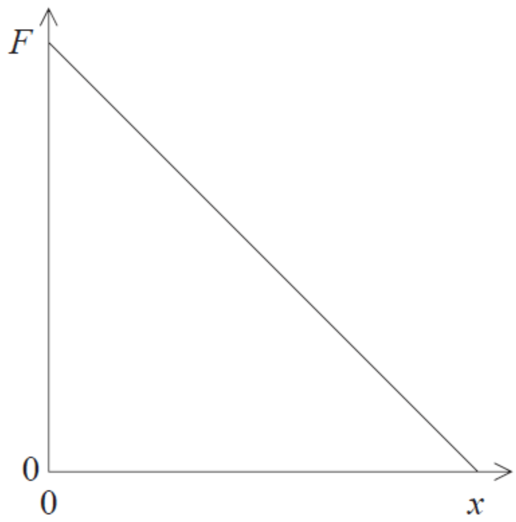
10. A particle accelerates from rest. The graph shows how the acceleration *a* of the particle varies with time *t*. *[1 mark]*



What is the speed of the particle at *t*=6.0s?

A. 0.5 ms^{-1}
B. 2.0 ms^{-1}
C. 9.0 ms^{-1}
D. 18 ms^{-1}

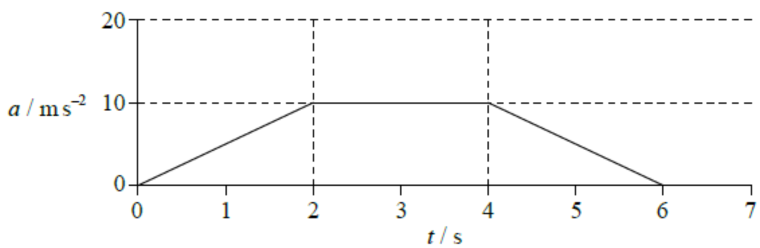
11. The graph shows the variation with distance x of the magnitude of the net force F acting on a body initially at rest. *[1 mark]*



Which of the following describes how the kinetic energy and the acceleration of the body change with distance?

	Kinetic energy	Acceleration
A.	decrease	decrease
B.	decrease	increase
C.	increase	decrease
D.	increase	increase

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

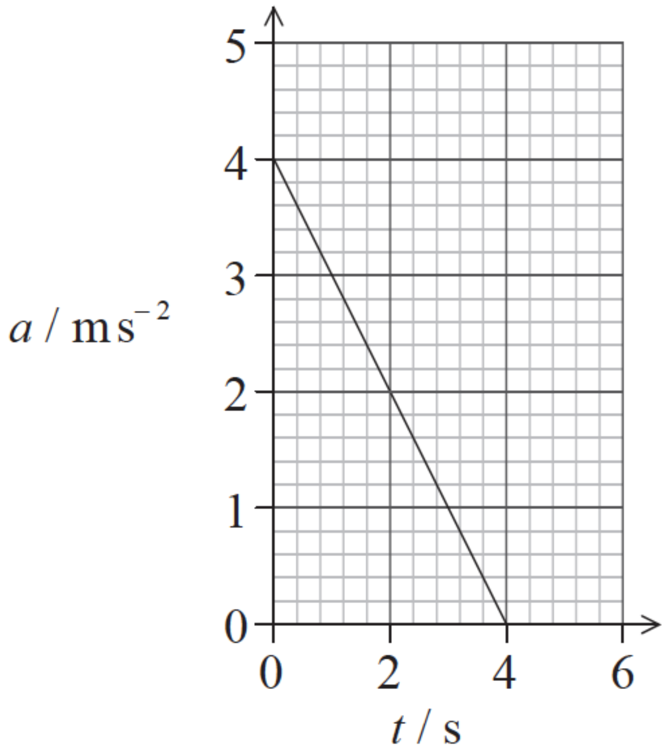


What is the magnitude of the change in the velocity of the object between 0 and 3 seconds?

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

13. *[1 mark]*

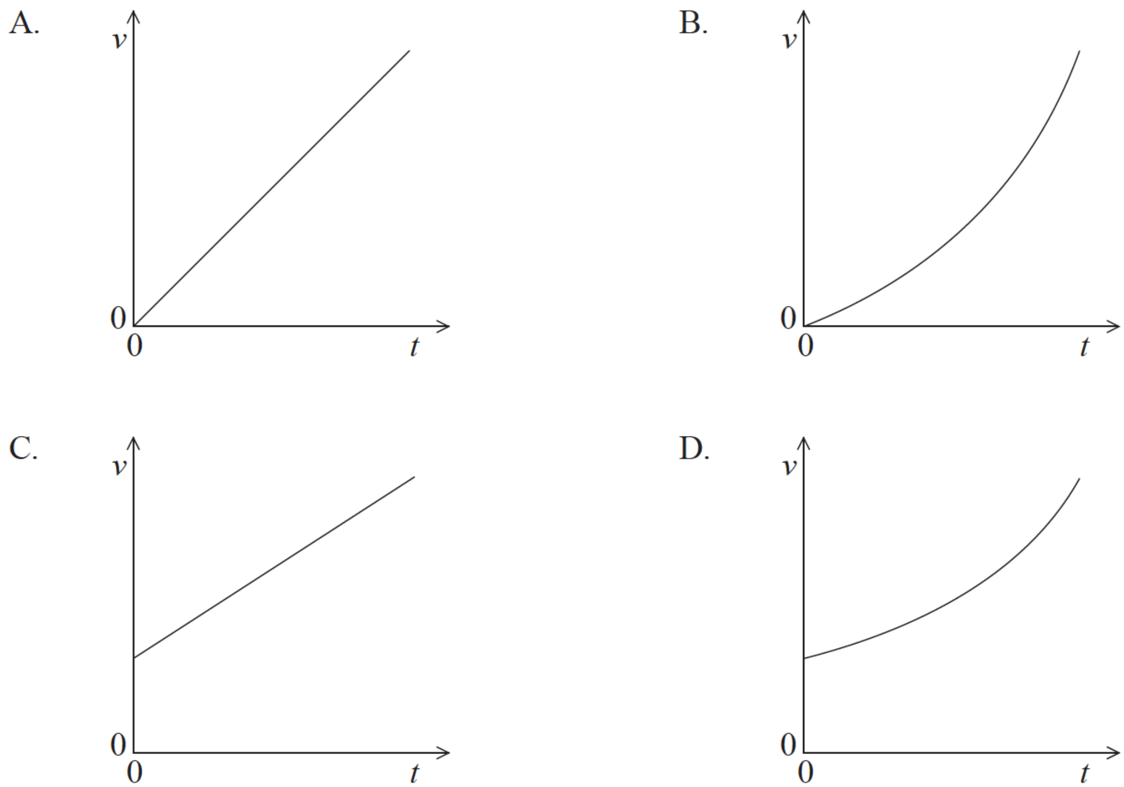
The graph shows the variation with time *t* of the acceleration *a* of an object.



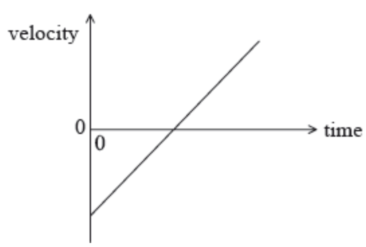
Which of the following is the change in velocity of the object in the time interval 0 to 4s?

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

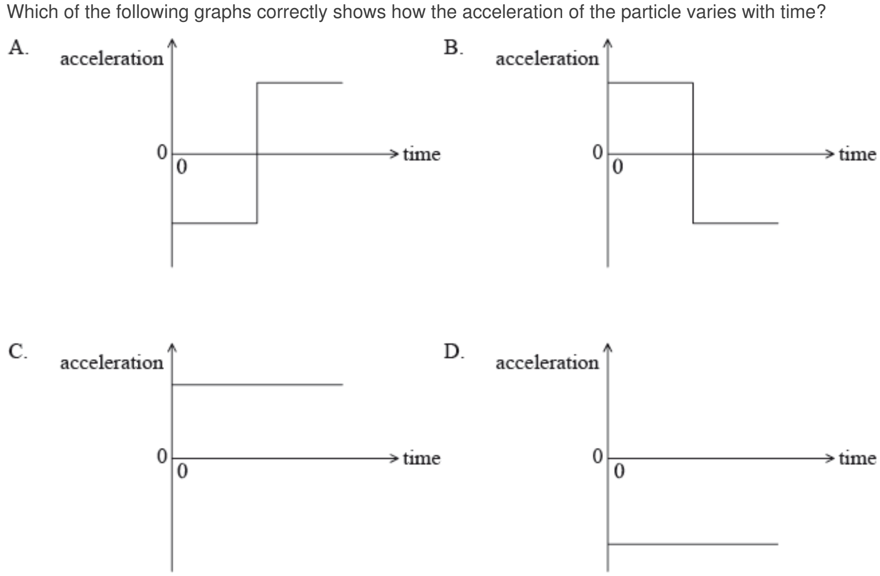
14. A car accelerates from rest. The acceleration increases with time. Which graph shows the variation with time *t* of the speed *v* of the car? *[1 mark]*



15. The graph shows how the velocity of a particle varies with time. *[1 mark]*



Which of the following graphs correctly shows how the acceleration of the particle varies with time?



16. A student measures the radius *r* of a sphere with an absolute uncertainty Δr. What is the fractional uncertainty in the volume of the sphere? *[1 mark]*

A. $\left(\frac{\Delta r}{r}\right)^3$

B. $3\frac{\Delta r}{r}$

C. $4\pi\frac{\Delta r}{r}$

D. $4\pi\left(\frac{\Delta r}{r}\right)^3$

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17. An object is projected vertically upwards at time $t = 0$. Air resistance is negligible. The object passes the same point above its starting position at times 2 s and 8 s. *[1 mark]*

If g = 10 m s^{-2}, what is the initial speed of the object?

A. 50

B. 30

C. 25

D. 4

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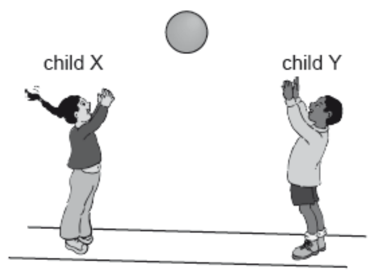
18. Child X throws a ball to child Y. The system consists of the ball, the children and the Earth. What is true for the system when the ball has been caught by Y? *[1 mark]*



[Source: https://pixabay.com/en/playing-ball-kids-boy-girl-31339/]

A. The momentum of child Y is equal and opposite to the momentum of child X.

B. The speed of rotation of the Earth will have changed.

C. The ball has no net momentum while it is in the air.

D. The total momentum of the system has not changed.

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19. A motor of input power 160 W raises a mass of 8.0 kg vertically at a constant speed of 0.50 m s^{-1}. *[1 mark]*

What is the efficiency of the system?

A. 0.63%

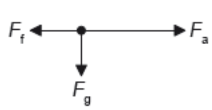
B. 25%

C. 50%

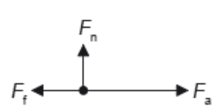
D. 100%

20. A box is accelerated to the right across rough ground by a horizontal force F_a. The force of friction is F_f. The weight of the box is F_g and the normal reaction is F_n. Which is the free-body diagram for this situation? *[1 mark]*

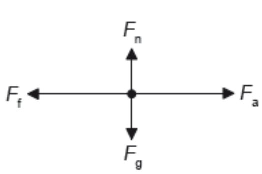
A.



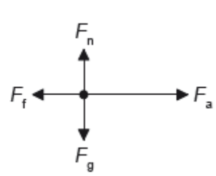
B.



C.



D.



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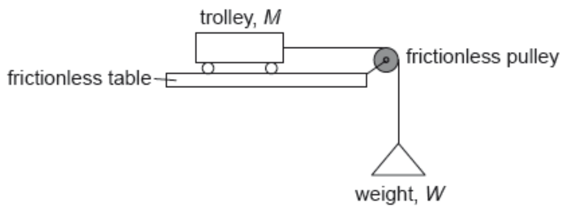
21. A weight W is tied to a trolley of mass M by a light string passing over a frictionless pulley. The trolley has an acceleration a on a frictionless table. The acceleration due to gravity is g. *[1 mark]*



What is W?

A. $\frac{Mag}{(g-a)}$

B. $\frac{Mag}{(g+a)}$

C. $\frac{Ma}{(g-a)}$

D. $\frac{Ma}{(g+a)}$

22. Two balls X and Y with the same diameter are fired horizontally with the same initial momentum from the same height above the ground. The mass of X is greater than the mass of Y. Air resistance is negligible. *[1 mark]*

What is correct about the horizontal distances travelled by X and Y and the times taken by X and Y to reach the ground?

	Horizontal distances	Time to reach ground
A.	X and Y the same	X and Y times the same
B.	X and Y the same	X takes a shorter time than Y
C.	X less than Y	X and Y times the same
D.	X less than Y	X takes a shorter time than Y

23. A parachutist of total mass 70 kg is falling vertically through the air at a constant speed of 8 m s^{-1}. *[1 mark]*

What is the total upward force acting on the parachutist?

A. 0 N

B. 70 N

C. 560 N

D. 700 N

24. A stopper of mass 8 g leaves the opening of a container that contains pressurized gas.The stopper accelerates from rest for a time of 16 ms and leaves the container at a speed of 20 m s^{-1}. *[1 mark]*

What is the order of magnitude of the force acting on the stopper?

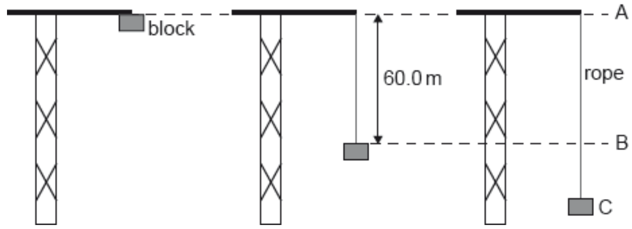
A. 10^{-3} N

B. 10^{0} N

C. 10^{1} N

D. 10^{3} N

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.



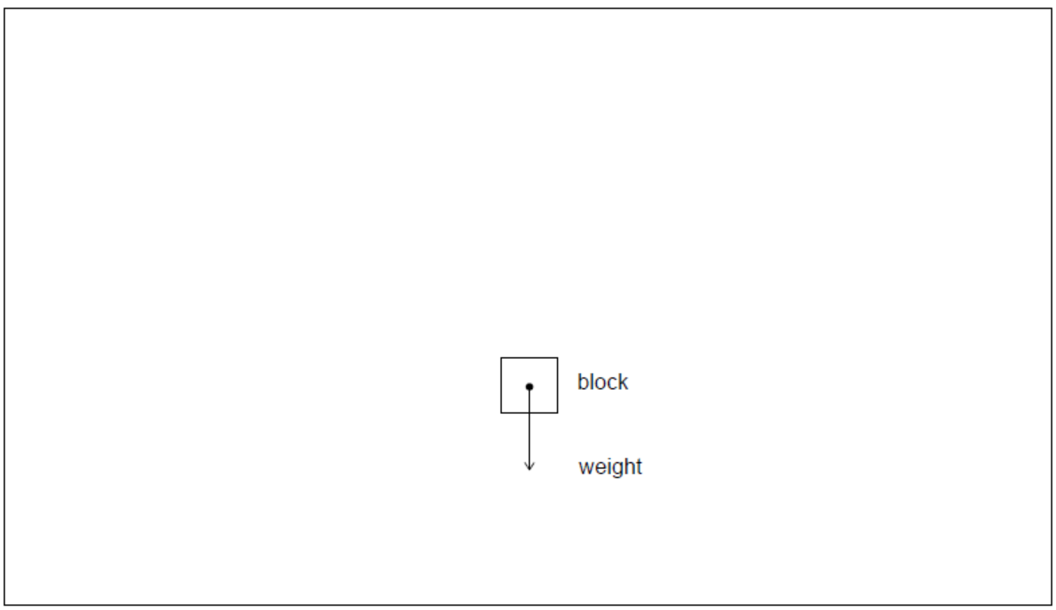
The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

25a. 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.

25b. Determine the magnitude of the average resultant force acting on the block between B and C. *[2 marks]*

25c. 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]*



25d. Calculate the magnitude of the average force exerted by the rope on the block between B and C. *[2 marks]*

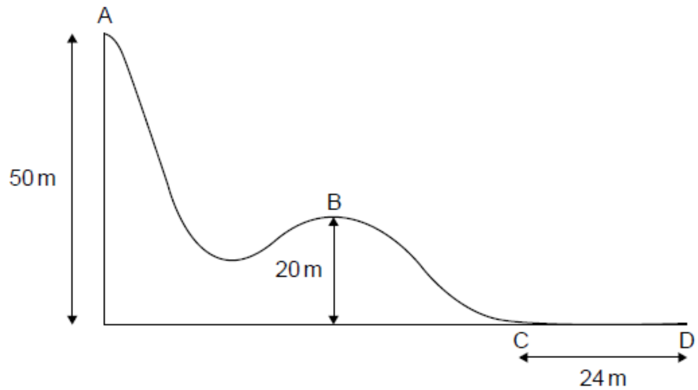
For the rope and block, describe the energy changes that take place

25e. between A and B. *[1 mark]*

25f. between B and C. *[1 mark]*

25g. 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]*

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.

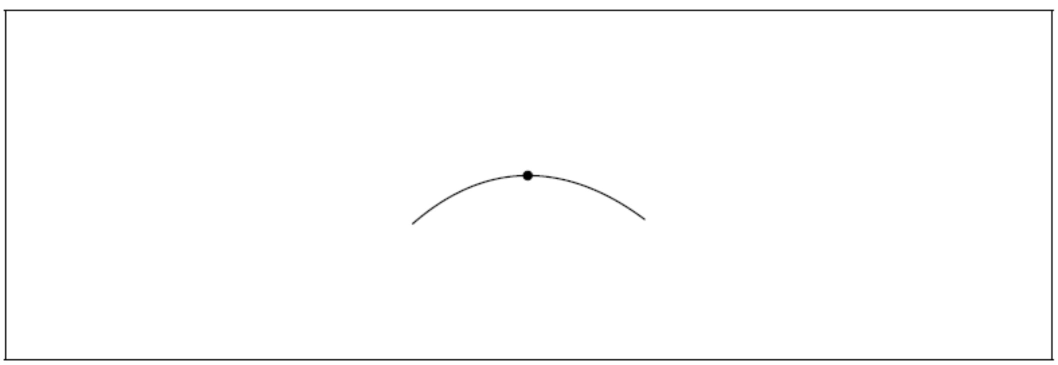


A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

26a. 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]*

26b. 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]*

26c. 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]*



26d. 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]*

26e. 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]*

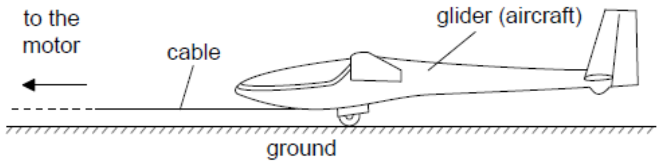
Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected.

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}.

26f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. *[2 marks]*

26g. 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]*

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.



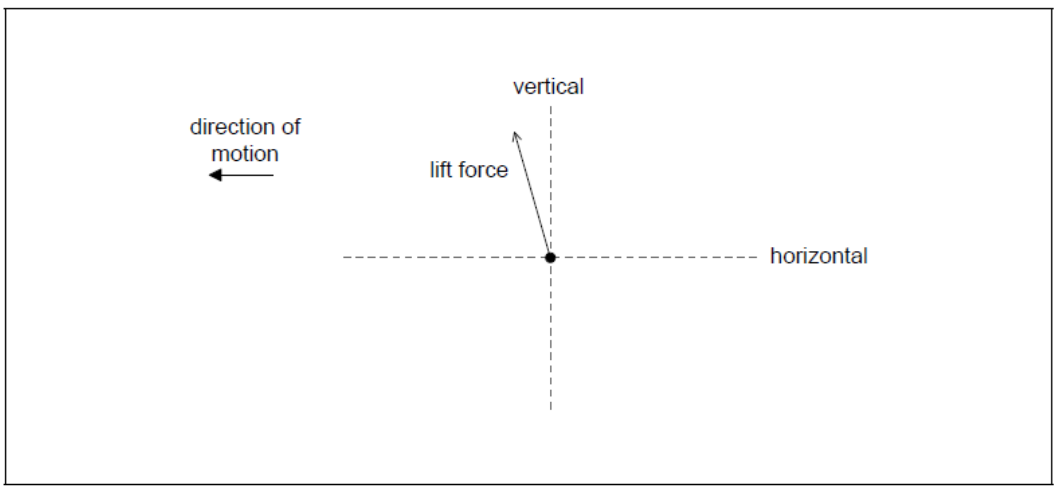
27a. The glider reaches its launch speed of 27.0 m s^{-1} after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. *[2 marks]*

27b. 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]*

27c. 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]*

27d. 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]*

27e. 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]*

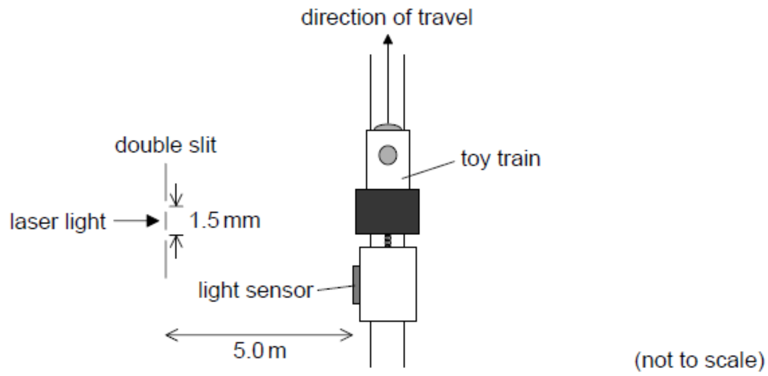


Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.

27f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. *[2 marks]*

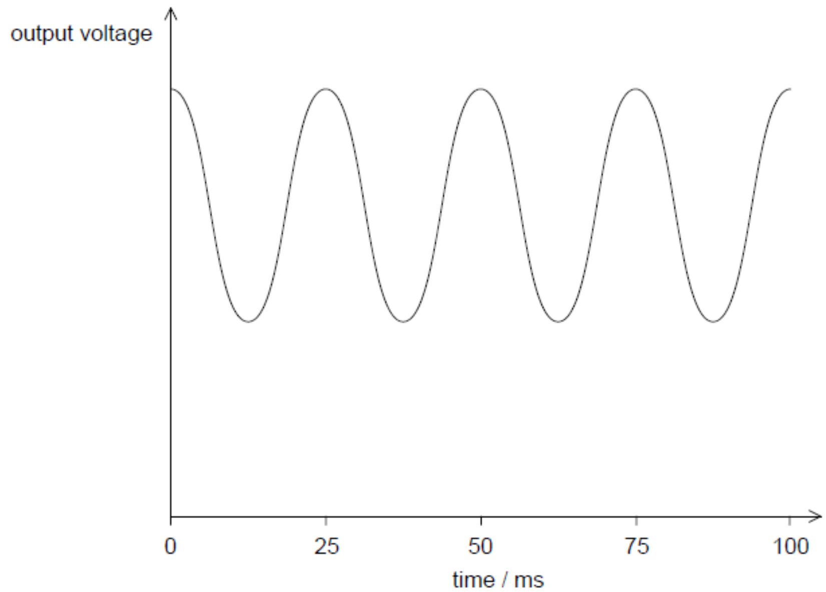
27g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s^{-1}. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. *[3 marks]*

A student investigates how light can be used to measure the speed of a toy train.



Light from a laser is incident on a double slit. The light from the slits is detected by a light sensor attached to the train.

The graph shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits. The output voltage is proportional to the intensity of light incident on the sensor.

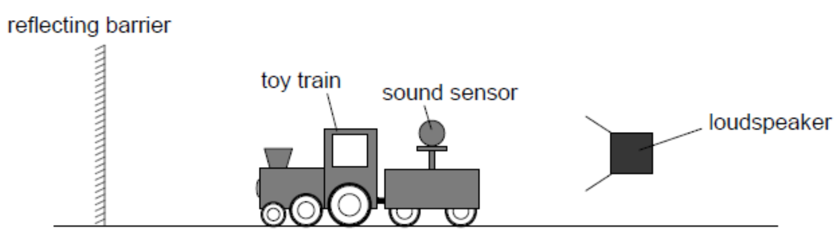


28a. Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs. *[3 marks]*

28b. The slits are separated by 1.5 mm and the laser light has a wavelength of 6.3×10^{-7} m. The slits are 5.0 m from the train track. Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum. *[1 mark]*

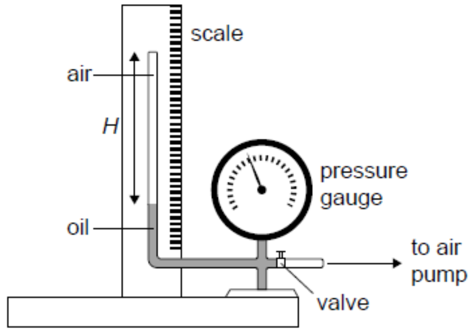
28c. Estimate the speed of the train. *[2 marks]*

28d. In another experiment the student replaces the light sensor with a sound sensor. The train travels away from a loudspeaker that is emitting sound waves of constant amplitude and frequency towards a reflecting barrier. *[2 marks]*



The sound sensor gives a graph of the variation of output voltage with time along the track that is similar in shape to the graph shown in the resource. Explain how this effect arises.

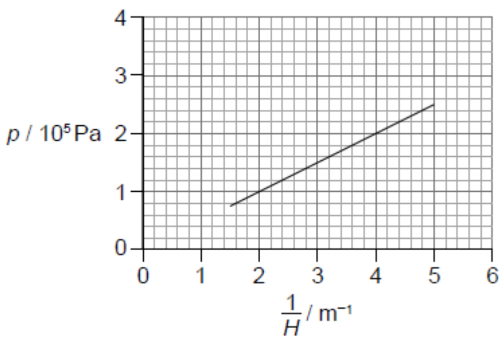
The equipment shown in the diagram was used by a student to investigate the variation with volume, of the pressure *p* of air, at constant temperature. The air was trapped in a tube of constant cross-sectional area above a column of oil.



The pump forces oil to move up the tube decreasing the volume of the trapped air.

29a. The student measured the height *H* of the air column and the corresponding air pressure *p*. After each reduction in the volume the student waited for some time before measuring the pressure. Outline why this was necessary. *[1 mark]*

29b. The following graph of *p* versus $\frac{1}{H}$ was obtained. Error bars were negligibly small. *[3 marks]*



The equation of the line of best fit is $p = a + \frac{b}{H}$.

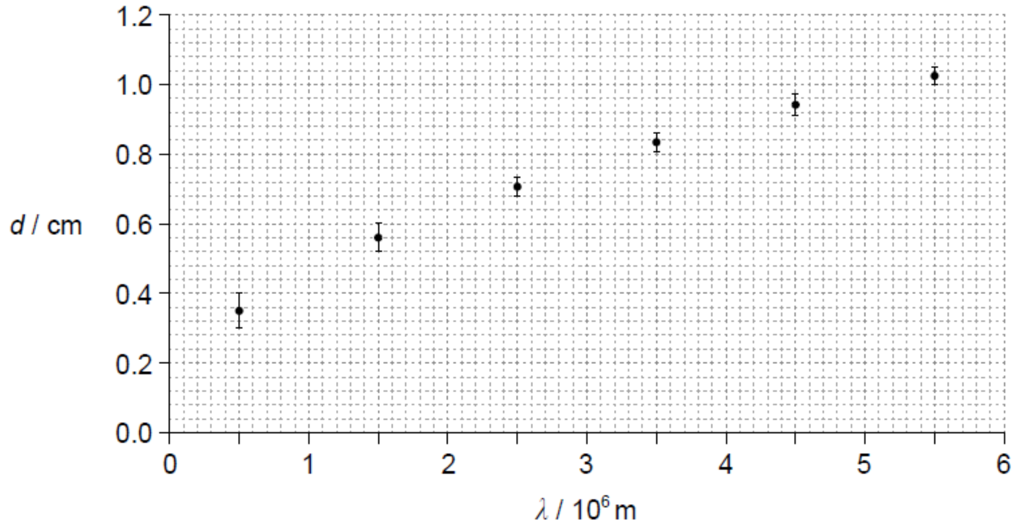
Determine the value of *b* including an appropriate unit.

29c. Outline how the results of this experiment are consistent with the ideal gas law at constant temperature. *[2 marks]*

29d. The cross-sectional area of the tube is 1.3×10^{-3} m^2 and the temperature of air is 300 K. Estimate the number of moles of air in the tube. *[2 marks]*

29e. The equation in (b) may be used to predict the pressure of the air at extremely large values of $\frac{1}{H}$. Suggest why this will be an unreliable estimate of the pressure. *[2 marks]*

A radio wave of wavelength λ is incident on a conductor. The graph shows the variation with wavelength λ of the maximum distance d travelled inside the conductor.



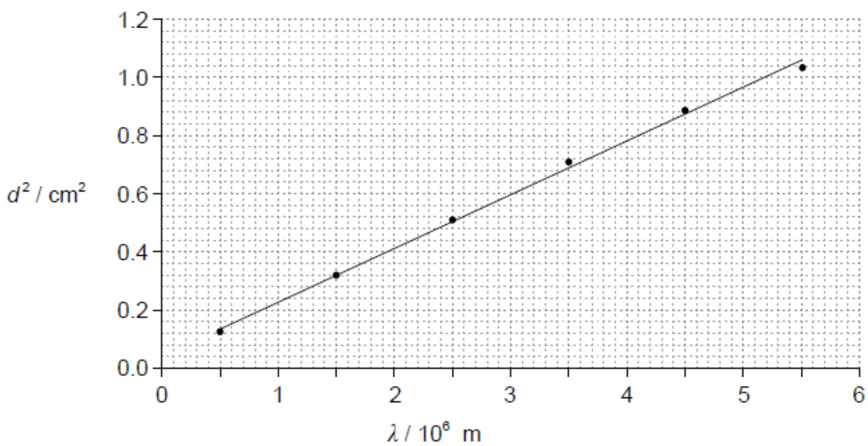
30a. Suggest why it is unlikely that the relation between d and λ is linear. *[1 mark]*

For $\lambda = 5.0 \times 10^5$ m, calculate the

30b. fractional uncertainty in d. *[2 marks]*

30c. percentage uncertainty in d^2. *[1 mark]*

The graph shows the variation with wavelength λ of d^2. Error bars are not shown and the line of best-fit has been drawn.



A student states that the equation of the line of best-fit is $d^2 = a + b\lambda$. When d^2 and λ are expressed in terms of fundamental SI units, the student finds that $a = 0.040 \times 10^{-4}$ and $b = 1.8 \times 10^{-11}$.

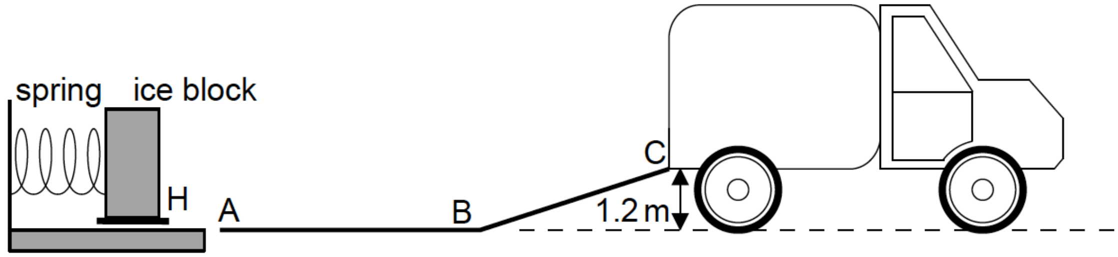
30d. State the fundamental SI unit of the constant a and of the constant b. *[2 marks]*

a: ....

b: ....

30e. Determine the distance travelled inside the conductor by very high frequency electromagnetic waves. *[2 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.

31a. (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]*

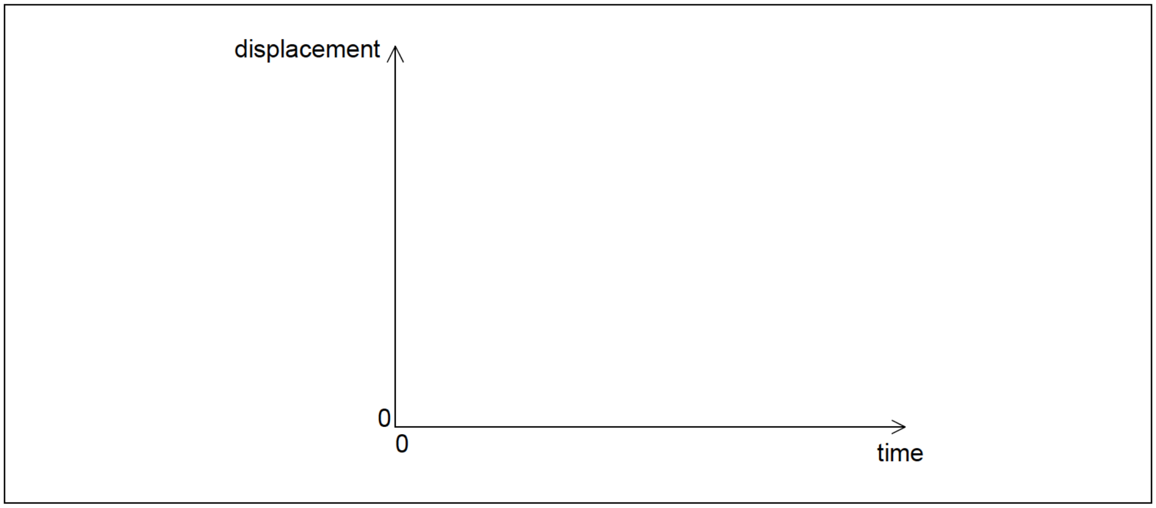
(ii) Calculate the speed of the block at A.

31b. 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.

31c. 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]*



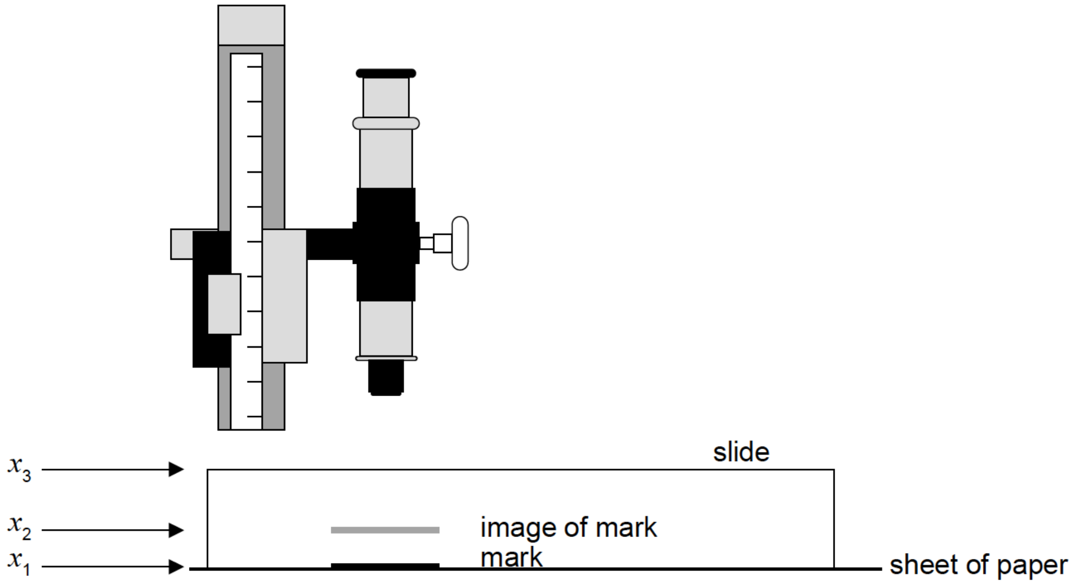
31d. The spring decompression takes 0.42s. Determine the average force that the spring exerts on the block. *[2 marks]*

31e. 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.

A student measures the refractive index of the glass of a microscope slide.

He uses a travelling microscope to determine the position x_1 of a mark on a sheet of paper. He then places the slide over the mark and finds the position x_2 of the image of the mark when viewed through the slide. Finally, he uses the microscope to determine the position x_3 of the top of the slide.



The table shows the average results of a large number of repeated measurements.

	Average position of mark / mm
x_1	0.20 ±0.02
x_2	0.59 ±0.02
x_3	1.35 ±0.02

32a. The refractive index of the glass from which the slide is made is given by [4 marks]

$$\frac{x_3 - x_1}{x_3 - x_2}$$

.

Determine

(i) the refractive index of the glass to the correct number of significant figures, ignoring any uncertainty.

(ii) the uncertainty of the value calculated in (a)(i).

32b. After the experiment, the student finds that the travelling microscope is badly adjusted so that the measurement of each position is too large by 0.05mm. [3 marks]

(i) State the name of this type of error.

(ii) Outline the effect that the error in (b)(i) will have on the calculated value of the refractive index of the glass.

32c. After correcting the adjustment of the travelling microscope, the student repeats the experiment using a glass block 10 times thicker than the original microscope slide. Explain the change, if any, to the calculated result for the refractive index and its uncertainty. [2 marks]

33. Which of the following is proportional to the net external force acting on a body? *[1 mark]*

A. Speed

B. Velocity

C. Rate of change of speed

D. Rate of change of velocity

34. A heat engine does 300 J of work during one cycle. In this cycle 900 J of energy is wasted. What is the efficiency of the engine? *[1 mark]*

A. 0.25

B. 0.33

C. 0.50

D. 0.75

35. An object is dropped from rest. Air resistance is **not** negligible. What is the acceleration of the object at the start of the motion? *[1 mark]*

A. Zero

B. Increasing

C. Decreasing

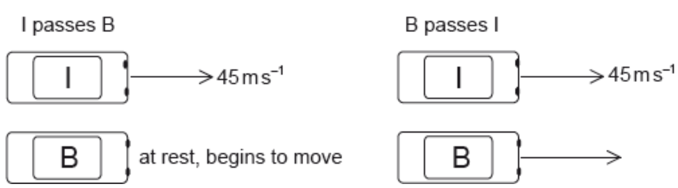
D. Constant

This question is in **two** parts. **Part 1** is about kinematics and Newton's laws of motion.

Part 2 is about electrical circuits.

Part 1 Kinematics and Newton's laws of motion

Cars I and B are on a straight race track. I is moving at a constant speed of $45\ \mathrm{m\,s^{-1}}$ and B is initially at rest. As I passes B, B starts to move with an acceleration of $3.2\ \mathrm{m\,s^{-2}}$.



At a later time B passes I. You may assume that both cars are point particles.

36a. Show that the time taken for B to pass I is approximately 28 s. *[4 marks]*

36b. Calculate the distance travelled by B in this time. *[2 marks]*

36c. B slows down while I remains at a constant speed. The driver in each car wears a seat belt. Using Newton's laws of motion, explain the difference in the tension in the seat belts of the two cars. *[3 marks]*

A third car O with mass 930 kg joins the race. O collides with I from behind, moving along the same straight line as I. Before the collision the speed of I is $45\ \mathrm{m\,s^{-1}}$ and its mass is 850 kg. After the collision, I and O stick together and move in a straight line with an initial combined speed of $52\ \mathrm{m\,s^{-1}}$.

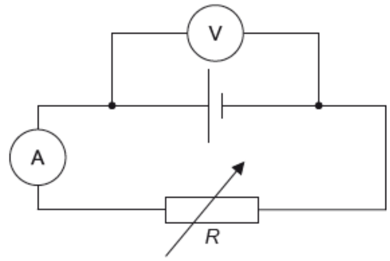
36d. Calculate the speed of O immediately before the collision. *[2 marks]*

36e. The duration of the collision is 0.45 s. Determine the average force acting on O. *[2 marks]*

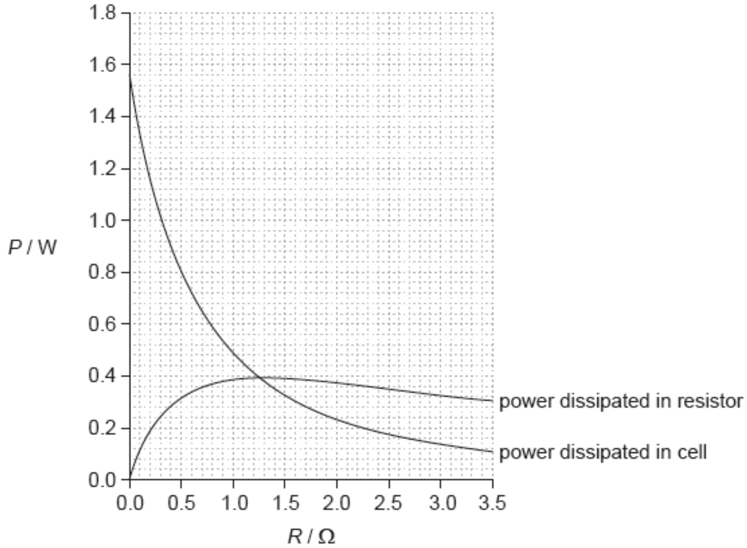
This question is in **two** parts. **Part 1** is about kinematics and Newton's laws of motion.

Part 2 Electrical circuits

The circuit shown is used to investigate how the power developed by a cell varies when the load resistance R changes.



The variable resistor is adjusted and a series of current and voltage readings are taken. The graph shows the variation with R of the power dissipated in the cell and the power dissipated in the variable resistor.



36f. An ammeter and a voltmeter are used to investigate the characteristics of a variable resistor of resistance R. State how the resistance of the ammeter and of the voltmeter compare to R so that the readings of the instruments are reliable. *[2 marks]*

36g. Show that the current in the circuit is approximately 0.70 A when $R = 0.80\ \Omega$. *[3 marks]*

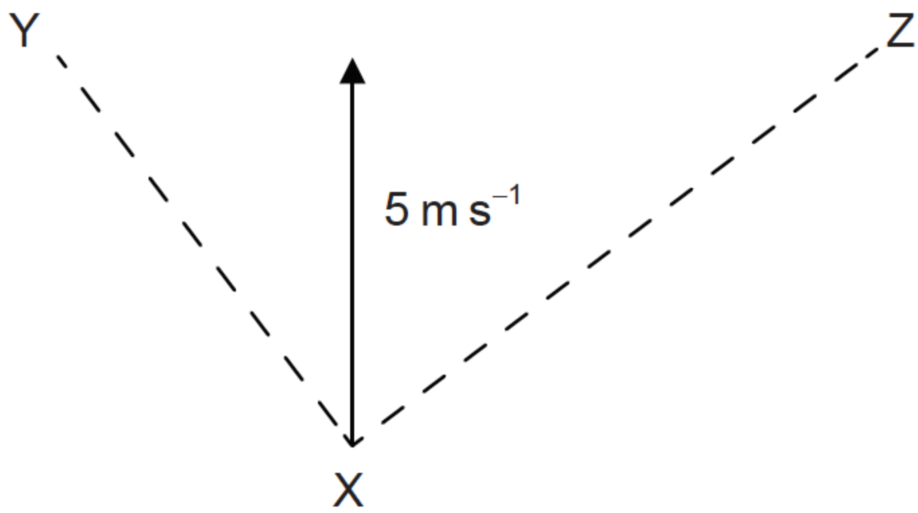
The cell has an internal resistance.

36h. Outline what is meant by the internal resistance of a cell. *[2 marks]*

36i. Determine the internal resistance of the cell. *[3 marks]*

36j. Calculate the electromotive force (emf) of the cell. *[2 marks]*

37. A velocity of 5 m s^{-1} can be resolved along perpendicular directions XY and XZ. *[1 mark]*



The component of the velocity in the direction XY is of magnitude 4 m s^{-1}. What is the magnitude of the component in the direction XZ?

A. 4 m s^{-1}

B. 3 m s^{-1}

C. 2 m s^{-1}

D. 1 m s^{-1}

38. What is the unit of energy density? *[1 mark]*

A. J kg^{-1}

B. J kg^{-1} m^{3}

C. J mol^{-1}

D. J K^{-1}