



Cambridge International AS & A Level

PHYSICS

9702/11

Paper 1 Multiple Choice

October/November 2023

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)

INSTRUCTIONS

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.

This document has **20** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

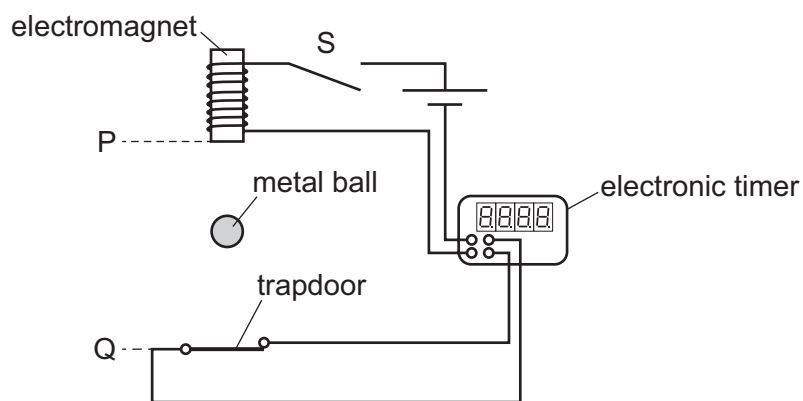
1 What is a reasonable estimate of the cross-sectional area of the wire in a paper clip?

- A** $1 \times 10^{-3} \text{ m}^2$ **B** $8 \times 10^{-5} \text{ m}^2$ **C** $8 \times 10^{-7} \text{ m}^2$ **D** $1 \times 10^{-9} \text{ m}^2$

2 Which quantity is **not** an SI base quantity?

- A** charge
B mass
C temperature
D time

3 A student determines the acceleration of free fall by using a small metal ball, as shown.



When switch S is opened, the ball is released from an electromagnet and an electronic timer is started. The ball then falls vertically downwards. The timer stops when the ball hits a trapdoor. The student measures the distance PQ between the electromagnet and the trapdoor. This distance and the reading on the timer are then used to calculate the acceleration of free fall.

Which statement about errors in the experiment is correct?

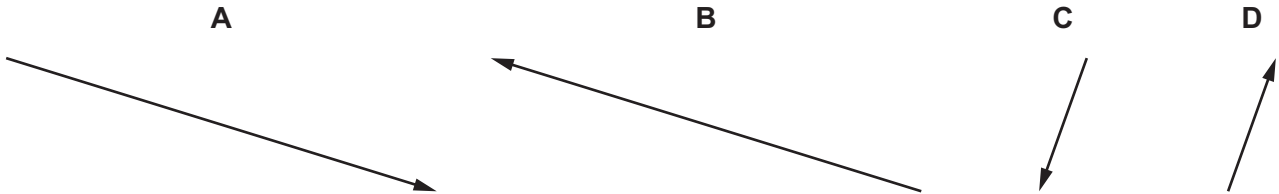
- A** The random error can be reduced by adding the diameter of the ball to the distance PQ.
B The random error can be reduced by subtracting the diameter of the ball from the distance PQ.
C The systematic error can be reduced by adding the diameter of the ball to the distance PQ.
D The systematic error can be reduced by subtracting the diameter of the ball from the distance PQ.

- 4 The diagram shows two coplanar forces, P and Q , drawn to scale.

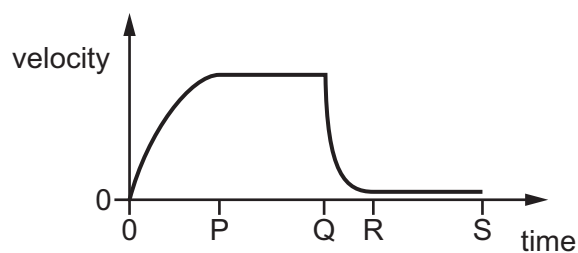


Force R is given by $R = Q - P$.

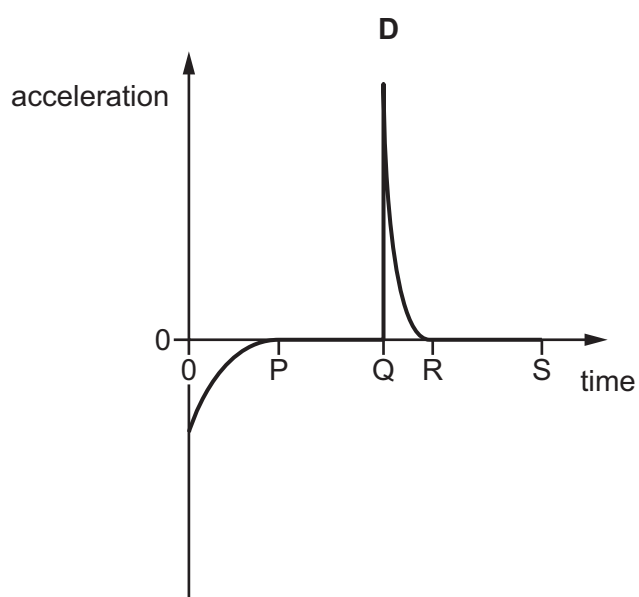
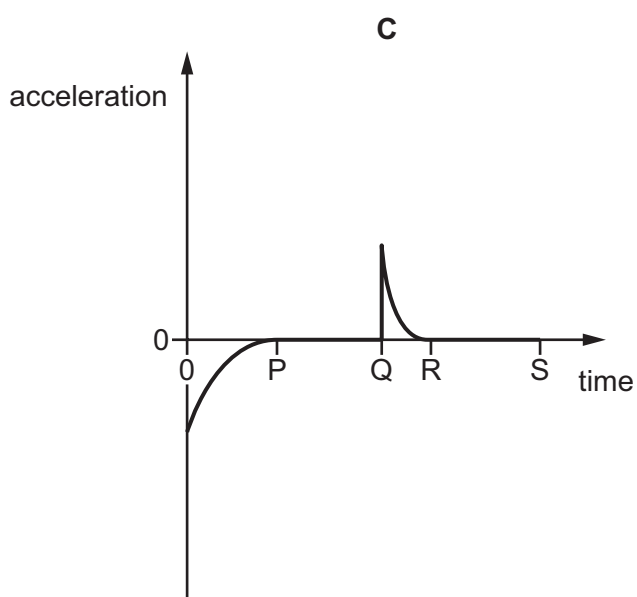
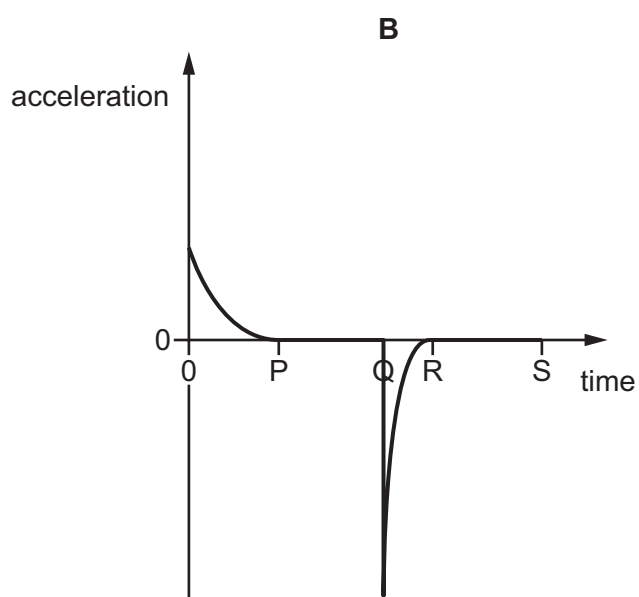
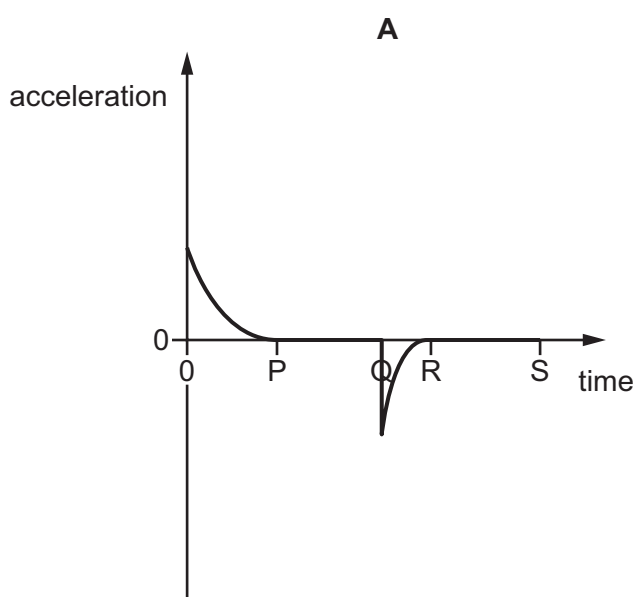
Which diagram represents R ?



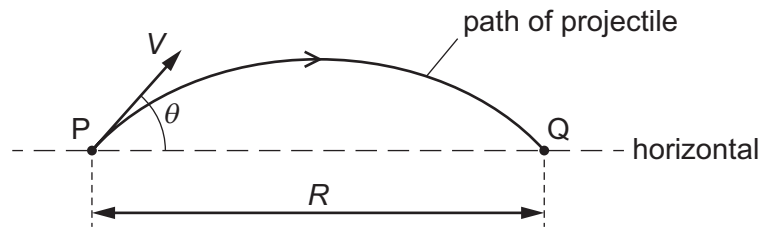
- 5 A parachutist falls from a stationary balloon at time $t = 0$. The velocity–time graph for the parachutist from time $t = 0$ until the time when he is just above the ground is shown.



Which graph best shows the variation with time of the acceleration of the parachutist?



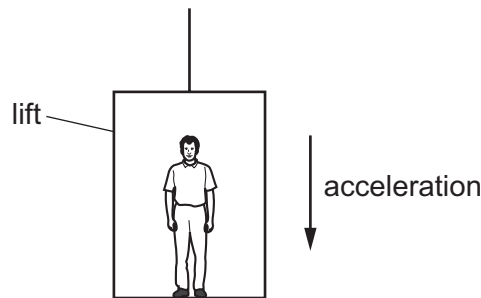
- 6 A projectile is fired from point P with velocity V at an angle θ to the horizontal. It lands at point Q, a horizontal distance R from P, after time T .



The acceleration of free fall is g . Air resistance is negligible.

Which equation is correct?

- A $R = VT \cos \theta$
 - B $R = VT \sin \theta$
 - C $R = VT \cos \theta - \frac{1}{2} g T^2$
 - D $R = VT \sin \theta - \frac{1}{2} g T^2$
- 7 A man stands in a lift that is accelerating vertically downwards, as shown.



Which statement describes the force exerted by the man on the floor?

- A It is equal to the weight of the man.
 - B It is greater than the force exerted by the floor on the man.
 - C It is less than the force exerted by the floor on the man.
 - D It is less than the weight of the man.
- 8 A ball of mass 200 g is thrown horizontally with a speed of 20 m s^{-1} against a vertical wall.

The ball is in contact with the wall for a time of 0.10 s before rebounding back along its original path with a speed of 10 m s^{-1} .

What is the average force exerted by the wall on the ball during the collision?

- A 20 N
- B 60 N
- C 20 kN
- D 60 kN

- 9 In an experiment, a metal ball is dropped into a viscous liquid. The terminal velocity of the ball in the liquid is measured.

The experiment is repeated four times. For each repeat, a change is made to one of the following.

- 1 the density of the metal of the ball
- 2 the height from which the ball is dropped
- 3 the density of the liquid
- 4 the depth of the liquid

Which two changes separately affect the terminal velocity of the ball in the liquid?

- A** 1 and 2 **B** 1 and 3 **C** 2 and 4 **D** 3 and 4

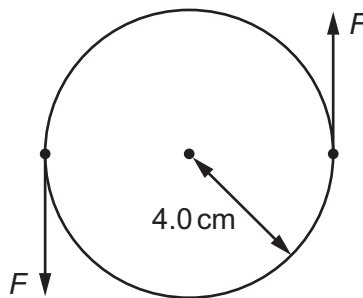
- 10 Two objects move towards each other along the same straight line.



After colliding, the two objects stick together and are stationary.

Which statement **must** be correct?

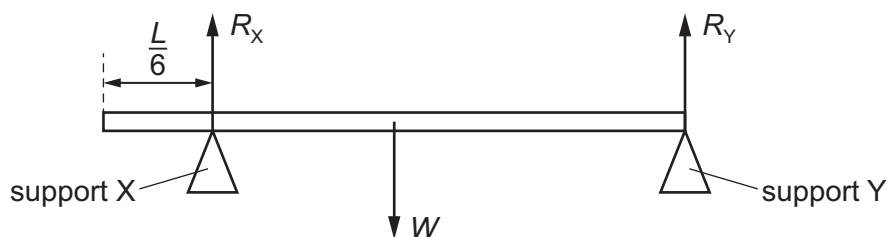
- A** The total kinetic energy of the two objects does not change during the collision.
B The total momentum of the two objects before the collision is zero.
C The two objects have equal mass.
D The two objects have the same speed before the collision.
- 11 A minimum torque of 20 N m must be applied to the lid of a jar for it to open. The radius of the lid is 4.0 cm.



What is the minimum force F that must act on each side of the lid in order to open it?

- A** 2.5 N **B** 5.0 N **C** 250 N **D** 500 N

- 12 A uniform bar of length L and weight W rests horizontally on two supports X and Y.



Support X exerts a vertical force R_X at a distance of $\frac{L}{6}$ from one end of the bar.

Support Y exerts a vertical force R_Y at the other end of the bar.

The bar is in equilibrium.

What is the ratio $\frac{R_X}{R_Y}$?

A $\frac{3}{2}$

B $\frac{2}{3}$

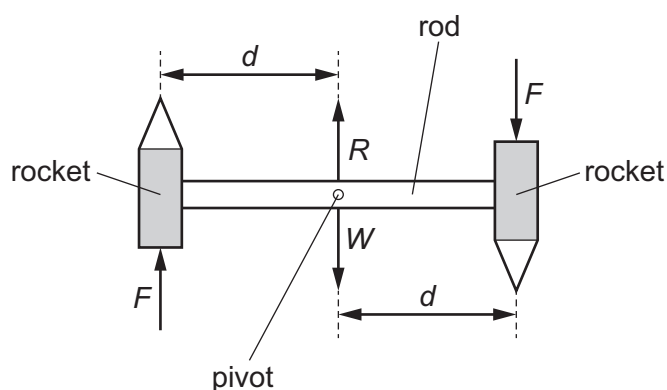
C $\frac{3}{5}$

D $\frac{2}{5}$

- 13 A type of firework is made by connecting two rockets, facing in opposite directions, to a rod, as shown.

The rod is attached to a frictionless pivot so that the firework can rotate in a vertical plane.

The firework has weight W . The pivot exerts a force R on the rod that is equal and opposite to W .



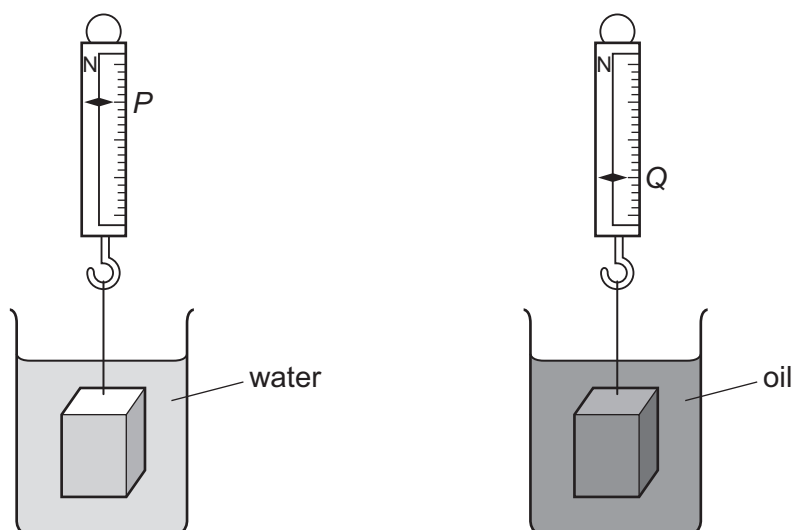
Each rocket exerts a force of magnitude F on the rod at a perpendicular distance d from the pivot. The forces exerted by the rockets are always in opposite directions.

Air resistance is negligible.

Which statement is correct?

- A The firework is in equilibrium because the resultant force acting on it is zero.
- B The firework is in equilibrium because the resultant torque acting on it is zero.
- C The firework is not in equilibrium because the resultant force acting on it is not zero.
- D The firework is not in equilibrium because the resultant torque acting on it is not zero.

- 14 An object of weight W is suspended from a newton meter. When the object is completely immersed in water, the newton meter reads P . When the object is completely immersed in oil, the newton meter reads Q .



What is the ratio $\frac{\text{density of oil}}{\text{density of water}}$?

- A $\frac{W-P}{Q-P}$ B $\frac{Q-P}{W-P}$ C $\frac{W-P}{W-Q}$ D $\frac{W-Q}{W-P}$
- 15 A crate of mass 50 kg is pushed a distance of 6.0 m along a horizontal surface against a constant resistive force of 70 N. The crate moves at a constant speed. It is then lifted, at a constant speed, through a vertical distance of 1.2 m onto the back of a lorry.

What is the total work done in this process?

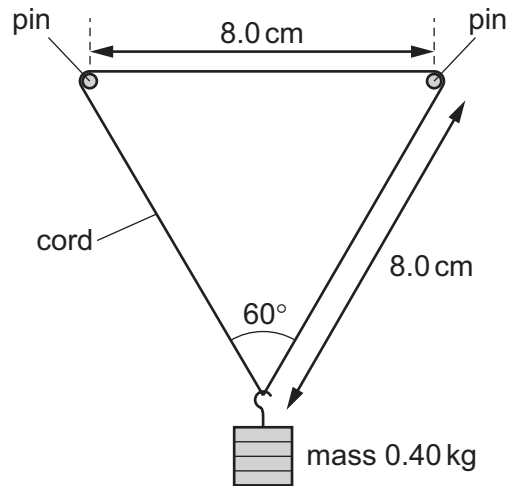
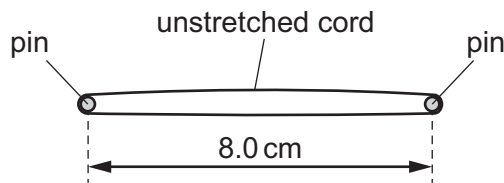
- A 420 J B 480 J C 590 J D 1000 J
- 16 The input power to a television is P_{in} . The useful sound and light power emitted by the television is P_{out} .

What is the efficiency of the television?

- A $\frac{P_{\text{out}}}{P_{\text{in}}}$ B $\frac{P_{\text{in}} - P_{\text{out}}}{P_{\text{in}}}$ C $\frac{P_{\text{in}}}{P_{\text{out}}}$ D $\frac{P_{\text{out}}}{P_{\text{in}} - P_{\text{out}}}$
- 17 A builder holding a brick of mass 3000 g drops the brick on his foot.
- What is a reasonable estimate of the change in gravitational potential energy of the brick?
- A 30 J B 300 J C 3000 J D 30 000 J

- 18** An elastic cord of unstretched total length 16.0 cm and cross-sectional area $2.0 \times 10^{-6}\text{ m}^2$ is held horizontally by two smooth pins a distance 8.0 cm apart.

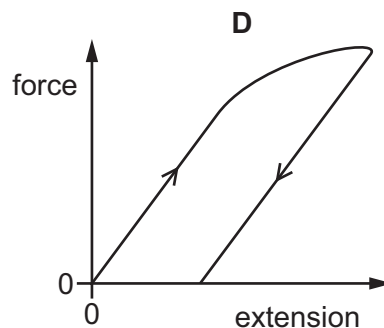
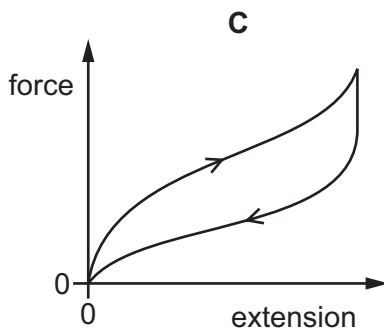
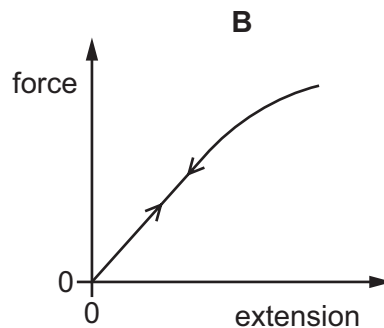
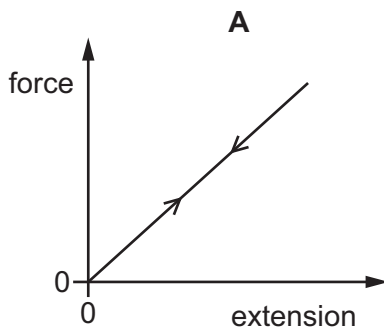
The cord obeys Hooke's law. A load of mass 0.40 kg is suspended centrally on the cord. The angle between the two sides of the cord supporting the load is 60° .



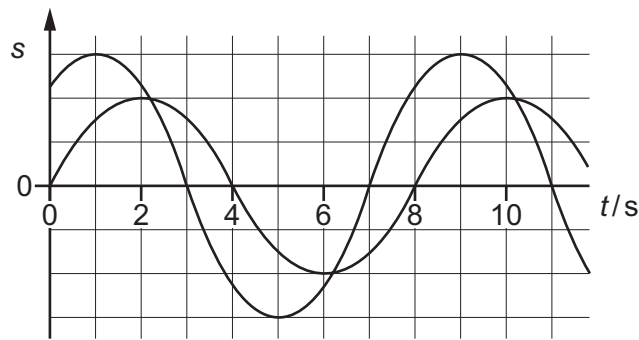
What is the Young modulus of the cord material?

- A** $5.7 \times 10^5\text{ Pa}$ **B** $1.1 \times 10^6\text{ Pa}$ **C** $2.3 \times 10^6\text{ Pa}$ **D** $3.9 \times 10^6\text{ Pa}$

- 19** Which force–extension graph shows plastic deformation of a sample of material?



- 20 Two waves pass through a point P. The graph shows the variation with time t of the displacement s of the two waves at point P.



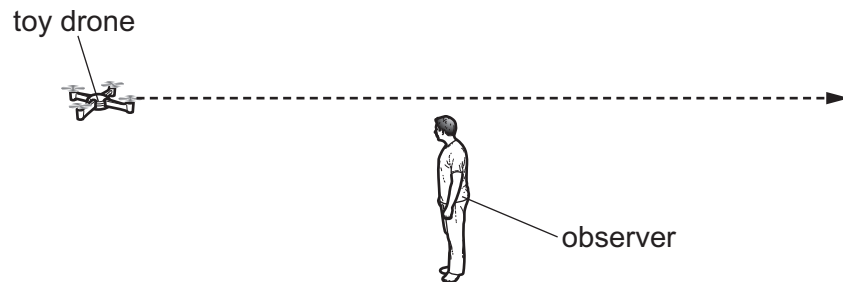
What is the phase difference between the two waves at point P?

- A 0° B 45° C 90° D 180°
- 21 Which row is correct for both progressive transverse waves and progressive longitudinal waves?

	transverse waves	longitudinal waves
A	contain compressions and rarefactions	some can travel in a vacuum
B	can be polarised	contain compressions and rarefactions
C	vibrations are perpendicular to the direction of travel of the wave energy	can be polarised
D	some can travel in a vacuum	vibrations are perpendicular to the direction of travel of the wave energy

- 22** A toy drone emits a sound of constant frequency 800 Hz. The speed of the sound in the air is 330 m s^{-1} .

The drone moves along a straight path directly towards an observer and then continues in a straight line directly away from the observer. The speed of the drone is constant.



What is the velocity of the drone when the frequency of the sound heard by the observer is 850 Hz?

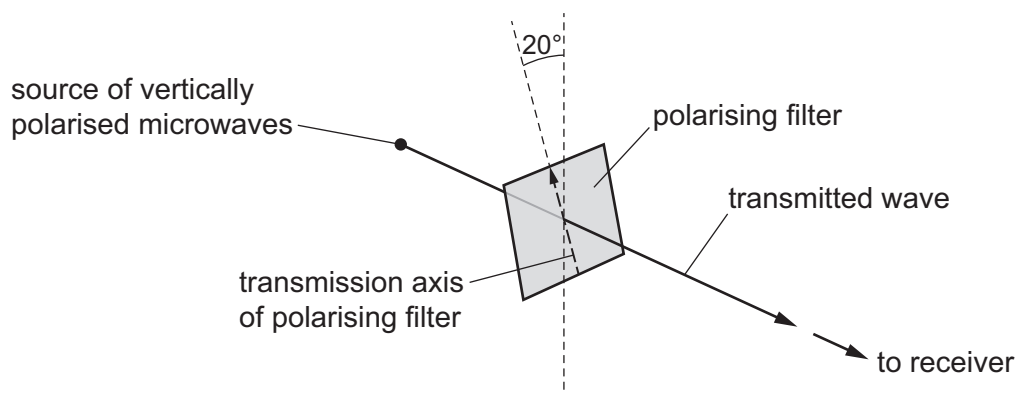
	magnitude of velocity / m s^{-1}	direction of velocity
A	19	away from the observer
B	21	away from the observer
C	19	towards the observer
D	21	towards the observer

- 23** Which statement about electromagnetic waves in a vacuum is correct?

- A** Infrared waves have shorter wavelengths than visible light waves.
- B** Microwaves have longer wavelengths than radio waves.
- C** Ultraviolet waves have higher frequencies than visible light waves.
- D** γ -rays have lower frequencies than X-rays.

- 24** Vertically polarised microwaves are emitted from a source. The microwaves are detected by a receiver that is connected to a cathode-ray oscilloscope (CRO). The waveform displayed on the screen of the CRO has an amplitude of 2.6 cm.

A metal wire grid that acts as a polarising filter is now placed between the source and the receiver. The filter is orientated so that the plane of polarisation of the transmitted wave is at an angle of 20° to the vertical.



The distance between the source and receiver is unchanged. The settings on the CRO are also unchanged.

What is now the amplitude of the waveform displayed on the screen of the CRO?

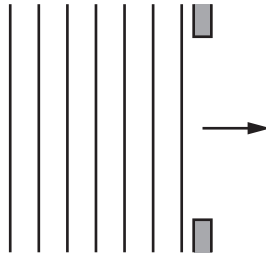
- A** 0.30 cm **B** 0.89 cm **C** 2.3 cm **D** 2.4 cm
- 25** In an experiment, a stationary wave is formed on a string stretched horizontally between two fixed points.
- Which statement about the experiment is correct?
- A** At certain times, the string between two nodes is horizontal with all points having zero displacement.
- B** Each point on the string between two antinodes has an oscillation of the same amplitude.
- C** The number of nodes is equal to the number of antinodes.
- D** Two adjacent antinodes oscillate in phase.
- 26** A musical organ produces notes by blowing air into a set of pipes that are open at one end and closed at the other.

The speed of sound in the air in the pipes is 320 m s^{-1} .

What is the lowest frequency of sound produced by a pipe of length 10 m?

- A** 4 Hz **B** 8 Hz **C** 16 Hz **D** 32 Hz

- 27 In an experiment, water waves in a ripple tank are incident on a gap, as shown.



Some diffraction of the water waves is observed.

Which change to the experiment would provide a better demonstration of diffraction?

- A Increase the amplitude of the waves.
 - B Increase the frequency of the waves.
 - C Increase the wavelength of the waves.
 - D Increase the width of the gap.
- 28 Light of wavelength λ is emitted from two point sources R and S and falls onto a distant screen.



At point P on the screen, the light intensity is zero.

What could explain the zero intensity at P?

- A Light from the two sources is emitted 180° out of phase and the path difference to P is $\frac{1}{2}\lambda$.
 - B Light from the two sources is emitted in phase and the path difference to P is λ .
 - C Light from the two sources is emitted 90° out of phase and the path difference to P is λ .
 - D Light from the two sources is emitted in phase and the path difference to P is $\frac{1}{2}\lambda$.
- 29 A beam of red light of wavelength 720 nm is incident normally on a diffraction grating and produces a diffraction pattern on a screen placed parallel to the grating.

The beam of red light is replaced with a beam of electromagnetic radiation of wavelength X, which is incident normally on the same diffraction grating.

The third-order maximum for the electromagnetic radiation of wavelength X is at the same position on the screen as the second-order maximum for the red light.

What is wavelength X?

- A 480 nm
- B 540 nm
- C 960 nm
- D 1100 nm

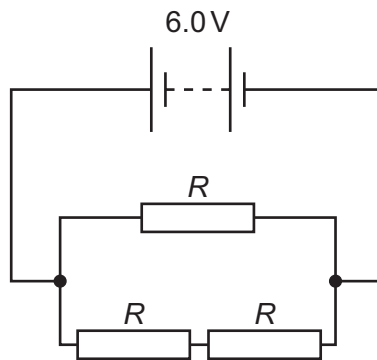
- 30 The current I in a conductor is given by the equation shown.

$$I = Anvq$$

What does the letter n represent in this equation?

- A** charge carried per charge carrier
B number of charge carriers per unit area
C number of charge carriers per unit volume
D total mass of charge carriers per unit volume
- 31 In the circuit shown, the battery has an electromotive force (e.m.f.) of 6.0 V and negligible internal resistance.

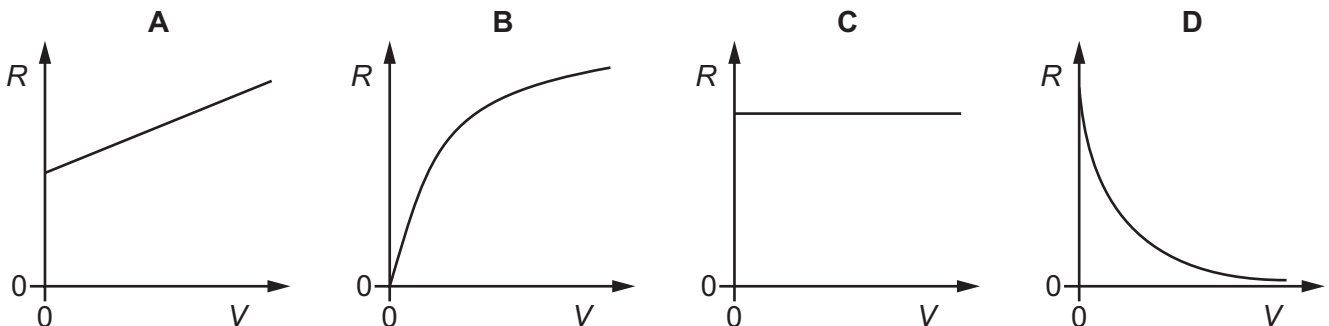
The three resistors each have resistance R .



The total power dissipated in the resistor network is 24 W.

What is the value of R ?

- A** $0.50\ \Omega$ **B** $1.0\ \Omega$ **C** $1.5\ \Omega$ **D** $2.3\ \Omega$
- 32 Which graph could show how the resistance R of a filament lamp varies with the applied potential difference (p.d.) V , as V is increased to the normal operating p.d.?



- 33 A piece of conducting putty is in the shape of a cylinder of length 60 mm and diameter 20 mm. The resistance between the ends of the cylinder is 20Ω .

What is the resistivity of the putty?

- A $0.033\Omega\text{m}$ B $0.10\Omega\text{m}$ C $0.42\Omega\text{m}$ D $5.2\Omega\text{m}$

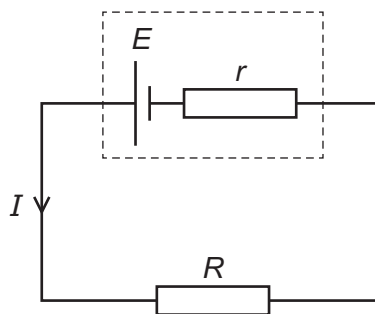
- 34 Which statement about the electromotive force (e.m.f.) of a cell is **always** correct?

- A The e.m.f. is the energy converted from electrical to other forms in the cell.
 B The e.m.f. is the energy provided by the cell per unit charge passing through it.
 C The e.m.f. is the potential difference across the internal resistance of the cell.
 D The e.m.f. is the potential difference across the terminals of the cell.

- 35 Kirchhoff's first and second laws are a consequence of the conservation of which quantities?

- A charge and energy
 B charge and resistance
 C mass and energy
 D mass and resistance

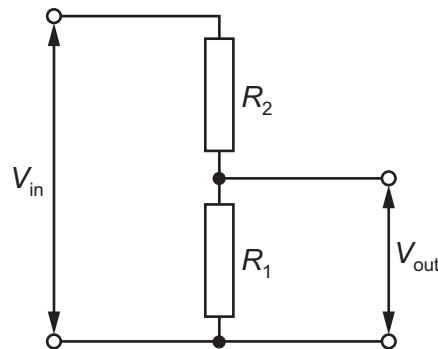
- 36 A circuit contains a cell of electromotive force E and internal resistance r connected to a resistor of resistance R . The current in the circuit is I .



Which equation is correct?

- A $E - Ir = IR$ B $E = Ir - IR$ C $E + Ir = IR$ D $E = IR$

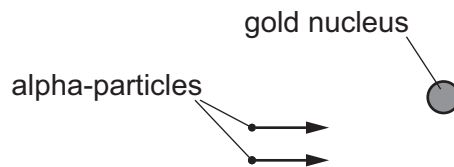
- 37 A potential divider consists of two resistors of resistances R_1 and R_2 connected in series across a source of potential difference (p.d.) V_{in} . The p.d. across R_1 is V_{out} .



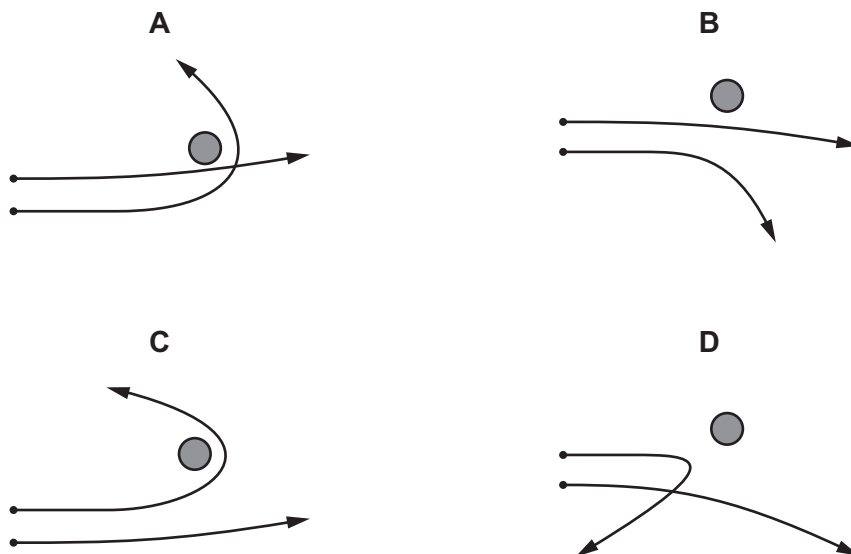
Which changes to R_1 and R_2 will increase the value of V_{out} ?

	R_1	R_2
A	doubled	doubled
B	doubled	halved
C	halved	doubled
D	halved	halved

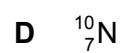
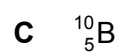
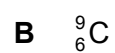
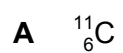
- 38 Two alpha-particles with the same kinetic energy are moving towards, and are then deflected by, a gold nucleus.



Which diagram could show the paths of the two alpha-particles?



39 Which nuclide is formed when $^{10}_6\text{C}$ undergoes β^+ decay?



40 A particular hadron is composed of three quarks and has zero charge.

What is a possible quark composition of the hadron?

A down, down, strange

B up, down, strange

C up, up, down

D up, up, strange

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unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

- 1 A student estimates the maximum speed of some different moving objects.

Which maximum speed is **not** a reasonable estimate?

- A container ship: 10 m s^{-1}
- B Olympic sprinter: 0.1 km s^{-1}
- C racing car: 9000 cm s^{-1}
- D snail: 0.01 km h^{-1}

- 2 Which quantity is an SI base quantity?

- A force
- B newton
- C second
- D time

- 3 A student takes measurements to determine the constant acceleration of a model car moving from rest in a straight line. The measured values with their absolute uncertainties are shown.

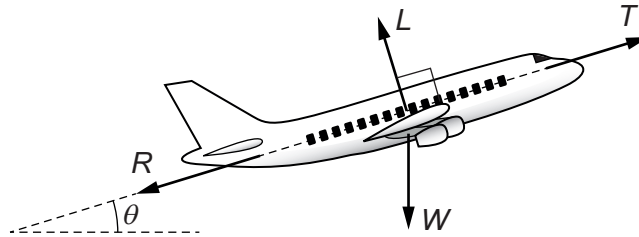
quantity	measured value	uncertainty
displacement	16.5 m	$\pm 0.1 \text{ m}$
time	15.0 s	$\pm 1.0 \text{ s}$

The student uses the equation $s = \frac{1}{2}at^2$ to calculate the acceleration of the car.

What is the acceleration and its absolute uncertainty?

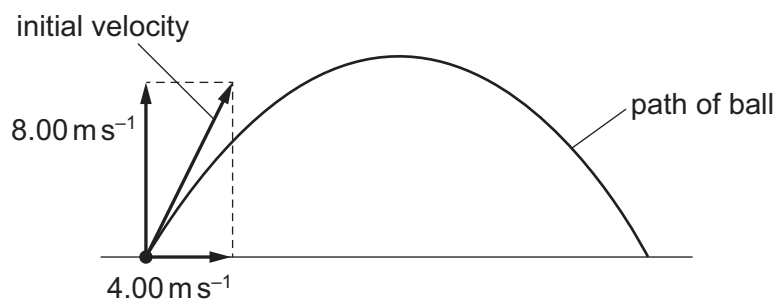
- A $(0.11 \pm 0.01) \text{ m s}^{-2}$
- B $(0.11 \pm 0.02) \text{ m s}^{-2}$
- C $(0.15 \pm 0.01) \text{ m s}^{-2}$
- D $(0.15 \pm 0.02) \text{ m s}^{-2}$

- 4 An aeroplane is moving at a constant speed in a straight line at an angle θ to the horizontal. Four forces act on the aeroplane: thrust force T , weight W , lift force L and resistive force R .



Which two equations must be correct?

- A** $L = W \cos \theta$ and $T = R + W \sin \theta$
- B** $L = W \sin \theta$ and $T = R + W \cos \theta$
- C** $L = W \cos \theta$ and $T = R - W \sin \theta$
- D** $L = W \sin \theta$ and $T = R - W \cos \theta$
- 5 What is the definition of acceleration?
- A** the rate of change of displacement
- B** the rate of change of kinetic energy
- C** the rate of change of momentum
- D** the rate of change of velocity
- 6 An astronaut on the Moon, where there is no air resistance, throws a ball. The ball's initial velocity has a vertical component of 8.00 m s^{-1} and a horizontal component of 4.00 m s^{-1} , as shown.

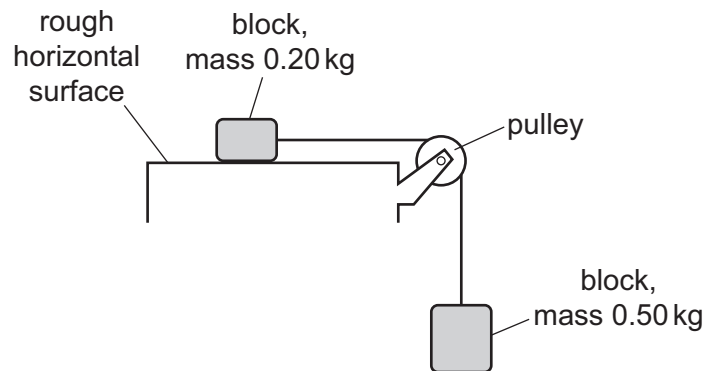


The acceleration of free fall on the Moon is 1.62 m s^{-2} .

What is the speed of the ball 9.00 s after being thrown?

- A** 6.58 m s^{-1} **B** 7.70 m s^{-1} **C** 10.6 m s^{-1} **D** 14.6 m s^{-1}

- 7 Two blocks, of mass 0.20 kg and 0.50 kg, are connected by a light inextensible string that passes over a frictionless pulley.



The blocks are initially held stationary. The block of mass 0.20 kg rests on a rough horizontal surface.

The block of mass 0.50 kg is suspended in air. Air resistance is negligible.

When the blocks are released, they have an acceleration of magnitude 2.0 m s^{-2} .

What is the magnitude of the frictional force between the block of mass 0.20 kg and the rough surface?

- A** 3.5 N **B** 3.9 N **C** 4.5 N **D** 6.3 N

- 8 A resultant force causes an object to accelerate.

What is equal to the resultant force?

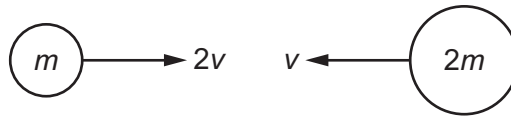
- A** the acceleration of the object per unit mass
B the change in kinetic energy of the object per unit time
C the change in momentum of the object per unit time
D the change in velocity of the object per unit time

- 9 An object falls from a stationary helicopter and reaches terminal velocity.

What happens to the acceleration of the object between leaving the helicopter and reaching terminal velocity?

- A** It decreases to 9.81 m s^{-2} .
B It decreases to zero.
C It increases to 9.81 m s^{-2} .
D It remains constant at 9.81 m s^{-2} .

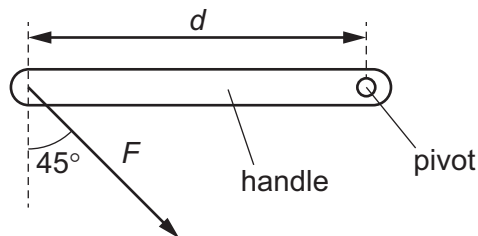
- 10 Two balls, of masses m and $2m$, travelling in a vacuum with initial velocities $2v$ and v respectively, collide with each other head-on, as shown.



After the collision, the ball of mass m rebounds to the left with velocity v .

What is the loss of kinetic energy in the collision?

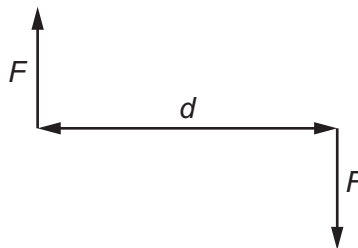
- A $\frac{3}{4}mv^2$ B $\frac{3}{2}mv^2$ C $\frac{9}{4}mv^2$ D $\frac{9}{2}mv^2$
- 11 A force F is applied at an angle of 45° to a door handle at a distance d from the pivot of the handle, as shown.



What is the moment of the force about the pivot?

- A $\frac{Fd}{\sqrt{2}}$ B Fd C $Fd\sqrt{2}$ D $2Fd$
- 12 A couple consists of two forces, each of magnitude F , that act in opposite directions in the same plane.

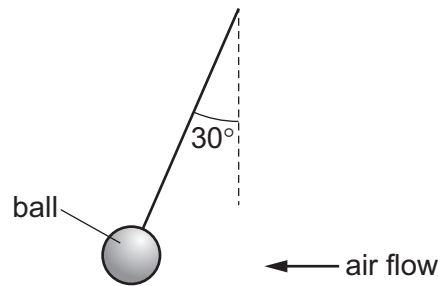
The perpendicular distance between the two forces is d .



What is the torque of the couple?

- A $\frac{Fd}{2}$ B $\frac{F}{d}$ C Fd D $2Fd$

- 13 The diagram shows an experiment to determine the force exerted on a ball by a horizontal air flow.

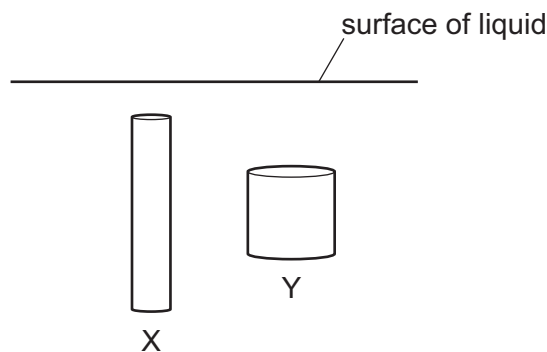


The ball is suspended by a light string and weighs 0.15 N.

The deflection of the string from vertical is 30° . The ball is in equilibrium.

What is the force on the ball from the air flow?

- A** 0.075 N **B** 0.087 N **C** 0.26 N **D** 0.30 N
- 14 Two solid cylindrical objects X and Y are held fully submerged in a liquid, as shown.



The objects have the same volume. The density of the material of Y is twice the density of the material of X. Both objects are stationary.

Which statement is correct?

- A** The force due to the liquid acting on the top surface of X is greater than that acting on the top surface of Y.
- B** The pressure difference due to the liquid between the top and bottom surfaces of X is the same as that for Y.
- C** The upthrust acting on X is the same as the upthrust acting on Y.
- D** The weight of X is the same as the weight of Y.

- 15** An electric car travels at a constant speed of 70 km h^{-1} for 80 km on a straight horizontal road and uses energy E from its battery.

The total resistive force acting on the car is proportional to $(\text{speed})^2$. Assume that the electric motor is 100% efficient.

How much energy is used from the battery when the car travels at a constant speed of 60 km h^{-1} for 80 km on the straight horizontal road?

- A** $0.73E$ **B** $0.86E$ **C** $1.2E$ **D** $1.4E$

- 16** What is meant by the efficiency of a system?

- A** the total energy input to the system divided by the useful energy output by the system
B the useful energy output from the system divided by the energy wasted by the system
C the useful energy output from the system divided by the total energy input to the system
D the energy wasted by the system divided by the total energy input to the system

- 17** When an object of mass m is raised through a vertical height Δh , the gain of its gravitational potential energy is ΔE_p .

ΔE_p and Δh are related by the equation

$$\Delta E_p = mg\Delta h,$$

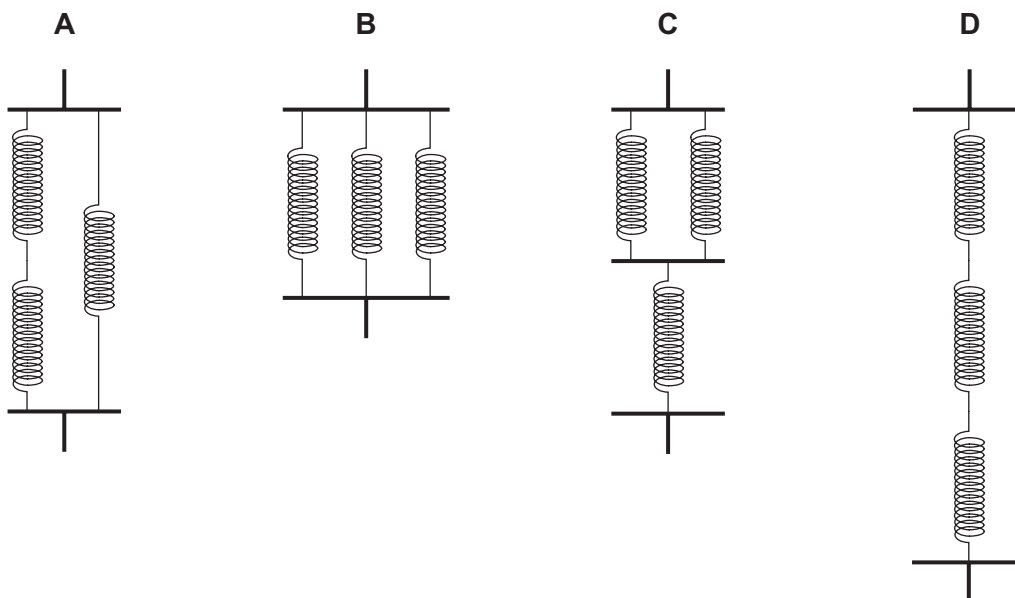
where g is the acceleration of free fall.

The definition of which physical quantity is needed to derive this equation?

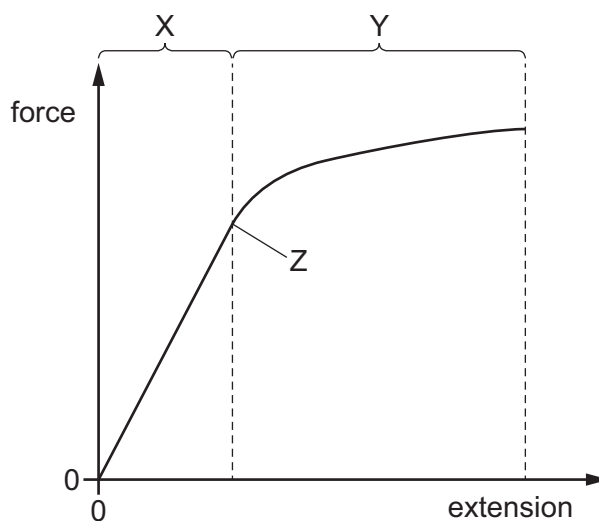
- A** acceleration
B momentum
C power
D work done

- 18 Three identical springs, each with the same spring constant, are connected together in four different arrangements, as shown.

Which arrangement has the largest combined spring constant?



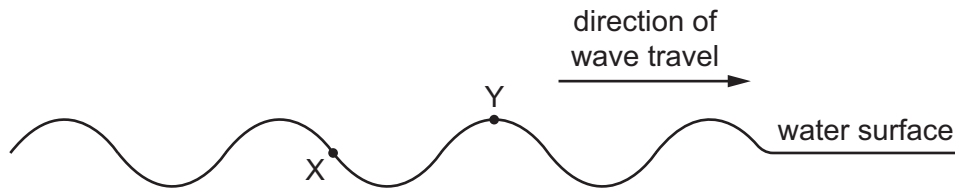
- 19 The force–extension graph for a wire is shown.



Which row could identify the labels X, Y and Z?

	limit of proportionality	region of elastic deformation	region of plastic deformation
A	X	Y	Z
B	Z	Y	X
C	Y	Z	X
D	Z	X	Y

- 20 X and Y are two points on the surface of water in a ripple tank. A source of constant frequency generates a wave which travels past X and Y, causing them to oscillate vertically.

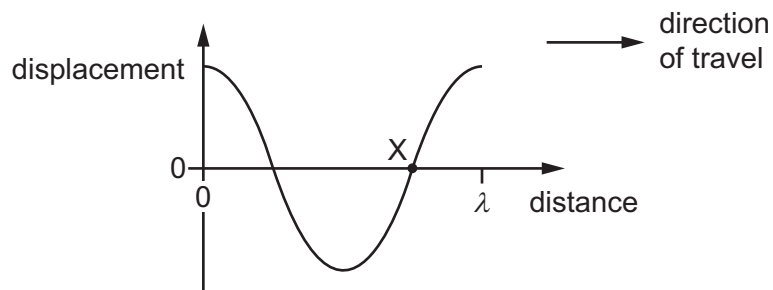


What is the phase difference between X and Y?

- A 45° B 135° C 180° D 270°

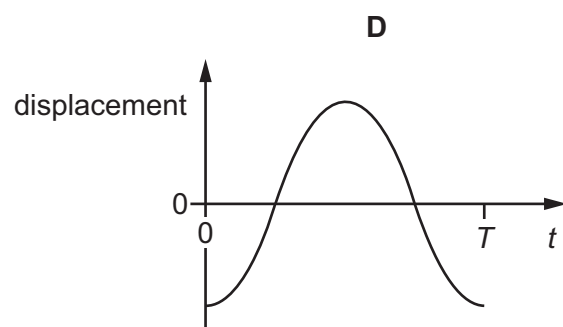
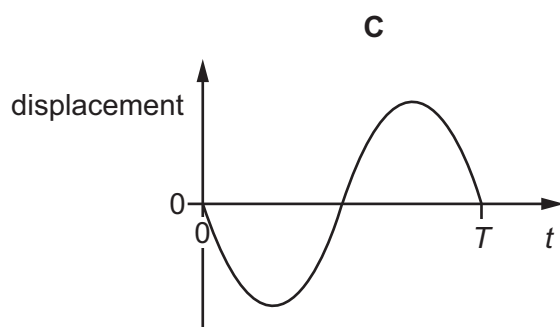
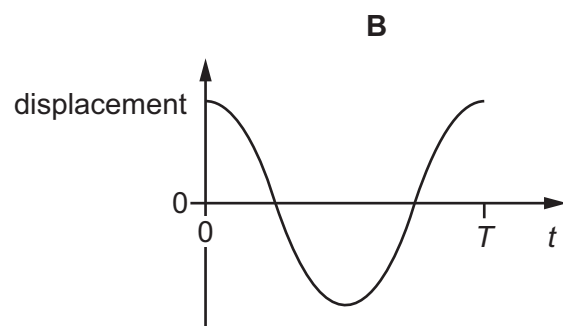
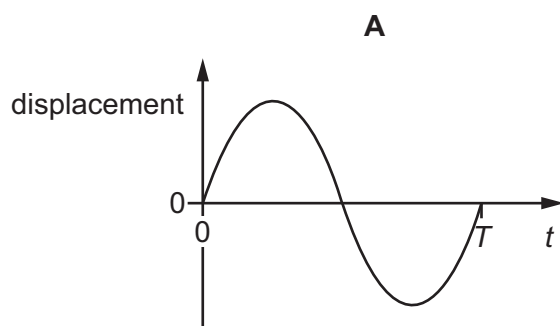
- 21 A transverse wave on a rope has wavelength λ and period T .

The graph shows the variation of the displacement of the particles of the rope with distance in the direction of travel of the wave at time $t = 0$.



A particle X is labelled.

Which graph shows the variation of the displacement of particle X with time t ?



- 22** A source of sound waves is moving at a constant speed directly towards a stationary observer.

The sound waves have a speed of 340 ms^{-1} and a frequency of 480 Hz . The observer hears sound waves of frequency 650 Hz .

What is the speed of the source?

- A** 89 ms^{-1} **B** 120 ms^{-1} **C** 250 ms^{-1} **D** 340 ms^{-1}

- 23** A student is investigating two electromagnetic waves, X and Y, in a vacuum.

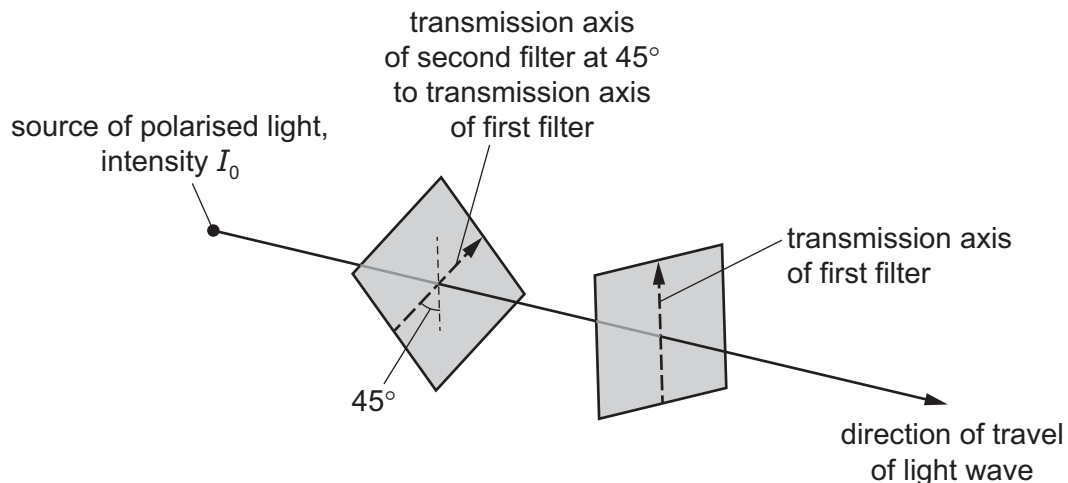
Wave X has a wavelength of $5.2 \times 10^{-7} \text{ m}$. Wave Y has a frequency of 9.4 GHz .

Which principal regions of the electromagnetic spectrum contain waves X and Y?

	X	Y
A	radio wave	ultraviolet
B	ultraviolet	visible
C	visible	microwave
D	microwave	radio wave

- 24** A plane polarised light wave of intensity I_0 is incident normally on a polarising filter. The initial intensity of the transmitted wave is 0.

A second polarising filter is then inserted between the source and the first filter. Its transmission axis is at 45° to the transmission axis of the first filter, as shown.



What is the intensity of the transmitted wave from the filter combination?

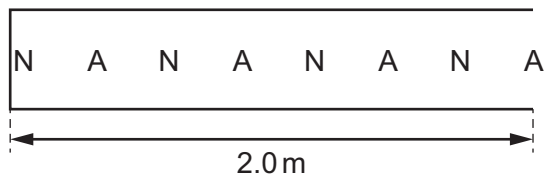
- A** 0 **B** $\frac{I_0}{8}$ **C** $\frac{I_0}{4}$ **D** $\frac{I_0}{2}$

25 What can explain how stationary waves are formed from progressive waves?

- A** diffraction
- B** polarisation
- C** superposition
- D** the Doppler effect

26 A pipe has a length of 2.0 m. It is open at one end and closed at the other end.

A stationary sound wave is set up within the pipe. There are four nodes (N) and four antinodes (A) within the length of the pipe.



What is the wavelength of the sound wave?

- A** 0.57 m
- B** 1.1 m
- C** 1.3 m
- D** 1.6 m

27 A teacher is explaining diffraction to a group of students.

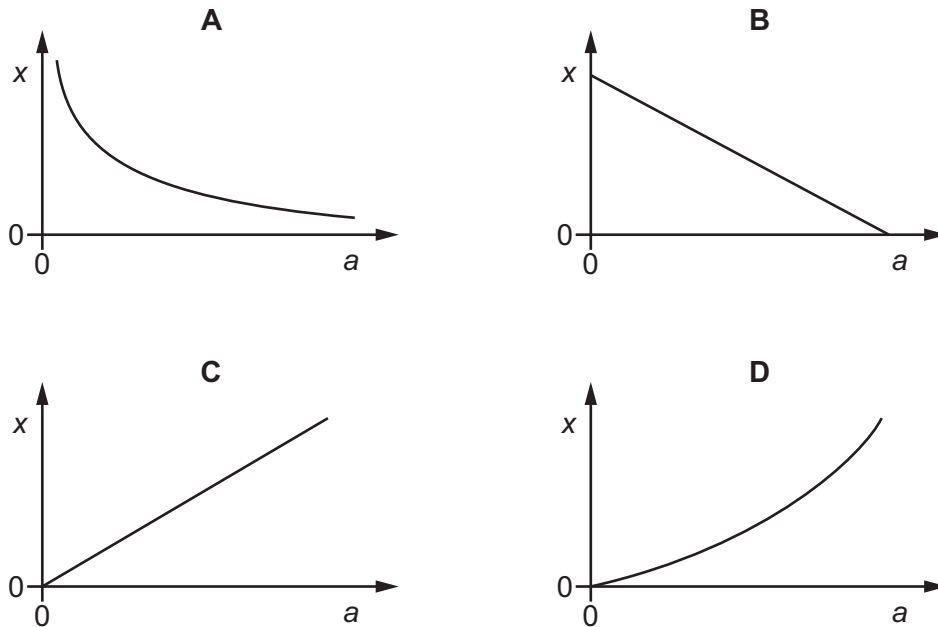
Which piece of apparatus is most appropriate for the teacher to use to demonstrate diffraction?

- A** a long spring
- B** a ripple tank
- C** a rope
- D** a stretched string

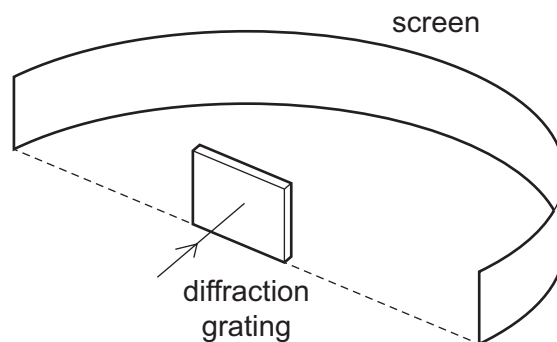
- 28 Coherent light of constant wavelength is incident normally on a double slit. Interference fringes are formed on a screen that is a fixed distance from the double slit. The screen is parallel to the double slit.

The separation of the slits is varied.

Which graph best shows the variation with slit separation a of the spacing x of the interference fringes?



- 29 Light of wavelength 690 nm passes through a diffraction grating with 300 lines per mm, producing a series of bright spots (maxima) on a screen.



What is the total number of bright spots that are produced?

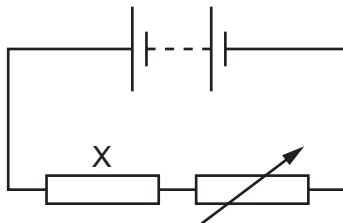
- A** 4 **B** 5 **C** 8 **D** 9

- 30 A fine mist of oil droplets is sprayed into air. As the oil droplets leave the nozzle of the spraying device they can become electrically charged.

What is **not** a possible value for the charge on an oil droplet?

- A zero
- B $1.0 \times 10^{-19} \text{ C}$
- C $4.8 \times 10^{-19} \text{ C}$
- D $8.0 \times 10^{-19} \text{ C}$

- 31 In the circuit shown, a fixed resistor X is connected in series with a battery and a variable resistor.



The power dissipated in resistor X is 7.2 W when a current of 3.0 A passes through it.

The variable resistor is adjusted so that the power dissipated in X increases by 50%.

What is the new current in the circuit?

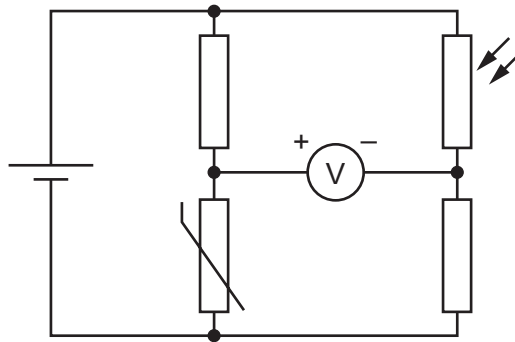
- A 2.4 A
- B 3.7 A
- C 4.5 A
- D 14 A

- 32 The potential difference across a metal wire is kept constant. The length l and the diameter d of the wire are both varied. The type of metal is kept the same.

How is the current in the wire related to l and d ?

- A It is directly proportional to l and inversely proportional to d .
- B It is directly proportional to l and inversely proportional to d^2 .
- C It is inversely proportional to l and directly proportional to d .
- D It is inversely proportional to l and directly proportional to d^2 .

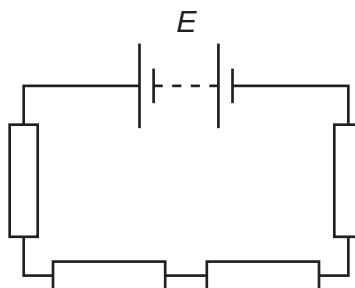
- 33 A student sets up a circuit. The circuit diagram shows how the positive and negative terminals of a voltmeter are connected to the circuit. The voltmeter has an initial reading that is positive.



Which changes, if any, in temperature and light intensity would cause the voltmeter reading to **decrease**?

	temperature	light intensity
A	increase	increase
B	no change	decrease
C	decrease	no change
D	decrease	decrease

- 34 Some resistors and a battery of electromotive force (e.m.f.) E and negligible internal resistance are connected in series, as shown.



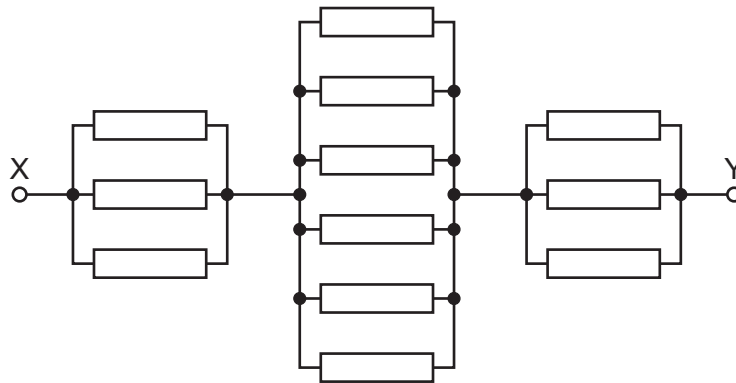
Which statement is correct?

- A** The e.m.f. across each resistor equals the potential difference across the battery.
- B** The potential difference across each resistor equals the e.m.f. E of the battery.
- C** The sum of the e.m.f.s across the resistors equals the potential difference across the battery.
- D** The sum of the potential differences across the resistors equals the e.m.f. E of the battery.

35 Kirchhoff's first law is a consequence of the conservation of which physical quantity?

- A charge
- B energy
- C linear momentum
- D potential difference

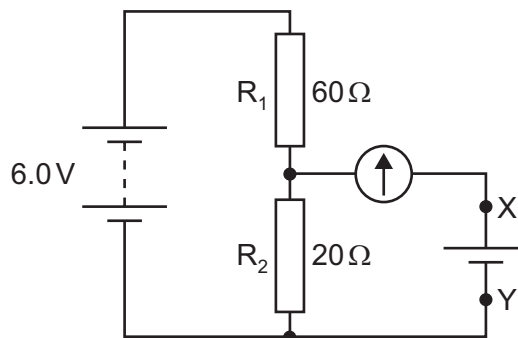
36 The diagram shows a network of resistors. Each resistor has a resistance of $6.0\ \Omega$.



What is the total resistance of the network between points X and Y?

- A $3.0\ \Omega$
- B $5.0\ \Omega$
- C $7.2\ \Omega$
- D $18\ \Omega$

37 In the circuit shown, a battery of negligible internal resistance is connected in series with a pair of fixed resistors R_1 and R_2 .



The circuit is to be used to test whether the electromotive force (e.m.f.) of a particular cell is $1.5\ \text{V}$. The cell is connected between terminals X and Y in parallel with R_2 and in series with a galvanometer.

Which statement about the test is correct?

- A Any non-zero reading on the galvanometer means the cell has an e.m.f. of $1.5\ \text{V}$.
- B The battery does not need to have an e.m.f. of $6.0\ \text{V}$.
- C The cell may be connected either way round between X and Y.
- D The galvanometer does not need a scale calibrated in amperes.

- 38 Two nuclides are different isotopes of the same element.

Which statement about the nuclides is correct?

- A Neutral atoms of the nuclides have the same number of electrons.
- B Nuclei of the nuclides have different numbers of protons.
- C Nuclei of the nuclides have the same number of nucleons.
- D Nuclei of the nuclides have the same number of neutrons.

- 39 The charge-to-mass ratio r of a particle is given by the equation shown.

$$r = \frac{\text{charge on particle}}{\text{mass of particle}}$$

The value of r is determined for an α -particle, a β^+ particle and a proton p .

Which list shows the particles in order of increasing magnitude of r from left to right?

- A $\alpha \rightarrow \beta^+ \rightarrow p$
- B $\alpha \rightarrow p \rightarrow \beta^+$
- C $p \rightarrow \alpha \rightarrow \beta^+$
- D $p \rightarrow \beta^+ \rightarrow \alpha$

- 40 Which combination of up (u) and down (d) quarks forms a neutron?

- A u u u
- B u u d
- C u d d
- D d d d

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Cambridge International AS & A Level

PHYSICS

9702/13

Paper 1 Multiple Choice

October/November 2023

1 hour 15 minutes

You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)

INSTRUCTIONS

- There are **forty** questions on this paper. Answer **all** questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.

This document has **20** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
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rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

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upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

1 What is the best estimate of the wavelength of green light?

- A** 260 nm **B** 540 nm **C** 780 nm **D** 920 nm

2 In an electric circuit, an ammeter reads $2\ \mu\text{A}$.

In a second circuit, the ammeter reads 1 mA.

How many times larger is the current in the second circuit compared with the current in the first circuit?

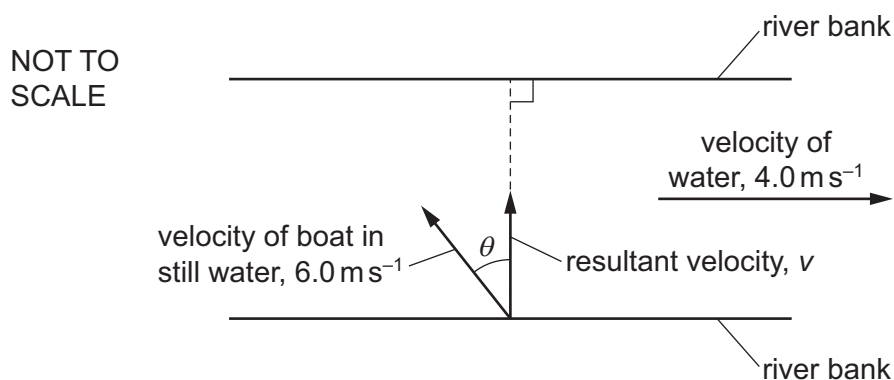
- A** 500 **B** 5000 **C** 500 000 **D** 5 000 000

3 A set of repeated measurements is made of a fixed quantity. An average of these measurements is calculated.

What is the effect of averaging on the random error and the systematic error in the measurements?

- A** Random error and systematic error are both reduced.
B Random error and systematic error are both unaffected.
C Random error is reduced but systematic error is unaffected.
D Random error is unaffected but systematic error is reduced.

- 4 A boat is crossing a river in which the water is moving at a speed of 4.0 m s^{-1} from left to right.



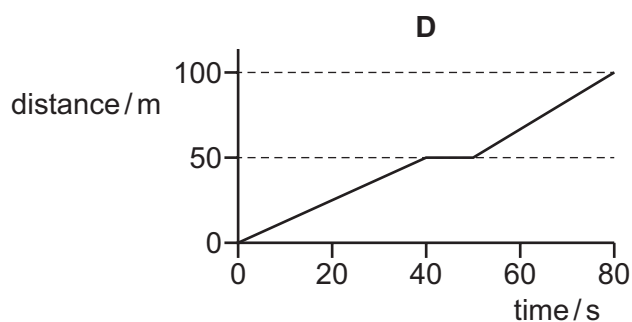
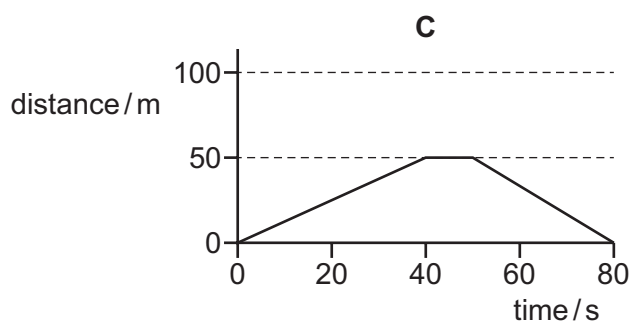
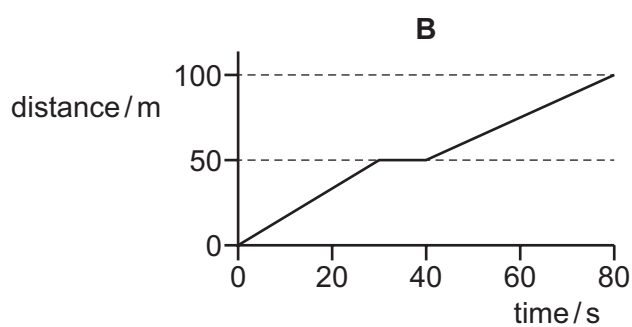
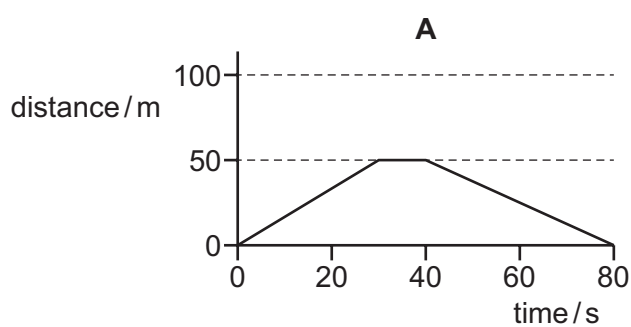
In still water, the speed of the boat is 6.0 m s^{-1} . The boat is directed at an angle θ to a line perpendicular to the river banks. The resultant velocity v of the boat is in a direction perpendicular to the river banks.

What are the values of θ and v ?

	$\theta / ^\circ$	$v / \text{m s}^{-1}$
A	42	4.5
B	42	7.2
C	48	4.5
D	48	7.2

- 5 A student walks at a constant speed for a distance of 50 m in a time of 40 s. The student rests for a time of 10 s and then walks back to the starting point at a constant speed in a time of 30 s.

What is the distance–time graph for the motion of the student?



- 6 The time taken for an object to fall from rest through a certain distance on Mars is T_M . The time taken for the same object to fall from rest through the same distance on Earth is T_E . The acceleration of free fall on Mars is 3.71 m s^{-2} .

Assume that air resistance is negligible on both Earth and Mars.

What is the ratio $\frac{T_M}{T_E}$?

- A** 0.378 **B** 0.615 **C** 1.63 **D** 2.64

- 7 Which statement about mass is correct?

- A** Mass has a magnitude and a direction.
B Mass resists changes in motion.
C The greater the mass of an object, the greater its acceleration when falling in a vacuum.
D The mass of an object depends on its location.

- 8 A snooker ball has a mass of 200 g. It hits the cushion of a snooker table and rebounds along its original path.

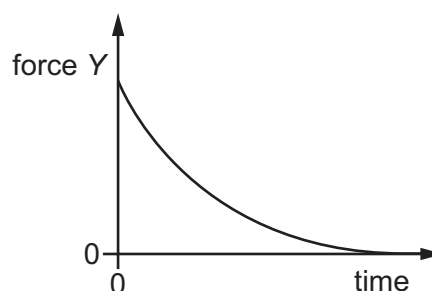
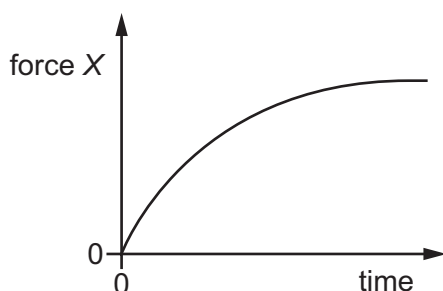
The ball arrives at the cushion with a speed of 14.0 m s^{-1} and then leaves it with a speed of 7.0 m s^{-1} . The ball and the cushion are in contact for a time of 0.60 s.

What is the average force exerted on the ball by the cushion?

- A** 1.4 N **B** 2.3 N **C** 4.2 N **D** 7.0 N

- 9 A ball falls from rest through air and eventually reaches a constant velocity.

For this fall, forces X and Y vary with time as shown.

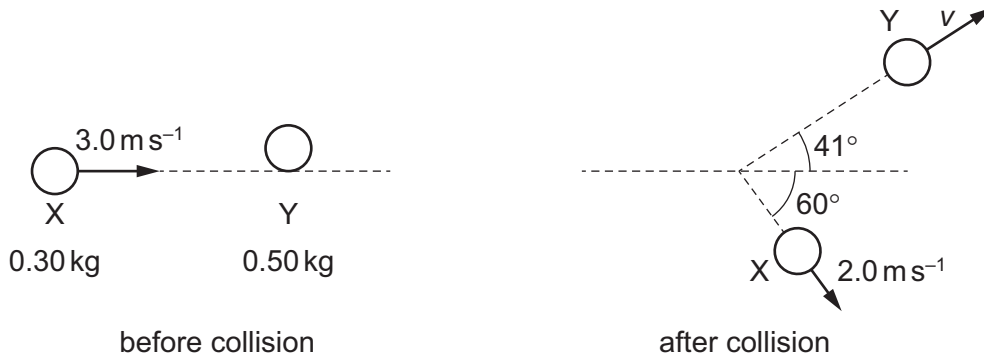


What could be forces X and Y ?

	force X	force Y
A	air resistance	resultant force
B	air resistance	weight
C	upthrust	resultant force
D	upthrust	weight

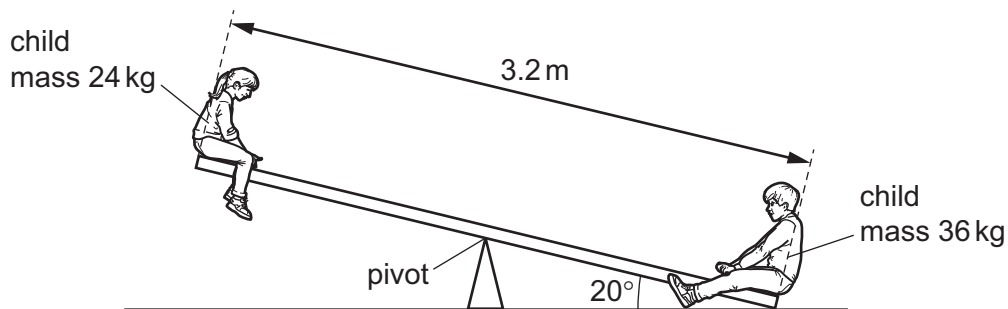
- 10** An object X of mass 0.30 kg is travelling in a straight line at a constant velocity of 3.0 ms^{-1} on a horizontal frictionless surface. Object X collides with a stationary object Y of mass 0.50 kg .

After the collision, X moves with a velocity of 2.0 ms^{-1} at an angle of 60° to its direction before the collision. Object Y moves with a velocity v at an angle of 41° to the direction of X before the collision, as shown.



What is the value of v ?

- A** 0.80 ms^{-1} **B** 1.2 ms^{-1} **C** 1.6 ms^{-1} **D** 1.8 ms^{-1}
- 11** A uniform rigid beam of length 3.2 m is pivoted at its centre. Two children sit at the opposite ends of the beam, as shown.

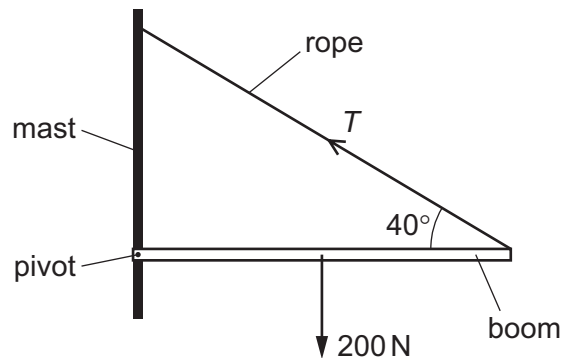


One child has a mass of 24 kg . The other child has a mass of 36 kg . The heavier child causes one end of the beam to permanently rest on the ground, so that the beam makes an angle of 20° to the horizontal ground.

What is the moment of the weight of the 24 kg child about the pivot?

- A** 72 Nm **B** 130 Nm **C** 350 Nm **D** 380 Nm

- 12** Two parts of a sailing boat are the mast and the boom. The mast is a vertical rigid beam and the boom is a horizontal rigid beam. One end of the boom is attached to the mast by a pivot. The other end of the boom is connected to the mast by a rope, as shown.



The rope is at an angle of 40° to the horizontal and exerts a tension force T on the boom. The weight of the boom is 200 N. The mass of the boom is uniformly distributed along its length. The boom is in equilibrium.

What is the magnitude of T ?

- A** 130 N **B** 160 N **C** 260 N **D** 310 N
- 13** Full-fat milk is made up of fat-free milk mixed with fat.

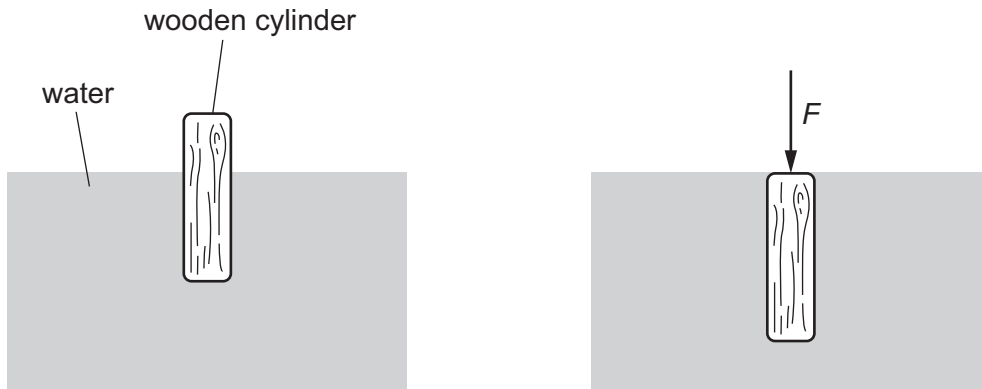
A volume of $1.000 \times 10^{-3} \text{ m}^3$ of full-fat milk has a mass of 1.035 kg. It contains 4.00% fat by volume.

The density of fat-free milk is $1.040 \times 10^3 \text{ kg m}^{-3}$.

What is the density of fat?

- A** $1.25 \times 10^2 \text{ kg m}^{-3}$
B $9.15 \times 10^2 \text{ kg m}^{-3}$
C $9.28 \times 10^2 \text{ kg m}^{-3}$
D $1.16 \times 10^3 \text{ kg m}^{-3}$
- 14** Which expression for pressure is correct?
- A** force per unit area
B mass per unit area
C mass per unit volume
D weight per unit volume

- 15 A wooden cylinder floats partially submerged in a bath of water. A force F is applied to the cylinder until it is just fully submerged.



Which statement is **not** correct?

- A Some of the water gains gravitational potential energy.
 - B The cylinder loses gravitational potential energy.
 - C Work is done by force F on the cylinder.
 - D Work is done by the upthrust on the cylinder.
- 16 A system has a useful power output of 4.0 W and a wasted power of 16 W.
- What is the efficiency of the system?
- A 5.0%
 - B 20%
 - C 25%
 - D 80%
- 17 A parachutist is falling towards the ground at a constant speed v . The rate at which she is losing gravitational potential energy is R .

The acceleration of free fall is g .

What is the mass of the parachutist?

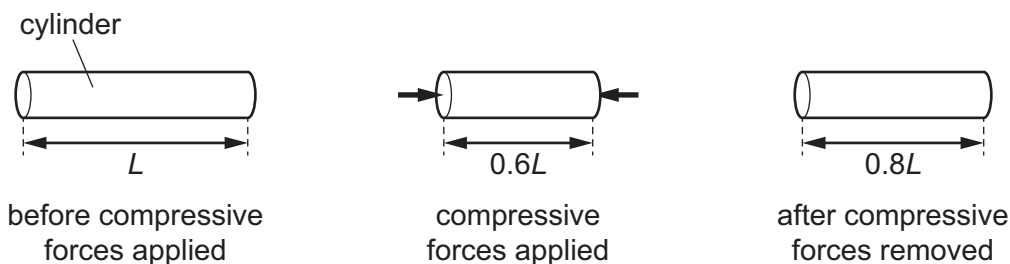
- A $\frac{gv}{R}$
 - B $\frac{R}{gv}$
 - C $\frac{2R}{v^2}$
 - D $\frac{v^2}{2R}$
- 18 A copper wire of diameter 1.6 mm is stretched within its limit of proportionality by a tensile force of 430 N.

The Young modulus of copper is 130 GPa.

What is the strain in the wire?

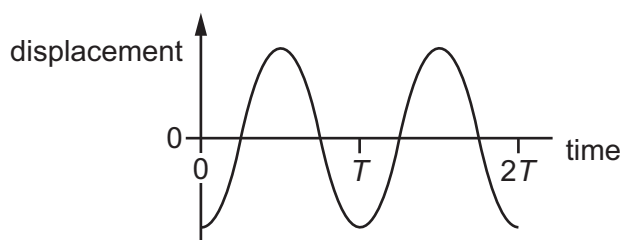
- A 4.1×10^{-4}
- B 1.3×10^{-3}
- C 1.6×10^{-3}
- D 5.2×10^{-3}

- 19 Compressive forces are applied normally to the end faces of a cylinder of initial length L . The cylinder is compressed by the forces so that its length decreases to $0.6L$. After the compressive forces are removed, the cylinder's length increases to $0.8L$.

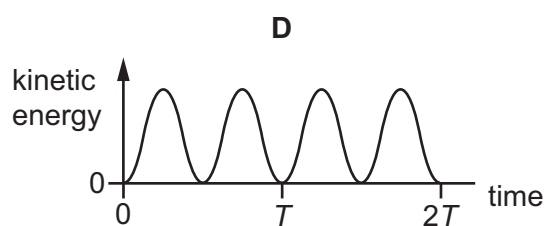
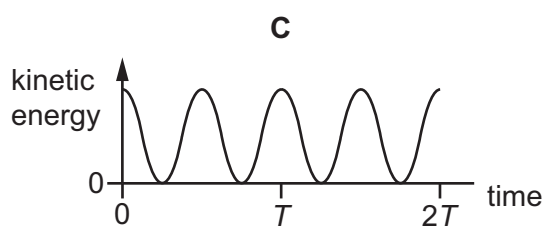
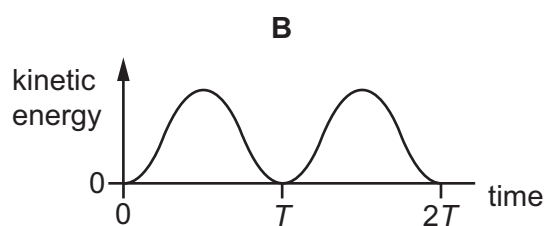
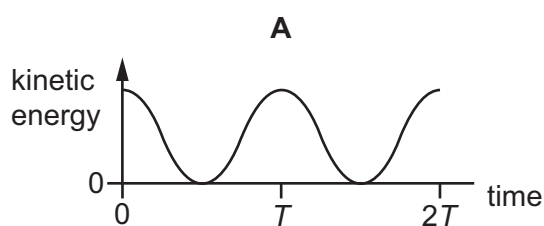


What describes the deformation of the cylinder when its length was $0.6L$?

- A both elastic and plastic
 B elastic only
 C plastic only
 D neither elastic nor plastic
- 20 When sound travels through air, the air particles vibrate. A graph of displacement against time for a single air particle is shown.

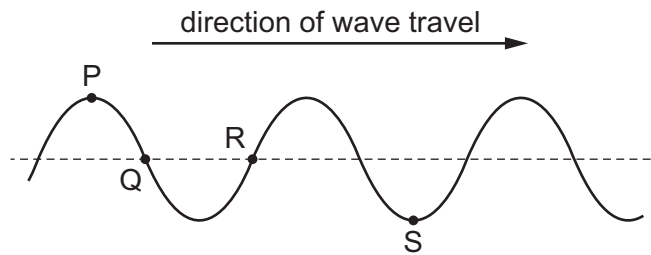


Which graph shows how the kinetic energy of the air particle varies with time?



- 21** A wave travels on the surface of water. P, Q, R and S are four particles of water on the surface.

The diagram shows the positions of the particles at one instant. The direction of travel of the wave is from left to right.

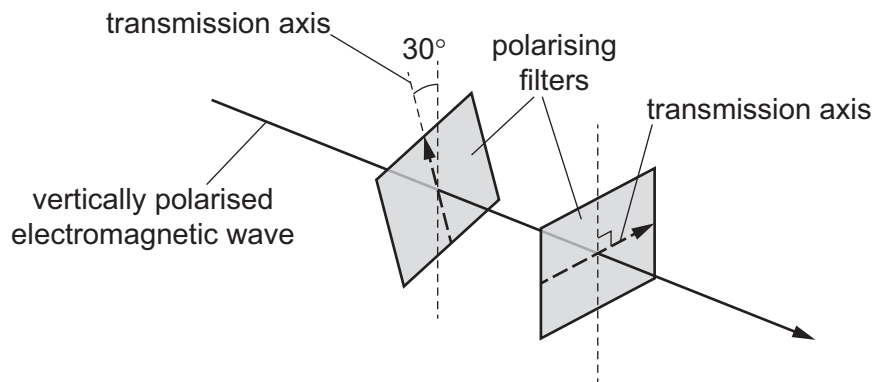


Which two particles are about to move upwards?

- A** P and R **B** P and S **C** R and S **D** Q and S
- 22** A loudspeaker emits sound of frequency f_s . The loudspeaker is attached to a car that moves with increasing speed directly towards a stationary observer.
- Which statement describes the frequency of the sound heard by the observer?
- A** a frequency greater than f_s and increasing
B a frequency greater than f_s but decreasing
C a frequency less than f_s and decreasing
D a frequency less than f_s but increasing
- 23** Which statement about electromagnetic waves in a vacuum is correct?
- A** Amplitude is inversely proportional to velocity.
B Frequency is inversely proportional to wavelength.
C Intensity is proportional to amplitude.
D Velocity is proportional to wavelength.

- 24** A vertically polarised electromagnetic wave of intensity I_0 is incident normally on a polarising filter. The transmission axis of the filter is at an angle of 30° to the vertical.

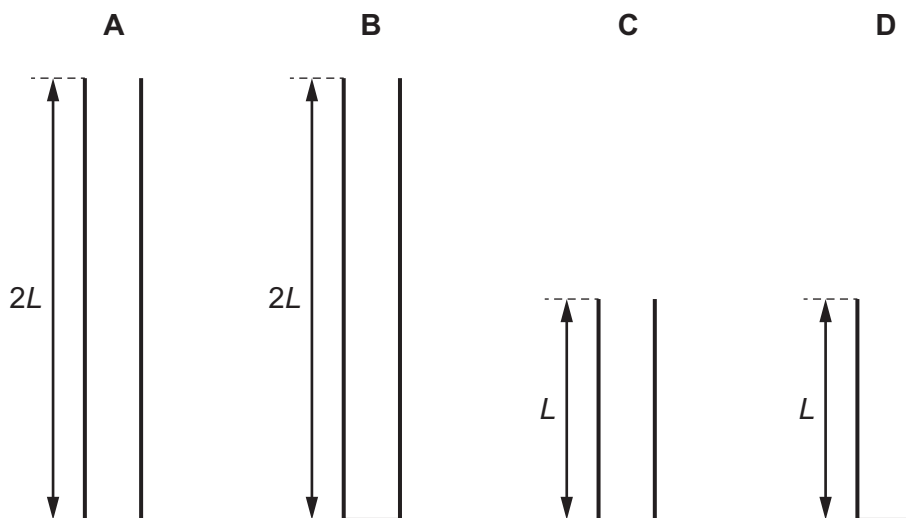
The transmitted wave from the first filter is then incident normally on a second polarising filter. The transmission axis of this filter is at an angle of 90° to the vertical.



What is the intensity of the wave after passing through the second filter?

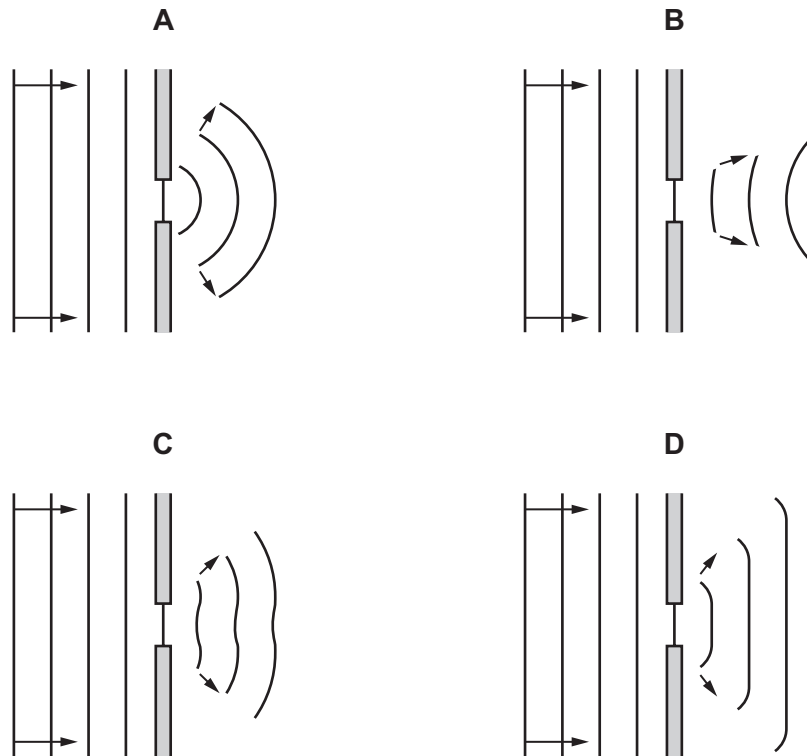
- A** 0 **B** $0.063 I_0$ **C** $0.19 I_0$ **D** $0.56 I_0$
- 25** Which statement concerning a stationary wave is correct?
- A** All the particles between two adjacent nodes oscillate in phase.
- B** The amplitude of the stationary wave is equal to the amplitude of one of the waves creating it.
- C** The wavelength of the stationary wave is equal to the separation of two adjacent nodes.
- D** There is no displacement of a particle at an antinode at any time.
- 26** Stationary sound waves can be formed in the air columns of pipes. One type of pipe is closed at one end and open at the other end. Another type of pipe is open at both ends.

Which pipe can form a stationary sound wave with the lowest frequency?



- 27** Water waves in a ripple tank are made to pass through a small gap, as shown.

Which diagram shows the waves after they have passed through the gap?

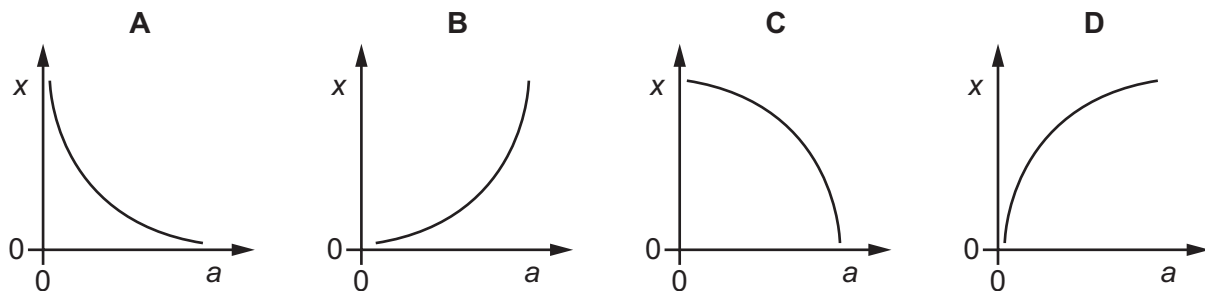


- 28** Light of a single wavelength is incident normally on a double slit. The slit separation can be varied.

A screen is placed a fixed distance away from the double slit. The screen and double slit are parallel. A pattern of bright interference fringes is observed on a screen.

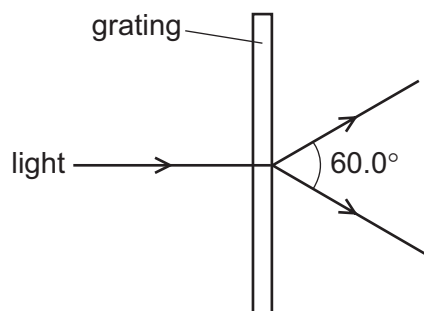


Which graph best shows the variation of the separation x of the bright interference fringes with the slit separation a ?



- 29 A diffraction grating is used to measure the wavelength of light.

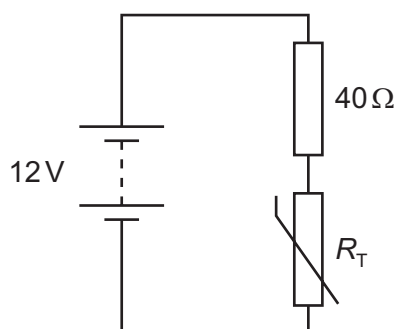
The spacing of the slits in the grating is $1.15 \times 10^{-6} \text{ m}$. The angle between the first-order diffraction maxima is 60.0° , as shown.



What is the wavelength of the light?

- A 288 nm B 498 nm C 575 nm D 996 nm
- 30 What could **not** be used to create an electric current?
- A alpha-particles
B beta-particles
C neutrons
D protons
- 31 What is the definition of the potential difference (p.d.) across a component?
- A the energy transferred per unit charge
B the energy transferred per unit current
C the power transferred per unit charge
D the power transferred per unit current
- 32 The resistance of a filament lamp increases as the current in it increases.
- What is the reason for this?
- A The charge of each charge carrier increases.
B The potential difference across the filament decreases.
C The power dissipated by the filament decreases.
D The temperature of the filament increases.

- 33** A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a fixed resistor of resistance $40\ \Omega$ and a thermistor of resistance R_T , as shown.



Initially, the temperature of the thermistor is 15°C and the current in the circuit is 0.10 A.

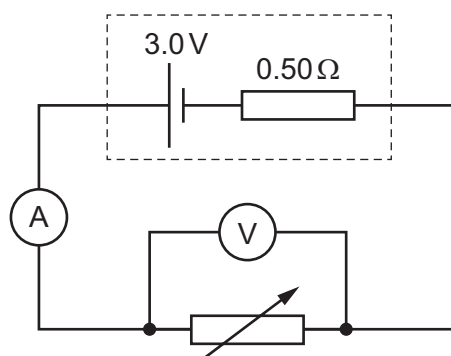
The temperature of the thermistor then changes, which causes the current to increase to 0.12 A.

How does the temperature of the thermistor change and what is R_T at the new temperature?

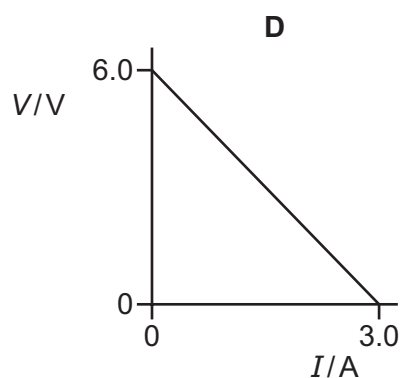
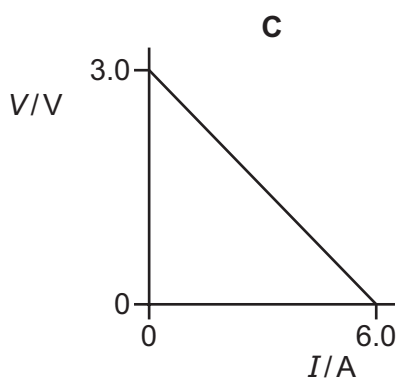
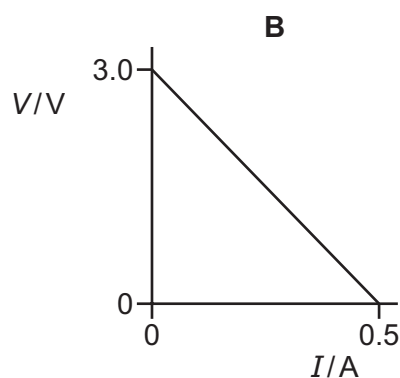
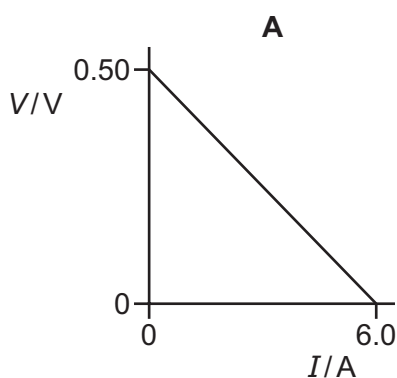
	temperature of thermistor	R_T at new temperature / Ω
A	increases	60
B	decreases	60
C	increases	100
D	decreases	100

- 34** A cell of electromotive force (e.m.f.) 3.0 V and internal resistance 0.50Ω is connected to a variable resistor, a voltmeter and an ammeter, as shown. The resistance of the variable resistor is varied.

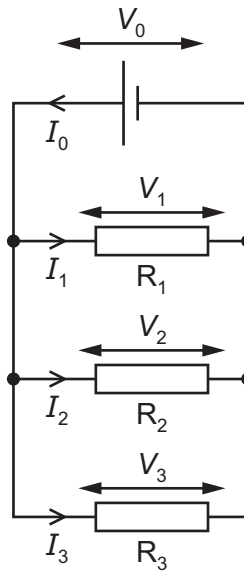
The reading on the ammeter I and the reading on the voltmeter V are recorded.



Which graph shows how V varies with I ?

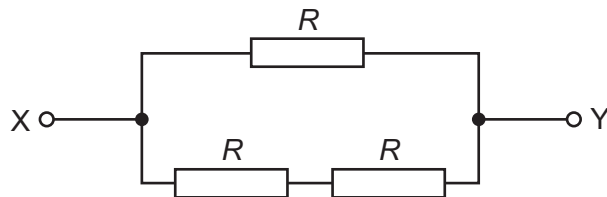


- 35** Three resistors, R_1 , R_2 and R_3 , are connected in parallel to a cell. The currents in the resistors are I_1 , I_2 and I_3 . The potential differences across the resistors are V_1 , V_2 and V_3 . The current in the cell is I_0 . The potential difference across the cell is V_0 , as shown.



Which equation can be obtained by applying Kirchhoff's second law to the circuit?

- A** $I_0 = I_1 = I_2 = I_3$
B $I_0 = I_1 + I_2 + I_3$
C $V_0 = V_1 = V_2 = V_3$
D $V_0 = V_1 + V_2 + V_3$
- 36** Three resistors, each of resistance R , are connected in a network, as shown.



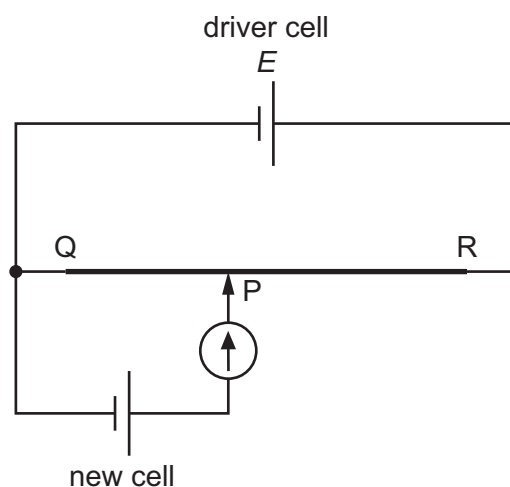
The total resistance between points X and Y is $8.0\ \Omega$.

What is the value of R ?

- A** $2.7\ \Omega$ **B** $4.0\ \Omega$ **C** $5.3\ \Omega$ **D** $12\ \Omega$

- 37 A potentiometer and a driver cell of electromotive force (e.m.f.) E are used to measure the e.m.f. of a new cell.

A sliding contact at P is moved along a resistance wire QR until the reading on the galvanometer is zero.



What is an essential requirement for the e.m.f. of the new cell to be measured accurately?

- A The e.m.f. of the driver cell must be less than the e.m.f. of the new cell.
 - B The galvanometer must have a large resistance.
 - C The internal resistance of the new cell must be zero.
 - D The resistance per unit length of the wire QR must be constant.
- 38 The table shows the number of nucleons and the total number of particles (protons, neutrons and electrons) in neutral atoms of four nuclides W, X, Y and Z.

	number of nucleons	total number of particles
W	19	30
X	19	31
Y	21	32
Z	22	31

Which two nuclides are isotopes of each other?

- A W and X
- B W and Y
- C X and Z
- D Y and Z

- 39** When a sample of a radioactive isotope decays by α -particle emission, the α -particles emitted have a single discrete energy.

When a sample of a radioactive isotope decays by β^- particle emission, the β^- particles emitted have a continuous range of energies.

What is the explanation for this?

- A** An antineutrino is emitted with a β^- particle but not with an α -particle.
 - B** An antineutrino is emitted with an α -particle but not with a β^- particle.
 - C** The α -particles have much more energy than the β^- particles.
 - D** The β^- particles have much more energy than the α -particles.
- 40** Some particles are a combination of three quarks.

Which combination of quarks does **not** result in a particle with a charge of either $+1.6 \times 10^{-19} \text{ C}$ or zero?

- A** up, down, down
- B** up, strange, strange
- C** up, up, down
- D** up, up, up

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