AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________

A-level
PHYSICS

Paper 1

Monday 4 June 2018   Afternoon   Time allowed: 2 hours

Materials
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 85.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7–31	
TOTAL	

A-level Physics data and formulae

For use in exams from the June 2017 Series onwards

DATA - FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\ s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\ m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\ m^{2}\ kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\ m^{-2}\ K^{-4}}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	$\mathrm{C\ kg^{-1}}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^{7}	$\mathrm{C\ kg^{-1}}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$\mathrm{N\ kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\ s^{-2}}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.97×10^{24}	6.37×10^{6}

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
curved surface area of cylinder	$= 2\pi rh$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

		Lepton number
Particles:	$e^-, \nu_e ; \mu^-, \nu_\mu$	+1
Antiparticles:	$e^+, \overline{\nu_e}, \mu^+, \overline{\nu_\mu}$	−1

Photons and energy levels

photon energy $E = hf = \frac{hc}{\lambda}$

photoelectricity $hf = \phi + E_{k\,(max)}$

energy levels $hf = E_1 - E_2$

de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

Waves

wave speed $c = f\lambda$ *period* $f = \frac{1}{T}$

first harmonic $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

fringe spacing $w = \frac{\lambda D}{s}$ *diffraction grating* $d \sin\theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 and n_2,

law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

critical angle $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

moments moment $= Fd$

velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

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

$v^2 = u^2 + 2as$ $s = ut + \frac{at^2}{2}$

force $F = ma$

force $F = \frac{\Delta(mv)}{\Delta t}$

impulse $F\Delta t = \Delta(mv)$

work, energy and power $W = Fs\cos\theta$

$E_k = \frac{1}{2}mv^2$ $\Delta E_p = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

$efficiency = \frac{useful\ output\ power}{input\ power}$

Materials

density $\rho = \frac{m}{V}$ *Hooke's law* $F = k\Delta L$

Young modulus $= \frac{tensile\ stress}{tensile\ strain}$ *tensile stress* $= \frac{F}{A}$ *tensile strain* $= \frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

Electricity

current and pd	$I = \frac{\Delta Q}{\Delta t}$ $\quad V = \frac{W}{Q}$ $\quad R = \frac{V}{I}$
resistivity	$\rho = \frac{RA}{L}$
resistors in series	$R_T = R_1 + R_2 + R_3 + \ldots$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$
power	$P = VI = I^2R = \frac{V^2}{R}$
emf	$\varepsilon = \frac{E}{Q}$ $\quad \varepsilon = I(R + r)$

Circular motion

magnitude of angular speed	$\omega = \frac{v}{r}$
	$\omega = 2\pi f$
centripetal acceleration	$a = \frac{v^2}{r} = \omega^2 r$
centripetal force	$F = \frac{mv^2}{r} = m\omega^2 r$

Simple harmonic motion

acceleration	$a = -\omega^2 x$
displacement	$x = A\cos(\omega t)$
speed	$v = \pm\omega\sqrt{(A^2 - x^2)}$
maximum speed	$v_{\max} = \omega A$
maximum acceleration	$a_{\max} = \omega^2 A$
for a mass-spring system	$T = 2\pi\sqrt{\frac{m}{k}}$
for a simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$

Thermal physics

energy to change temperature	$Q = mc\Delta\theta$
energy to change state	$Q = ml$
gas law	$pV = nRT$
	$pV = NkT$
kinetic theory model	$pV = \frac{1}{3}Nm(c_{\mathrm{rms}})^2$
kinetic energy of gas molecule	$\frac{1}{2}m(c_{\mathrm{rms}})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$

Gravitational fields

force between two masses	$F = \frac{Gm_1m_2}{r^2}$
gravitational field strength	$g = \frac{F}{m}$
magnitude of gravitational field strength in a radial field	$g = \frac{GM}{r^2}$
work done	$\Delta W = m\Delta V$
gravitational potential	$V = -\frac{GM}{r}$
	$g = -\frac{\Delta V}{\Delta r}$

Electric fields and capacitors

force between two point charges	$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$
force on a charge	$F = EQ$
field strength for a uniform field	$E = \frac{V}{d}$
work done	$\Delta W = Q\Delta V$
field strength for a radial field	$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$
electric potential	$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$
field strength	$E = \frac{\Delta V}{\Delta r}$
capacitance	$C = \frac{Q}{V}$
	$C = \frac{A\varepsilon_0\varepsilon_r}{d}$
capacitor energy stored	$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$
capacitor charging	$Q = Q_0(1 - e^{-\frac{t}{RC}})$
decay of charge	$Q = Q_0 e^{-\frac{t}{RC}}$
time constant	RC

Magnetic fields

force on a current	$F = BIl$
force on a moving charge	$F = BQv$
magnetic flux	$\Phi = BA$
magnetic flux linkage	$N\Phi = BAN\cos\theta$
magnitude of induced emf	$\varepsilon = N\dfrac{\Delta\Phi}{\Delta t}$
	$N\Phi = BAN\cos\theta$
emf induced in a rotating coil	$\varepsilon = BAN\omega\sin\omega t$
alternating current	$I_{rms} = \dfrac{I_0}{\sqrt{2}}$ $V_{rms} = \dfrac{V_0}{\sqrt{2}}$
transformer equations	$\dfrac{N_s}{N_p} = \dfrac{V_s}{V_p}$
	$efficiency = \dfrac{I_s V_s}{I_p V_p}$

Nuclear physics

inverse square law for γ radiation	$I = \dfrac{k}{x^2}$
radioactive decay	$\dfrac{\Delta N}{\Delta t} = -\lambda N$, $N = N_0 e^{-\lambda t}$
activity	$A = \lambda N$
half-life	$T_{½} = \dfrac{\ln 2}{\lambda}$
nuclear radius	$R = R_0 A^{1/3}$
energy-mass equation	$E = mc^2$

OPTIONS

Astrophysics

1 astronomical unit = 1.50×10^{11} m

1 light year = 9.46×10^{15} m

1 parsec = 2.06×10^5 AU = 3.08×10^{16} m = 3.26 ly

Hubble constant, $H = 65$ km s^{-1} Mpc^{-1}

$$M = \frac{angle\ subtended\ by\ image\ at\ eye}{angle\ subtended\ by\ object\ at\ unaided\ eye}$$

telescope in normal adjustment	$M = \dfrac{f_0}{f_e}$
Rayleigh criterion	$\theta \approx \dfrac{\lambda}{D}$
magnitude equation	$m - M = 5\log\dfrac{d}{10}$
Wien's law	$\lambda_{max} T = 2.9 \times 10^{-3}$ m K
Stefan's law	$P = \sigma A T^4$
Schwarzschild radius	$R_s \approx \dfrac{2GM}{c^2}$
Doppler shift for v << c	$\dfrac{\Delta f}{f} = -\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$
red shift	$z = -\dfrac{v}{c}$
Hubble's law	$v = Hd$

Medical physics

lens equations	$P = \dfrac{1}{f}$
	$m = \dfrac{v}{u}$
	$\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$
threshold of hearing	$I_0 = 1.0 \times 10^{-12}$ W m^{-2}
intensity level	$intensity\ level = 10\log\dfrac{I}{I_0}$
absorption	$I = I_0 e^{-\mu x}$
	$\mu_m = \dfrac{\mu}{\rho}$
ultrasound imaging	$Z = \rho c$
	$\dfrac{I_r}{I_i} = \left(\dfrac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$
half-lives	$\dfrac{1}{T_E} = \dfrac{1}{T_B} + \dfrac{1}{T_P}$

Engineering physics

moment of inertia $I = \Sigma mr^2$

angular kinetic energy $E_k = \frac{1}{2}I\omega^2$

equations of angular motion

$\omega_2 = \omega_1 + \alpha t$

${\omega_2}^2 = {\omega_1}^2 + 2\alpha\theta$

$\theta = \omega_1 t + \frac{\alpha t^2}{2}$

$\theta = \frac{(\omega_1 + \omega_2)\, t}{2}$

torque $T = I\,\alpha$

$T = F\,r$

angular momentum $\text{angular momentum} = I\omega$

angular impulse $T\Delta t = \Delta(I\omega)$

work done $W = T\theta$

power $P = T\omega$

thermodynamics $Q = \Delta U + W$

$W = p\Delta V$

adiabatic change $pV^\gamma = \text{constant}$

isothermal change $pV = \text{constant}$

heat engines

efficiency $= \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$

maximum theoretical efficiency $= \frac{T_H - T_C}{T_H}$

work done per cycle = area of loop

input power = calorific value × fuel flow rate

indicated power = $(\text{area of } p - V \text{ loop}) \times (\text{number of cycles per second}) \times (\text{number of cylinders})$

output or brake power $P = T\omega$

friction power = indicated power – brake power

heat pumps and refrigerators

refrigerator: $COP_{\text{ref}} = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C}$

heat pump: $COP_{\text{hp}} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C}$

Turning points in physics

electrons in fields $F = \frac{eV}{d}$

$F = Bev$

$r = \frac{mv}{Be}$

$\frac{1}{2} mv^2 = eV$

Millikan's experiment $\frac{QV}{d} = mg$

$F = 6\pi\eta rv$

Maxwell's formula $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

special relativity $t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

$l = l_0 \sqrt{1 - \frac{v^2}{c^2}}$

$E = m\,c^2 = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$

Electronics

resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$

Q-factor $Q = \frac{f_0}{f_B}$

operational amplifiers: open loop $V_{\text{out}} = A_{\text{OL}}(V_+ - V_-)$

inverting amplifier $\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_f}{R_{\text{in}}}$

non-inverting amplifier $\frac{V_{\text{out}}}{V_{\text{in}}} = 1 + \frac{R_f}{R_1}$

summing amplifier $V_{\text{out}} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \cdots\right)$

difference amplifier $V_{\text{out}} = (V_+ - V_-)\frac{R_f}{R_1}$

Bandwidth requirement:

for AM $\text{bandwidth} = 2f_M$

for FM $\text{bandwidth} = 2(\Delta f + f_M)$

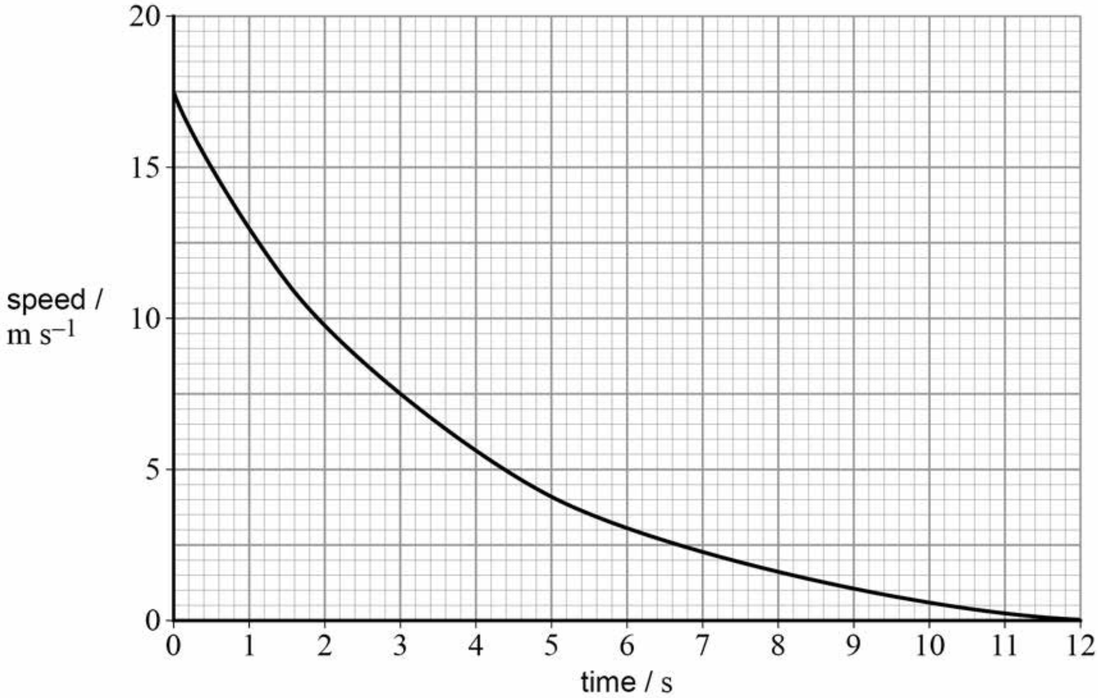
Section A

Answer **all** questions in this section.

0 1 Horizontal escape lanes made of loose gravel have been constructed at the side of some roads on steep hills so that vehicles can stop safely when their brakes fail.

Figure 1 shows an engineer's prediction of how the speed of an unpowered vehicle of mass 1.8×10^4 kg will vary with time as the vehicle comes to rest in an escape lane.

Figure 1



0 1 . 1 Determine the force decelerating the vehicle 2.0 s after entering the escape lane.

[3 marks]

force decelerating the vehicle = ____________________ N

Do not write outside the box

0 1 . 2 Deduce whether a lane of length $85\ \text{m}$ is long enough to stop the vehicle, assuming that the engineer's graph is correct.

[3 marks]

0 1 . 3 Discuss the energy transfers that take place when a vehicle is decelerated in an escape lane.

[2 marks]

Question 1 continues on the next page

0 1 . 4 An alternative to an escape lane containing gravel is an escape lane that consists of a ramp. An escape ramp is a straight road with a concrete surface that has a constant upward gradient.

One escape ramp makes an angle of $25°$ to the horizontal and is $85\ \mathrm{m}$ long.

Deduce whether this escape ramp is sufficient to stop the vehicle.

Assume that any frictional forces and air resistance that decelerate the vehicle are negligible.

[3 marks]

0 1 . 5 Discuss whether an escape lane containing gravel or an escape ramp would provide the safer experience for the driver of the vehicle as it comes to rest.

[1 mark]

12

Do not write outside the box

0 2 **Table 1** shows results of an experiment to investigate how the de Broglie wavelength λ of an electron varies with its velocity v.

Table 1

v / 10^7 m s^{-1}	λ / 10^{-11} m
1.5	4.9
2.5	2.9
3.5	2.1

0 2 . 1 Show that the data in **Table 1** are consistent with the relationship $\lambda \propto \frac{1}{v}$

[2 marks]

0 2 . 2 Calculate a value for the Planck constant suggested by the data in **Table 1**.

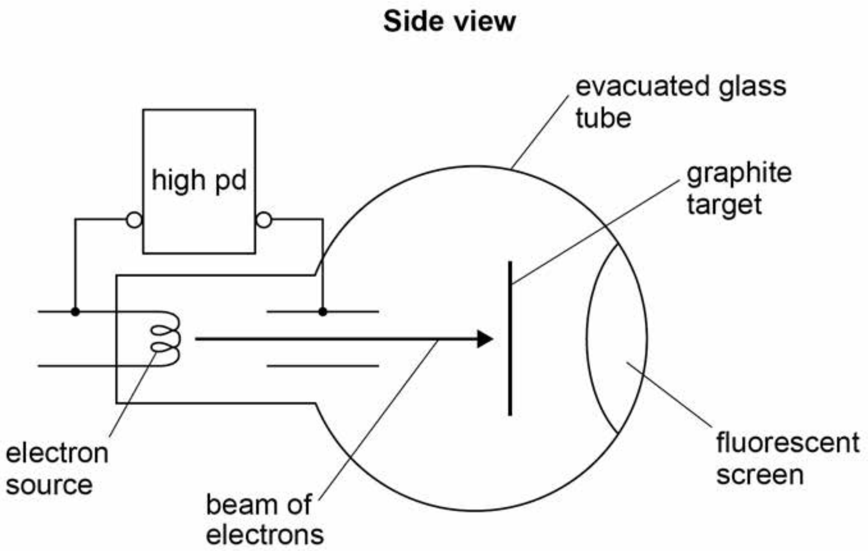
[2 marks]

Planck constant = ____________________ J s

Question 2 continues on the next page

0 2 . 3 **Figure 2** shows the side view of an electron diffraction tube used to demonstrate the wave properties of an electron.

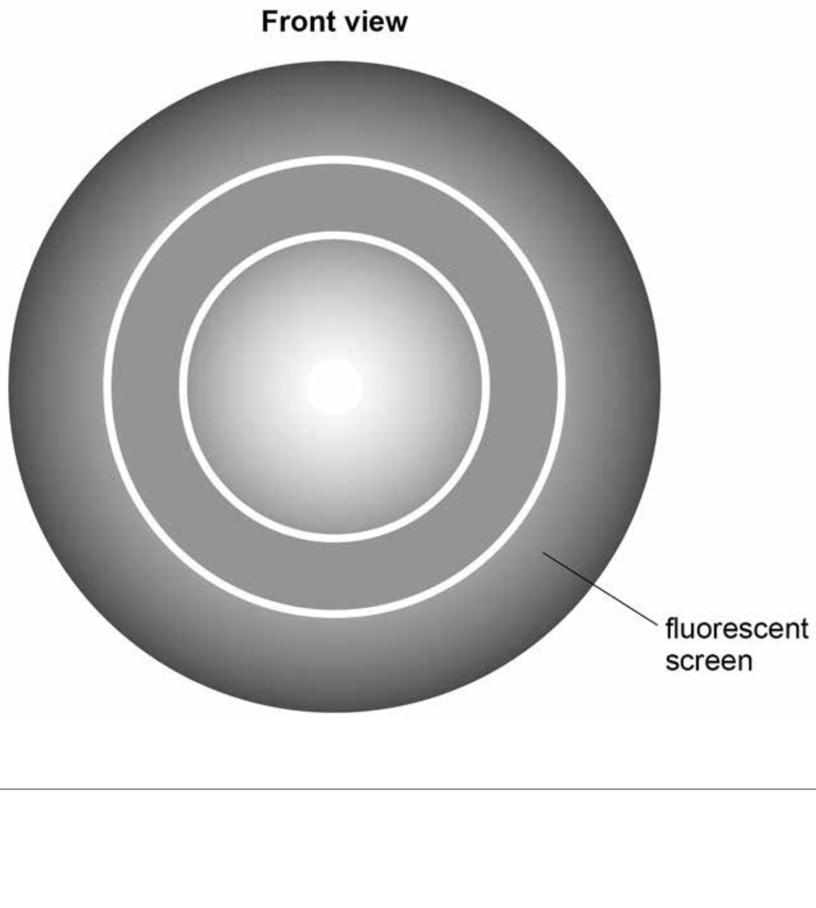
Figure 2



An electron beam is incident on a thin graphite target that behaves like the slits in a diffraction grating experiment. After passing through the graphite target the electrons strike a fluorescent screen.

Figure 3 shows the appearance of the fluorescent screen when the electrons are incident on it.

Figure 3



Do not write outside the box

Explain how the pattern produced on the screen supports the idea that the electron beam is behaving as a wave rather than as a stream of particles.

[3 marks]

0 2 . 4 Explain how the emission of light from the fluorescent screen shows that the electrons incident on it are behaving as particles.

[3 marks]

10

Do not write outside the box

0 3 **Figure 4** shows the structure of a violin and **Figure 5** shows a close-up image of the tuning pegs.

Figure 4

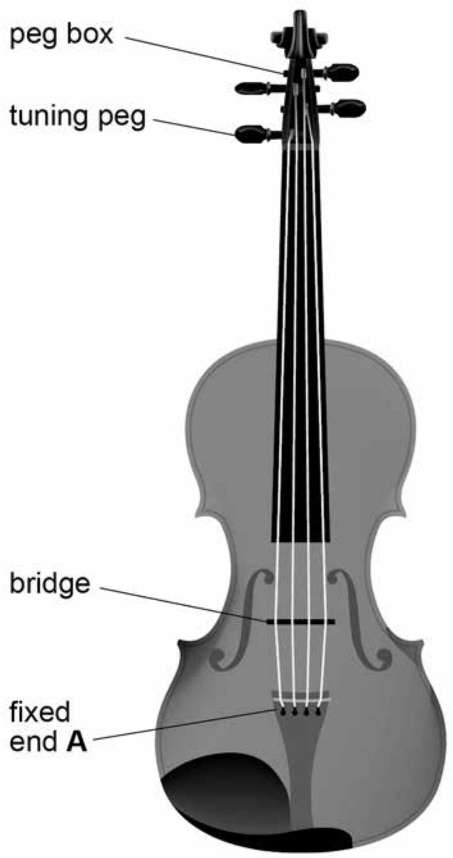
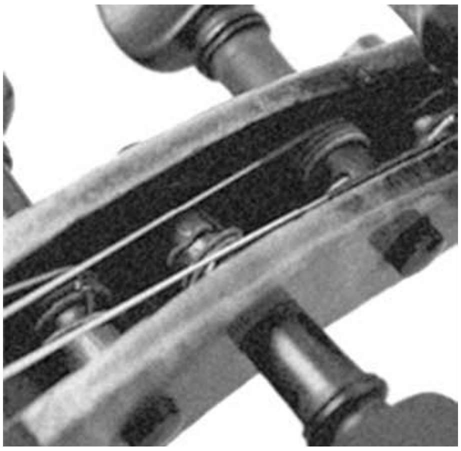


Figure 5



The strings are fixed at end **A**. The strings pass over a bridge and the other ends of the strings are wound around tuning pegs that have a circular cross-section. The tension in the strings can be increased or decreased by rotating the tuning pegs.

0 3 . 1 Explain how a stationary wave is produced when a stretched string is plucked.

[3 marks]

0 3 . 2 The vibrating length of one of the strings of a violin is 0.33 m
When the tension in the string is 25 N, the string vibrates with a first-harmonic frequency of 370 Hz

Show that the mass of a 1.0 m length of the string is about 4×10^{-4} kg

[2 marks]

0 3 . 3 Determine the speed at which waves travel along the string in question **03.2** when it vibrates with a first-harmonic frequency of 370 Hz

[1 mark]

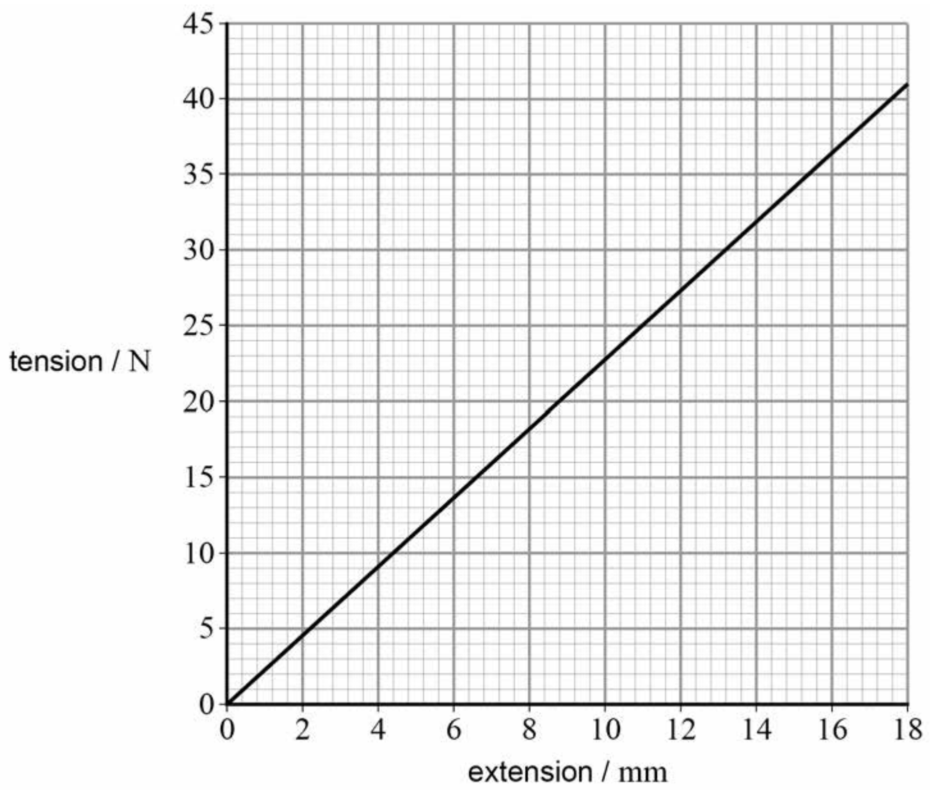
speed of waves = ____________________ $m\ s^{-1}$

Question 3 continues on the next page

Turn over ►

0 3 . 4 **Figure 6** shows how the tension in the string in question **03.2** varies with the extension of the string.

Figure 6



The string with its initial tension of 25 N is vibrating at a frequency of 370 Hz
The diameter of the circular peg is 7.02 mm

Do not write outside the box

Determine the higher frequency that is produced when the string is stretched by rotating the tuning peg through an angle of $75°$

Assume that there is no change in the diameter of the string.

[4 marks]

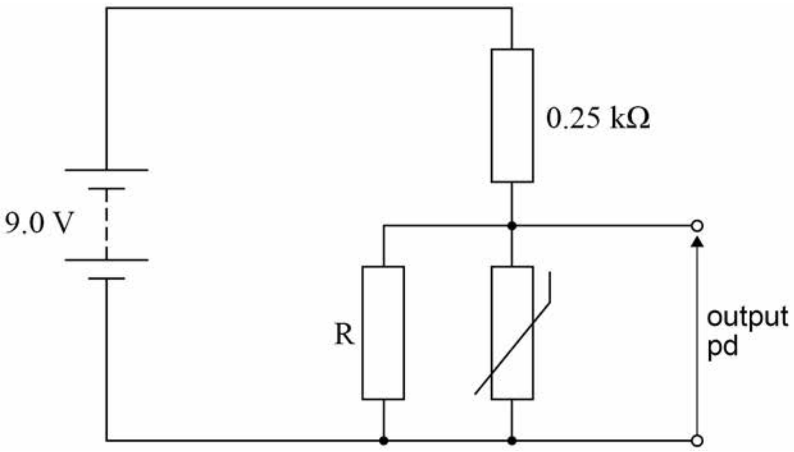
frequency = ____________________ Hz

10

Turn over for the next question

0 4 **Figure 7** shows a circuit designed by a student to monitor temperature changes.

Figure 7



The supply has negligible internal resistance and the thermistor has a resistance of $750\ \Omega$ at room temperature. The student wants the output potential difference (pd) at room temperature to be $5.0\ V$

0 4 . 1 The $0.25\ k\Omega$ resistor is made of 50 turns of wire that is wound around a non-conducting cylinder of diameter $8.0\ mm$

Resistivity of the wire $= 4.2 \times 10^{-7}\ \Omega\ m$

Determine the area of cross-section of the wire that has been used for the resistor.

[3 marks]

area of cross-section = ______________________ m^2

Do not write outside the box

0 4 . 2 The student selects a resistor rated at $0.36\ \text{W}$ for the $0.25\ \text{k}\Omega$ resistor in **Figure 7**.

Determine whether this resistor is suitable.

[2 marks]

0 4 . 3 Determine the value of R that the student should select.

Give your answer to an appropriate number of significant figures.

[5 marks]

value of R = ______________________ Ω

Question 4 continues on the next page

Do not write outside the box

0 4 . 4 State and explain the effect on the output pd of increasing the temperature of the thermistor.

[2 marks]

12

Do not write outside the box

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Turn over ►

Do not write outside the box

0 5 **Figure 8** shows a side view of an act performed by two acrobats. **Figure 9** shows the view from above.

Figure 8

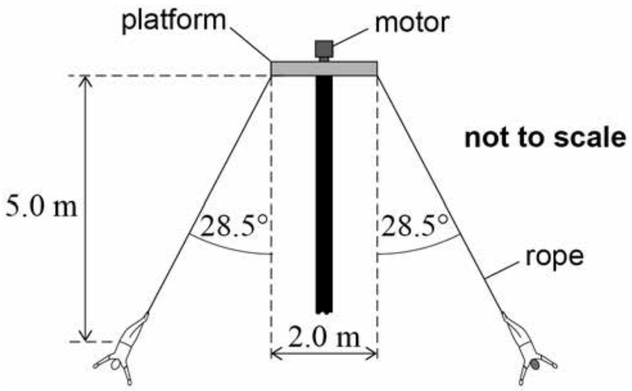
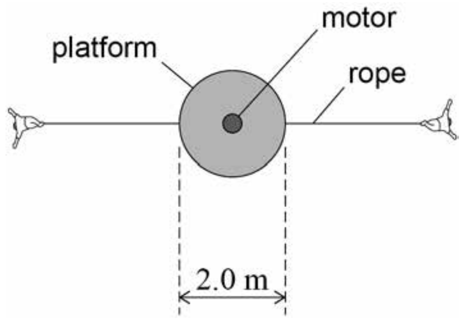


Figure 9



The acrobats, each of mass 85 kg, are suspended from ropes attached to opposite edges of a circular platform that is at the top of a vertical pole. The platform has a diameter of 2.0 m
A motor rotates the platform so that the acrobats move at a constant speed in a horizontal circle, on opposite sides of the pole.

When the period of rotation of the platform is 5.2 s, the centre of mass of each acrobat is 5.0 m below the platform and the ropes are at an angle of 28.5° to the vertical as shown in **Figure 8**.

0 5 . 1 Show that the linear speed of the acrobats is about $4.5\ \mathrm{m\ s^{-1}}$

[2 marks]

Do not write outside the box

0 5 . 2 Determine the tension in each rope that supports the acrobats.

[3 marks]

tension = ____________________ N

0 5 . 3 Discuss the consequences for the forces acting on the pole when one acrobat has a much greater mass than the other.

[3 marks]

____

____

____

____

____

____

____

____

____

____

____

8

Turn over ►

0 6 **Figure 10** shows two railway trucks **A** and **B** travelling towards each other on the same railway line which is straight and horizontal.

Figure 10

The trucks are involved in an inelastic collision. They join when they collide and then move together.

The trucks move a distance of 15 m before coming to rest.

Truck **A** has a total mass of 16 000 kg and truck **B** has a total mass of 12 000 kg

Just before the collision, truck **A** was moving at a speed of $2.8\ \text{m s}^{-1}$ and truck **B** was moving at a speed of $3.1\ \text{m s}^{-1}$

0 6 . 1 State the quantity that is **not** conserved in an inelastic collision.

[1 mark]

---

0 6 . 2 Show that the speed of the joined trucks immediately after the collision is about $0.3\ \text{m s}^{-1}$

[3 marks]

Do not write outside the box

0 6 . 3 Calculate the impulse that acts on each truck during the collision.
Give an appropriate unit for your answer.

[2 marks]

impulse = ____________________ unit __________

0 6 . 4 Explain, without doing a calculation, how the motion of the trucks immediately after the collision would be different for a collision that is perfectly elastic.

[2 marks]

____

____

____

____

____

____

____

____

8

Turn over ►

Section B

Each of Questions **07** to **31** is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.
For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD   WRONG METHODS

If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 7 What is a correct unit for the area under a force–time graph?

[1 mark]

A N m

B $kg\ m\ s^{-1}$

C $kg\ m\ s^{-2}$

D $N\ s^{-1}$

0 8 A student carries out an experiment to determine the resistivity of a metal wire.
She determines the resistance from measurements of potential difference between the ends of the wire and the corresponding current. She measures the length of the wire with a ruler and the diameter of the wire using a micrometer. Each measurement is made with an uncertainty of 1%

Which measurement gives the largest uncertainty in the calculated value of the resistivity?

[1 mark]

A current

B diameter

C length

D potential difference

Do not write outside the box

0 9 Fluoride ions are produced by the addition of a single electron to an atom of fluorine $^{19}_{9}F$.

What is the magnitude of specific charge of the fluoride ion?

[1 mark]

A 3.2×10^{-26} C kg^{-1}

B 8.4×10^{-21} C kg^{-1}

C 5.0×10^{6} C kg^{-1}

D 4.5×10^{7} C kg^{-1}

1 0 Two gamma photons are produced when a muon and an antimuon annihilate each other.

What is the minimum frequency of the gamma radiation that could be produced?

[1 mark]

A 2.55×10^{16} Hz

B 5.10×10^{16} Hz

C 2.55×10^{22} Hz

D 5.10×10^{22} Hz

1 1 The Σ^0 baryon, composed of the quark combination uds, is produced through the strong interaction between a π^+ meson and a neutron.

$$\pi^+ + n \rightarrow \Sigma^0 + X$$

What is the quark composition of X?

[1 mark]

A $u\bar{s}$

B ud

C $u\bar{d}$

D $ud\bar{s}$

Turn over ►

1 2 An iodine nucleus decays into a nucleus of Xe−131, a beta-minus particle and particle Y.

$$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e} + \mathrm{Y}$$

Which is a property of particle Y?

[1 mark]

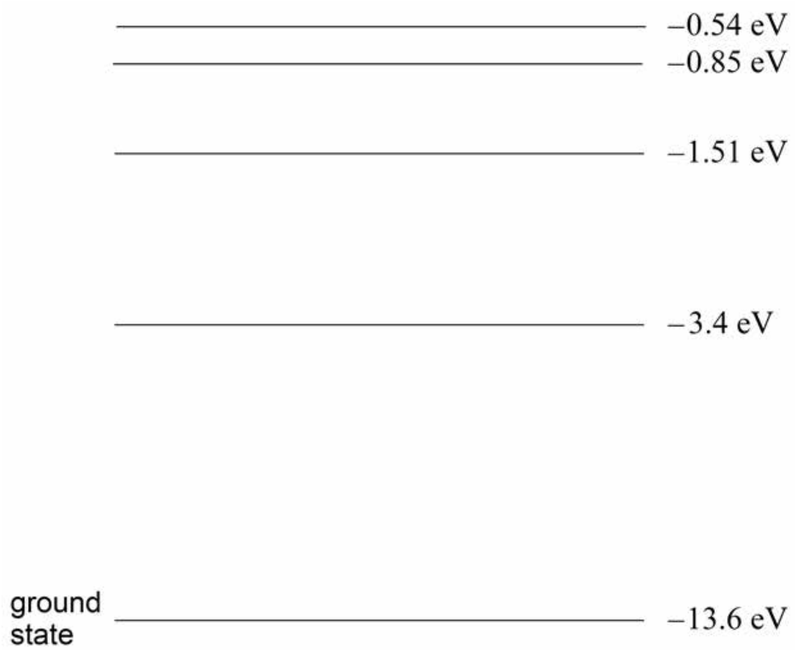
A It has a lepton number of +1

B It is an antiparticle

C It is negatively charged

D It experiences the strong interaction

1 3 The diagram shows an energy-level diagram for a hydrogen atom.



Electrons, each having a kinetic energy of 2.0×10^{-18} J, collide with atoms of hydrogen in their ground state. Photons are emitted when the atoms de-excite.

How many different wavelengths can be observed with incident electrons of this energy?

[1 mark]

A 1

B 3

C 6

D 7

Do not write outside the box

1 4 Photons of wavelength $290\ \text{nm}$ are incident on a metal plate. The work function of the metal is $4.1\ \text{eV}$

What is the maximum kinetic energy of the emitted electrons?

[1 mark]

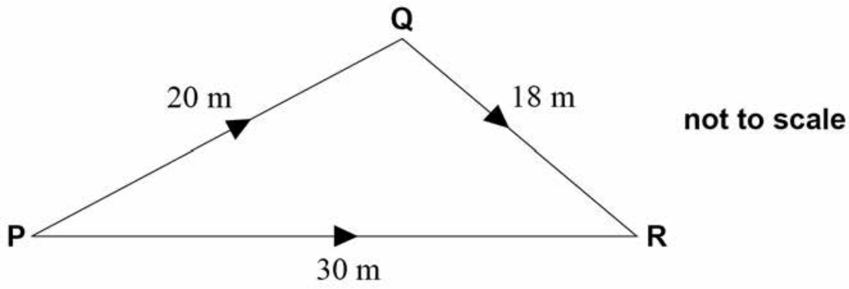
A $0.19\ \text{eV}$

B $4.3\ \text{eV}$

C $6.9\ \text{eV}$

D $8.4\ \text{eV}$

1 5 In the diagram, **P** is the source of a wave of frequency $50\ \text{Hz}$



The wave travels to **R** by two routes, **P** → **Q** → **R** and **P** → **R**. The speed of the wave is $30\ \text{m s}^{-1}$

What is the path difference between the two waves at **R** in terms of the wavelength λ of the waves?

[1 mark]

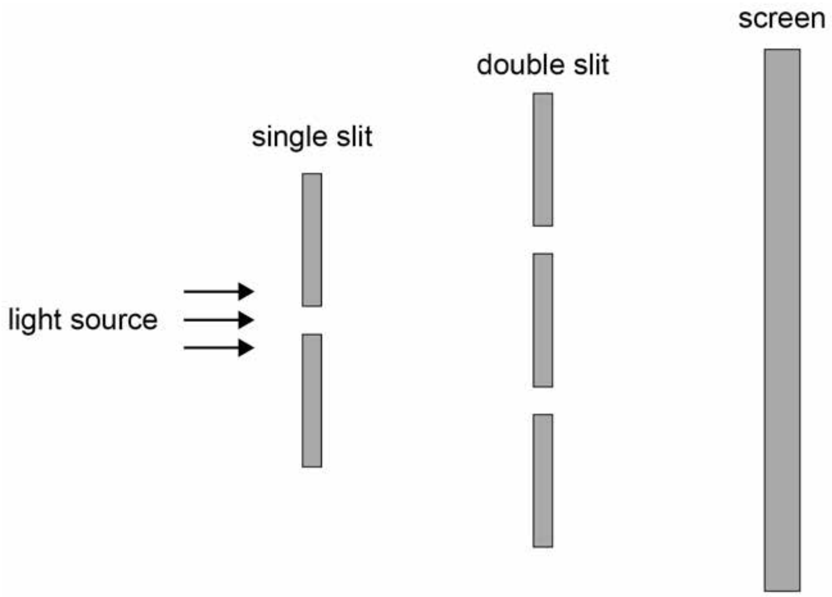
A 4.8λ

B 8.0λ

C 13.3λ

D 20.0λ

1 6 Light from a point source passes through a single slit and is then incident on a double-slit arrangement. An interference pattern is observed on the screen.



What will increase the fringe spacing?

[1 mark]

A increasing the separation of the single slit and the double slit

B increasing the width of the single slit

C decreasing the distance between the double slits and the screen

D decreasing the separation of the double slits

1 7 A diffraction grating has 500 lines per mm. When monochromatic light is incident normally on the grating the third-order spectral line is formed at an angle of 60° from the normal to the grating.

What is the wavelength of the monochromatic light?

[1 mark]

A 220 nm

B 580 nm

C 960 nm

D 1700 nm

Do not write outside the box

1 8 An electromagnetic wave enters a fibre-optic cable from air. On entering the cable, the wave slows down to three-fifths of its original speed.

What is the refractive index of the core of the fibre-optic cable?

[1 mark]

A 0.67 ⬭

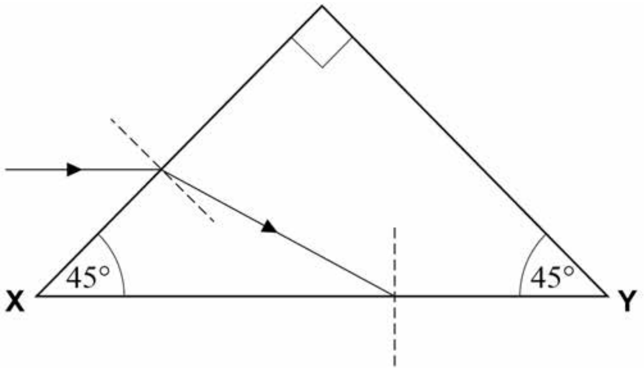
B 1.33 ⬭

C 1.50 ⬭

D 1.67 ⬭

Turn over for the next question

1 9 The diagram shows part of the path of a ray of light through a right-angled prism.

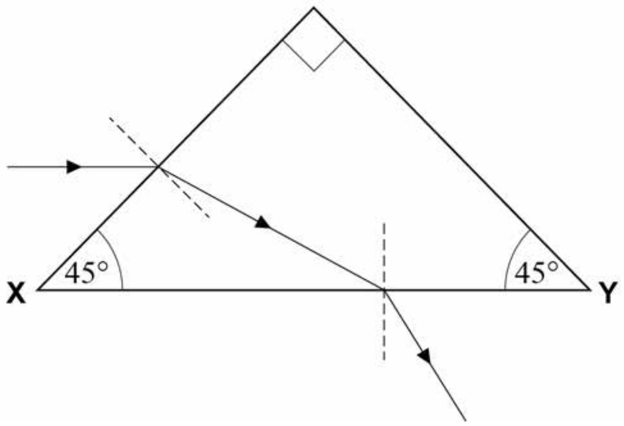


The prism is made of glass of refractive index 1.5
The incident light ray is parallel to the face **XY**. The ray is refracted towards the face **XY**.

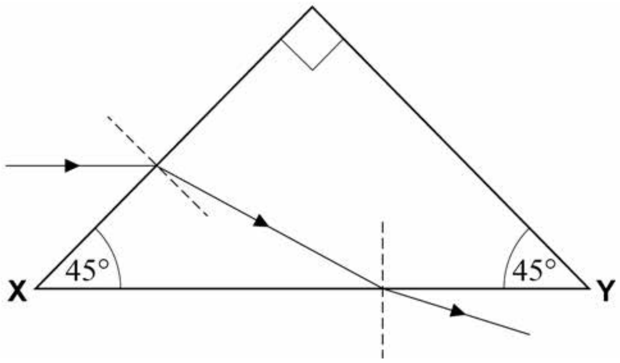
What is the path of the ray after it is incident on face **XY**?

[1 mark]

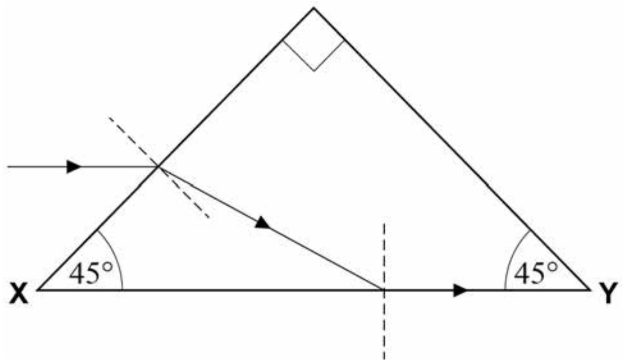
A



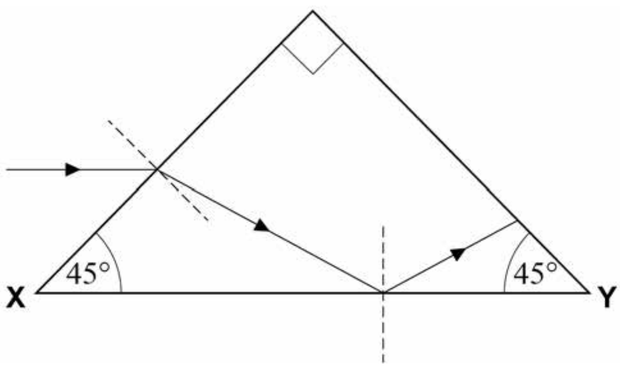
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

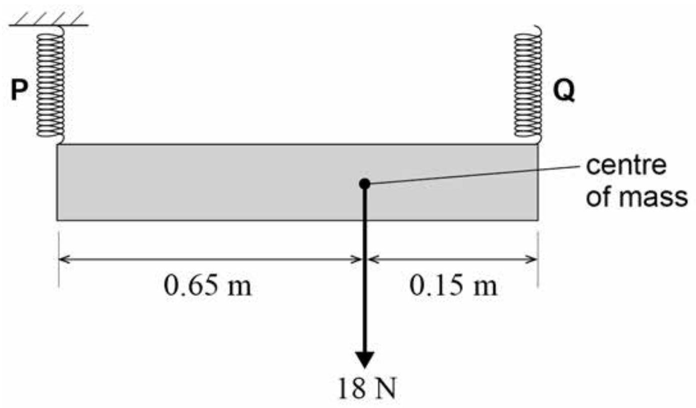
2 0 Three coplanar forces F_1, F_2 and F_3 act on a point object.

Which combination of forces can never produce a resultant force of zero?

[1 mark]

	F_1 / N	F_2 / N	F_3 / N	
A	3	4	5	⬭
B	8	8	8	⬭
C	2	10	10	⬭
D	3	6	10	⬭

2 1 A non-uniform sign is 0.80 m long and has a weight of 18 N
It is suspended from two vertical springs **P** and **Q**. The springs obey Hooke's law and the spring constant of each spring is 240 N m^{-1}



The top end of spring **P** is fixed and the top end of spring **Q** is adjusted until the sign is horizontal and in equilibrium.

What is the extension of spring **Q**?

[1 mark]

A 0.014 m ⬭

B 0.038 m ⬭

C 0.049 m ⬭

D 0.061 m ⬭

Turn over ►

Do not write outside the box

2 2 Immediately after take-off from the surface of the Earth, a rocket of mass $12\ 000\ \text{kg}$ accelerates vertically upwards at $1.4\ \text{m s}^{-2}$

What is the thrust produced by the rocket motor?

[1 mark]

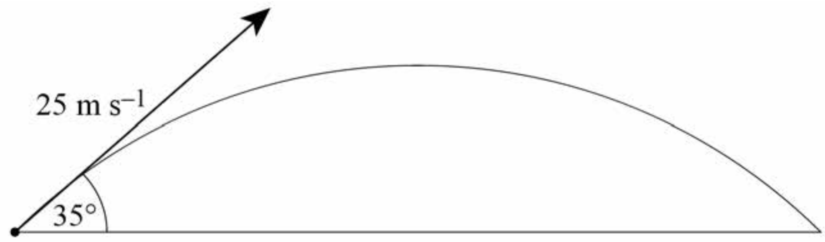
A 1.7×10^4 N ○

B 1.0×10^5 N ○

C 1.3×10^5 N ○

D 1.6×10^5 N ○

2 3 A projectile is launched with a speed of $25\ \text{m s}^{-1}$ at an angle of $35°$ to the horizontal, as shown in the diagram.



Air resistance is negligible.

What is the time taken for the projectile to return to the ground?

[1 mark]

A 1.5 s ○

B 2.1 s ○

C 2.9 s ○

D 4.2 s ○

2 4 A steel wire **W** has a length l and a circular cross-section of radius r. When **W** hangs vertically and a load is attached to the bottom end, it extends by e.
Another wire **X** made from the same material has the same load attached to it.

Which length and radius for **X** will produce an extension of $\frac{e}{4}$?

[1 mark]

	Length of X	**Radius of X**	
A	$0.5l$	$2r$	⬭
B	l	$4r$	⬭
C	$2l$	$2r$	⬭
D	$4l$	$4r$	⬭

2 5 A gas containing doubly-charged ions flows to give an electric current of 0.64 A

How many ions pass a point in 1.0 minute?

[1 mark]

A 2.0×10^{18} ⬭

B 4.0×10^{18} ⬭

C 1.2×10^{20} ⬭

D 2.4×10^{20} ⬭

2 6 A mobile phone operates at a constant power of 200 mW
It has a 3.7 V lithium-ion battery that has a charge capacity of 9400 C

What is the time taken for the battery to discharge completely?

[1 mark]

A 2 hours ⬭

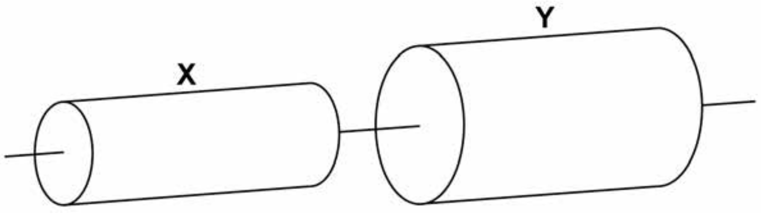
B 48 hours ⬭

C 120 hours ⬭

D 140 hours ⬭

Turn over ►

2 7 The two resistors shown are both uniform cylinders of equal length made from the same conducting putty.



The diameter of **Y** is twice that of **X**. The resistance of **Y** is R.

What is the total resistance of the combination?

[1 mark]

A $\frac{4R}{5}$ ⬭

B $3R$ ⬭

C $4R$ ⬭

D $5R$ ⬭

2 8 A voltmeter is used to measure potential difference for a component **X**.

Which row gives the position and ideal resistance for the voltmeter?

[1 mark]

	Position	**Ideal resistance**	
A	in series with **X**	infinite	⬭
B	in series with **X**	zero	⬭
C	in parallel with **X**	infinite	⬭
D	in parallel with **X**	zero	⬭

Do not write outside the box

2 9 A body performs simple harmonic motion.

What is the phase difference between the variation of displacement with time and the variation of acceleration with time for the body?

[1 mark]

A 0

B $\frac{\pi}{4}$ rad

C $\frac{\pi}{2}$ rad

D π rad

3 0 An object of mass 0.15 kg performs simple harmonic motion. It oscillates with amplitude 55 mm and frequency 0.80 Hz

What is the maximum value of its kinetic energy?

[1 mark]

A 5.7×10^{-3} J

B 11×10^{-3} J

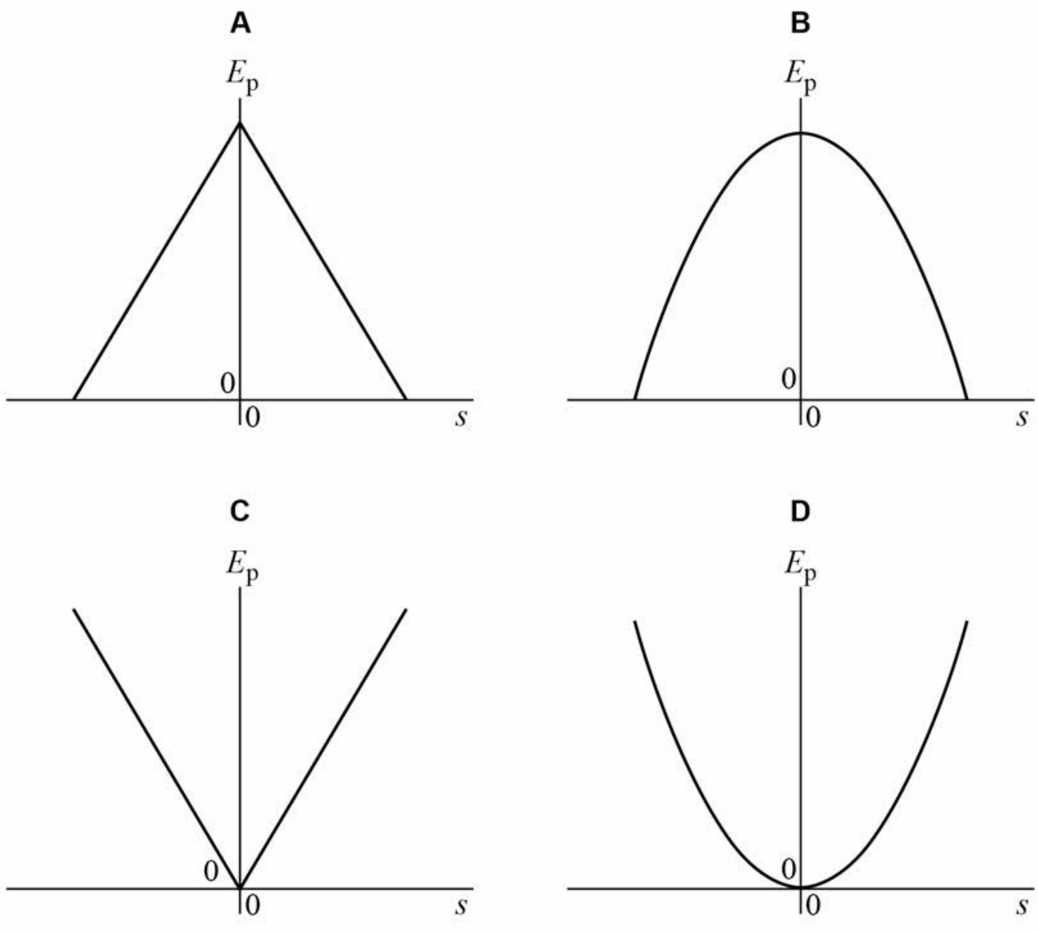
C 0.57 J

D 11 J

Turn over for the next question

3 1 Which graph shows how the gravitational potential energy E_p of a simple pendulum varies with displacement s from the equilibrium position?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

END OF QUESTIONS