Please write clearly in block capitals.

Centre number						Candidate number				

Surname ________________________________

Forename(s) ________________________________

Candidate signature ________________________________

A-level
PHYSICS
Paper 2

Friday 8 June 2018 Morning 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	
8–32	
TOTAL	

AQA

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}	$\mathrm{J\ s}$
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}	$\mathrm{m\ K}$
electron rest mass (equivalent to 5.5×10^{-4} u)	m_{e}	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_{\mathrm{e}}}$	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	$\frac{e}{m_{\mathrm{p}}}$	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^-, ν_e ; μ^-, ν_μ	+1
Antiparticles:	e^+, $\overline{\nu_e}$, μ^+, $\overline{\nu_\mu}$	−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	$v_{\text{max}} = \omega A$
maximum acceleration	$a_{\text{max}} = \omega^2 A$
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	$pV = \frac{1}{3}Nm(c_{\text{rms}})^2$
kinetic energy of gas molecule	$\frac{1}{2}m(c_{\text{rms}})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$

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	$T_{1/2} = \dfrac{\ln 2}{\lambda}$
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}

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

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 $I = \Sigma m r^2$

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 $= \frac{W}{Q_\mathrm{H}} = \frac{Q_\mathrm{H} - Q_\mathrm{C}}{Q_\mathrm{H}}$

maximum theoretical efficiency $= \frac{T_\mathrm{H} - T_\mathrm{C}}{T_\mathrm{H}}$

work done per cycle = area of loop

input power = calorific value × fuel flow rate

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

output or brake power $P = T\omega$

friction power = indicated power – brake power

heat pumps and refrigerators

refrigerator: $COP_\mathrm{ref} = \frac{Q_\mathrm{C}}{W} = \frac{Q_\mathrm{C}}{Q_\mathrm{H} - Q_\mathrm{C}}$

heat pump: $COP_\mathrm{hp} = \frac{Q_\mathrm{H}}{W} = \frac{Q_\mathrm{H}}{Q_\mathrm{H} - Q_\mathrm{C}}$

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 $\frac{QV}{d} = mg$

$F = 6\pi\eta r v$

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

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

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

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

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

Electronics

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

Q-factor $Q = \frac{f_0}{f_\mathrm{B}}$

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

inverting amplifier $\frac{V_\mathrm{out}}{V_\mathrm{in}} = -\frac{R_\mathrm{f}}{R_\mathrm{in}}$

non-inverting amplifier $\frac{V_\mathrm{out}}{V_\mathrm{in}} = 1 + \frac{R_\mathrm{f}}{R_\mathrm{l}}$

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

difference amplifier $V_\mathrm{out} = (V_+ - V_-)\frac{R_\mathrm{f}}{R_\mathrm{l}}$

Bandwidth requirement:

for AM $bandwidth = 2f_\mathrm{M}$

for FM $bandwidth = 2(\Delta f + f_\mathrm{M})$

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 . 1 Explain what is meant by specific latent heat of fusion.

[2 marks]

____

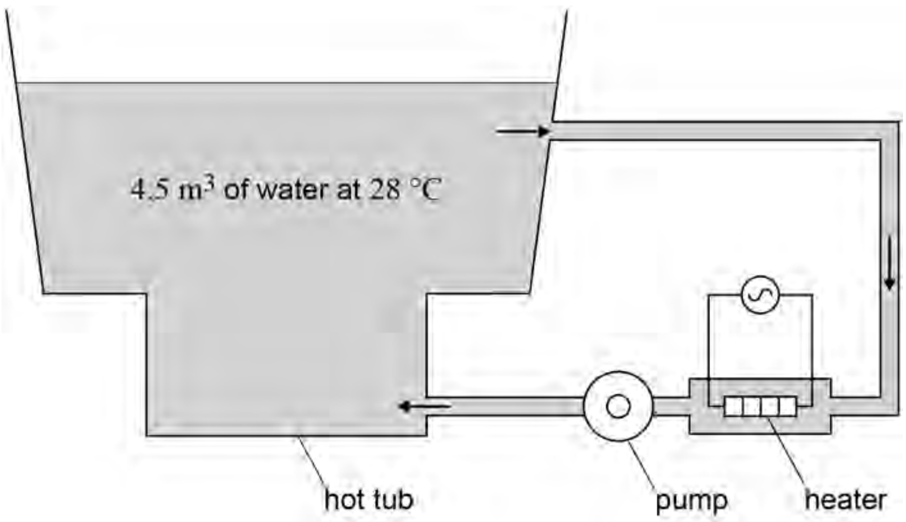
____

____

____

0 1 . 2 **Figure 1** shows how the temperature of the water is maintained in a hot tub.

Figure 1



The hot tub system has a volume of $4.5\ \text{m}^3$ and is filled with water at a temperature of $28\ °\text{C}$

The heater transfers thermal energy to the water at a rate of $2.7\ \text{kW}$ while a pump circulates the water.

Assume that no heat is transferred to the surroundings.

Do not write outside the box

Calculate the rise in water temperature that the heater could produce in 1.0 hour.

density of water = 1000 kg m^{-3}
specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

[3 marks]

temperature rise = ____________________ K

0 1 . 3 The pump can circulate the water at different speeds.
When working at higher speeds the rise in temperature is greater.

Explain why.
Again assume that no heat is transferred to the surroundings.

[2 marks]

____

____

____

____

____

7

Turn over for the next question

Do not write outside the box

0 2 . 1 Define the electric field strength at a point in an electric field.

[2 marks]

____

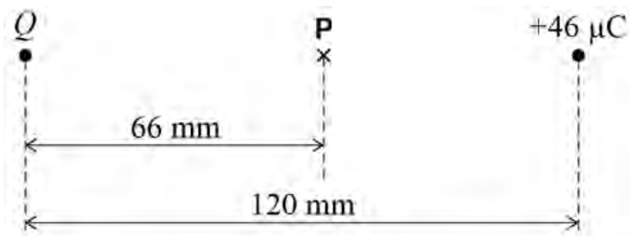
____

____

____

0 2 . 2 **Figure 2** shows a point charge of $+46\ \mu C$ placed $120\ mm$ from a point charge Q.

Figure 2



Position **P** is on the line joining the charges at a distance $66\ mm$ from charge Q.
The resultant electric field strength at position **P** is zero.

Calculate the charge Q.

[3 marks]

Q = ______________________ C

Do not write outside the box

0 2 . 3 Explain, without calculation, whether net work must be done in moving a proton from infinity to position **P** in **Figure 2**.

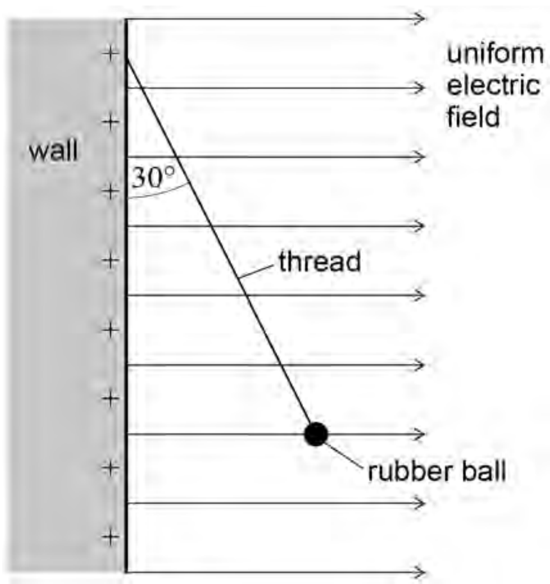
[2 marks]

Question 2 continues on the next page

Do not write outside the box

0 2 . 4 A small rubber ball coated with a conducting paint carries a positive charge. The ball is suspended in equilibrium from a vertical wall by an uncharged non-conducting thread of negligible mass. The wall is positively charged and produces a horizontal uniform electric field perpendicular to the wall along the whole of its length.
Figure 3 shows that the thread makes an angle of $30°$ to the wall.

Figure 3



The thread breaks.

Explain the motion of the ball.

[2 marks]

9

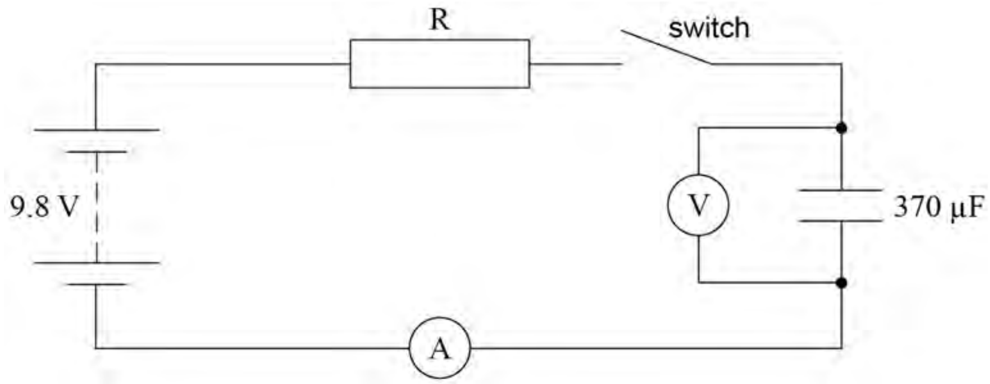
Do not write outside the box

0 3 . 1 State what is meant by a capacitance of 370 μF

[2 marks]

0 3 . 2 The charging of a 370 μF capacitor is investigated using the circuit shown in **Figure 4**. Both meters in the circuit are ideal.

Figure 4



The power supply of emf 9.8 V has a negligible internal resistance. The capacitor is initially uncharged. When the switch is closed at time $t = 0$ charge begins to flow through resistor R. The time constant of the charging circuit is 1.0 s

Calculate the resistance of R.

[1 mark]

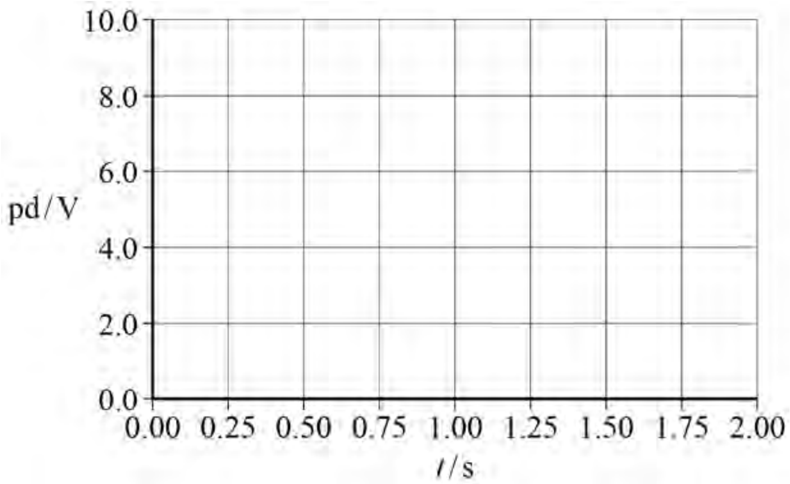
resistance of R = ____________________ Ω

Question 3 continues on the next page

0 3 . 3 Identify, with the symbol X on **Figure 5**, the potential difference (pd) across the capacitor when the switch has been closed for 2.0 s
Sketch the graph that shows how the pd varies from $t = 0$ to $t = 2.0$ s

[2 marks]

Figure 5



0 3 . 4 Calculate the time taken for the charging current to fall to half its initial value.

[1 mark]

time = ______________________ s

Do not write outside the box

0 3 . 5 Calculate the time taken for the charge on the capacitor to reach 3.0 mC

[3 marks]

time = ____________________ s

9

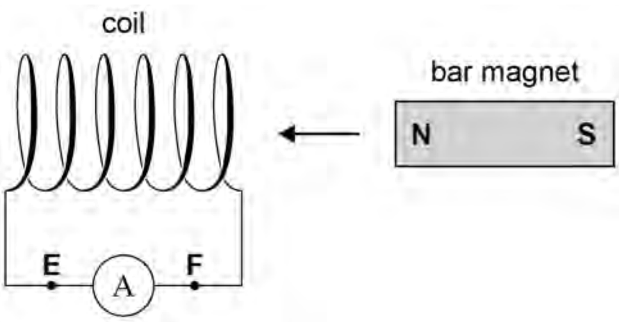
Turn over for the next question

0 4 . 1 State Lenz's law.

[1 mark]

0 4 . 2 Lenz's law can be demonstrated using a bar magnet and a coil of wire connected to a sensitive ammeter as shown in **Figure 6**.

Figure 6



The bar magnet is moved towards the coil and is then brought to a halt.

State how the reading on the ammeter changes during this process.

[1 mark]

0 4 . 3 During the demonstration an induced current is detected by the ammeter. The induced current is in the direction **E** to **F**.

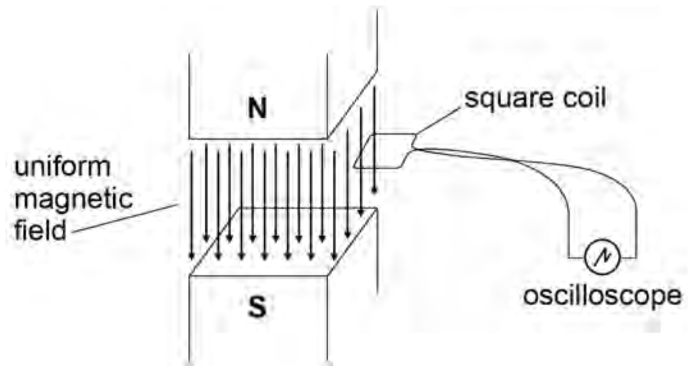
Explain how this demonstrates Lenz's law.

[2 marks]

Do not write outside the box

0 4 . 4 **Figure 7** shows an arrangement for investigating induced emf.

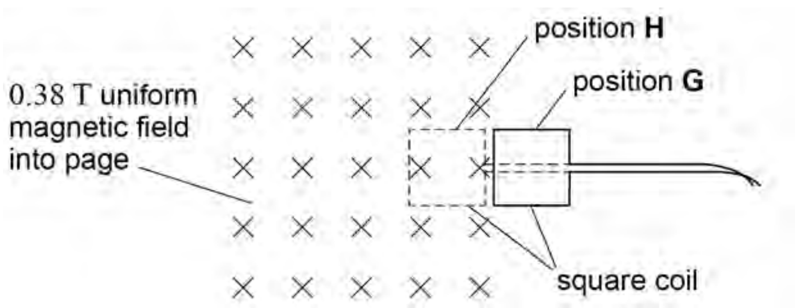
Figure 7



As shown, the uniform vertical magnetic field is confined to the gap between the poles of the magnet. The plane of the square coil is horizontal and is made of conducting wire. The coil consists of a single turn and is attached by flexible wire to an oscilloscope.

The oscilloscope gives a reading of 2.9×10^{-4} V when the coil is moved at uniform speed from position **G** outside the field to position **H** inside the field, as shown in **Figure 8**.

Figure 8



Length of side of square coil = 32 mm

Magnetic flux density of uniform magnetic field = 0.38 T

Calculate the time taken to move the coil from position **G** to position **H**.

[2 marks]

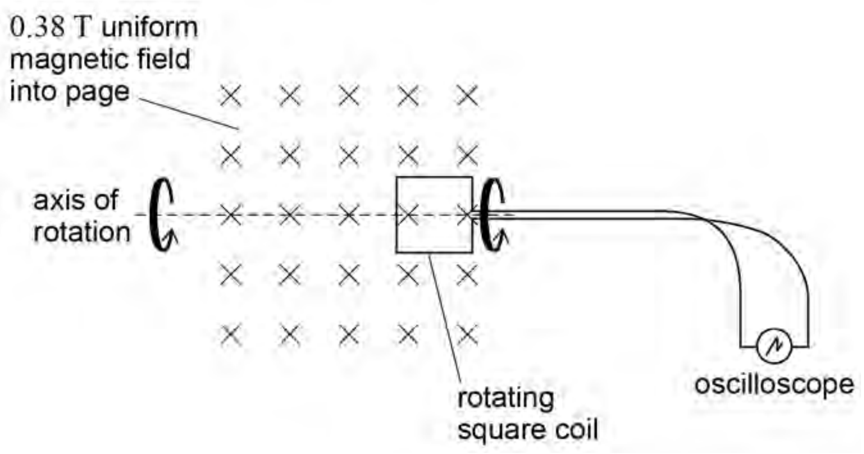
time = ______________________ s

Question 4 continues on the next page

Do not write outside the box

0 4 . 5 The square coil is rotated through $360°$ at a constant angular speed about the horizontal axis shown in **Figure 9**.

Figure 9



Calculate the angular speed of the coil when the maximum reading on the oscilloscope is 5.1 mV

[2 marks]

angular speed = ____________________ rad s^{-1}

8

0 5 . 1 Suggest, with a reason, which type of radiation is likely to be the most appropriate for the sterilisation of metallic surgical instruments.

[1 mark]

0 5 . 2 Explain why the public need not worry that irradiated surgical instruments become radioactive once sterilised.

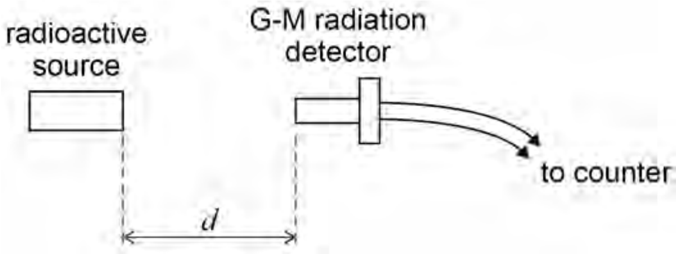
[1 mark]

Question 5 continues on the next page

Do not write outside the box

0 5 . 3 A student detects the counts from a radioactive source using a G-M radiation detector as shown in **Figure 10**.

Figure 10



The student measures the count rate for three different distances d. **Table 1** shows the count rate, in counts per minute, corrected for background for each of these distances.

Table 1

d/m	Corrected count rate / counts per minute			
0.20	9013			
0.50	1395			
1.00	242			

Explain, with the aid of suitable calculations, why the data in **Table 1** are **not** consistent with an inverse-square law. You may use the blank columns for your working.

[2 marks]

Do not write outside the box

0 5 . 4 State **two** possible reasons why the results do **not** follow the expected inverse-square law.

[2 marks]

Reason 1 ____

____

Reason 2 ____

____

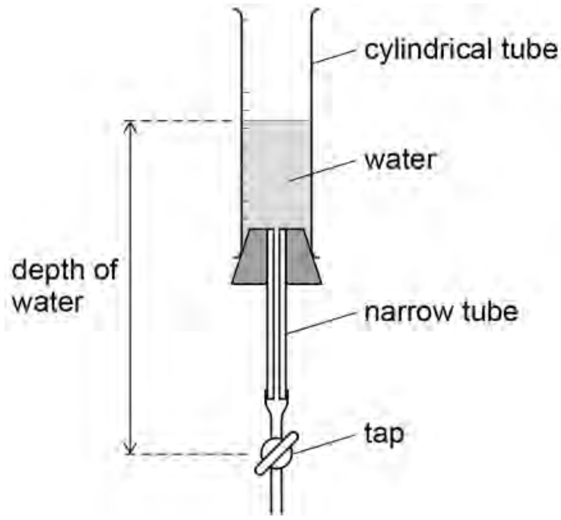
6

Turn over for the next question

Do not write outside the box

0 6 **Figure 11** shows how radioactive decay of one nuclide can be modelled by draining water through a tap from a cylindrical tube.

Figure 11

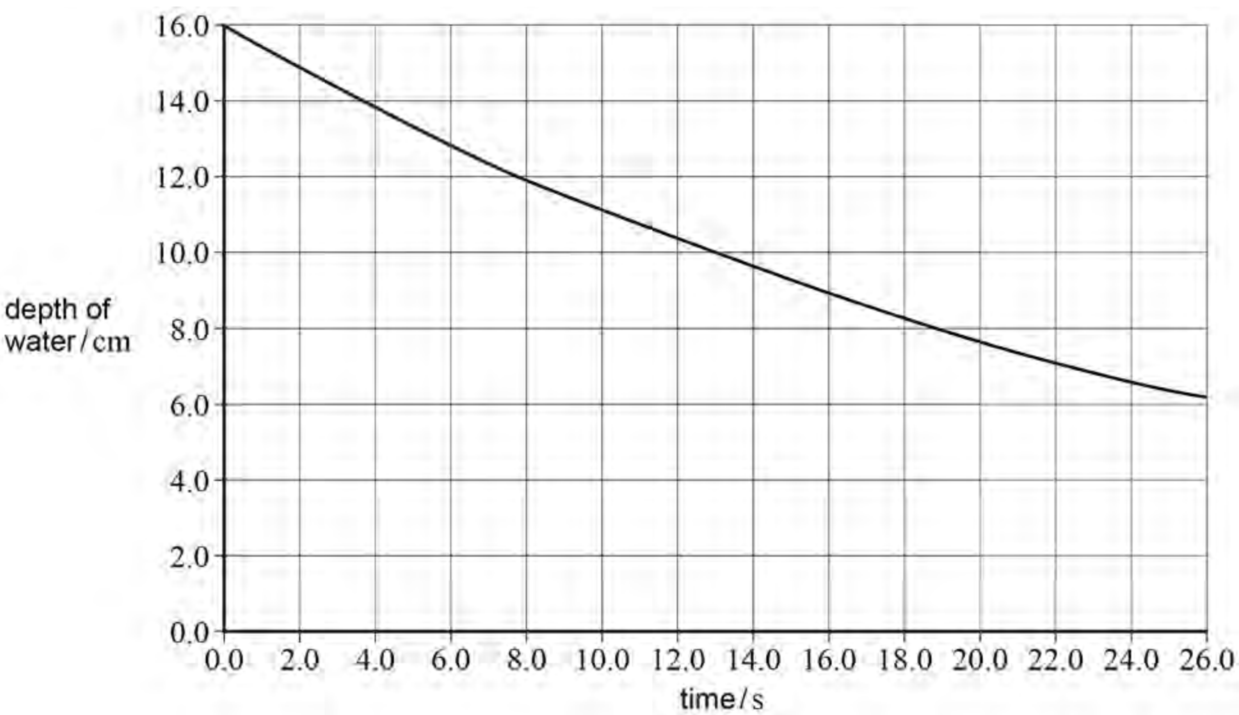


The water flow-rate is proportional to the pressure of the water. The pressure of the water is proportional to the depth of the water. Therefore the rate at which the depth decreases is proportional to the depth of the water.

Before the tap is opened the depth is 16.0 cm

The tap is opened and the depth is measured at regular intervals. These data are plotted on the graph in **Figure 12**.

Figure 12



0 6 . 1 Determine the predicted depth of water when the time is 57 s

[1 mark]

depth = ________________________ cm

0 6 . 2 Suggest how the apparatus in **Figure 11** may be changed to represent a radioactive sample of the same nuclide with a greater number of nuclei.

[1 mark]

____

____

0 6 . 3 Suggest how the apparatus in **Figure 11** may be changed to represent a radioactive sample of a nuclide with a smaller decay constant.

[1 mark]

____

____

0 6 . 4 The age of the Moon has been estimated from rock samples containing rubidium (Rb) and strontium (Sr), brought back from Moon landings.
$^{87}_{37}Rb$ decays to $^{87}_{38}Sr$ with a radioactive decay constant of 1.42×10^{-11} year^{-1}

Calculate, in years, the half-life of $^{87}_{37}Rb$.

[1 mark]

half-life = ________________________ years

Question 6 continues on the next page

Do not write outside the box

0 6 . 5 A sample of Moon rock contains $1.23\ \mathrm{mg}$ of $^{87}_{37}\mathrm{Rb}$.

Calculate the mass, in g, of $^{87}_{37}\mathrm{Rb}$ that the rock sample contained when it was formed 4.47×10^{9} years ago.

Give your answer to an appropriate number of significant figures.

[3 marks]

mass = ______________________ g

0 6 . 6 Calculate the activity of a sample of $^{87}_{37}\mathrm{Rb}$ of mass $1.23\ \mathrm{mg}$

Give an appropriate unit for your answer.

[3 marks]

activity = ______________________ unit __________

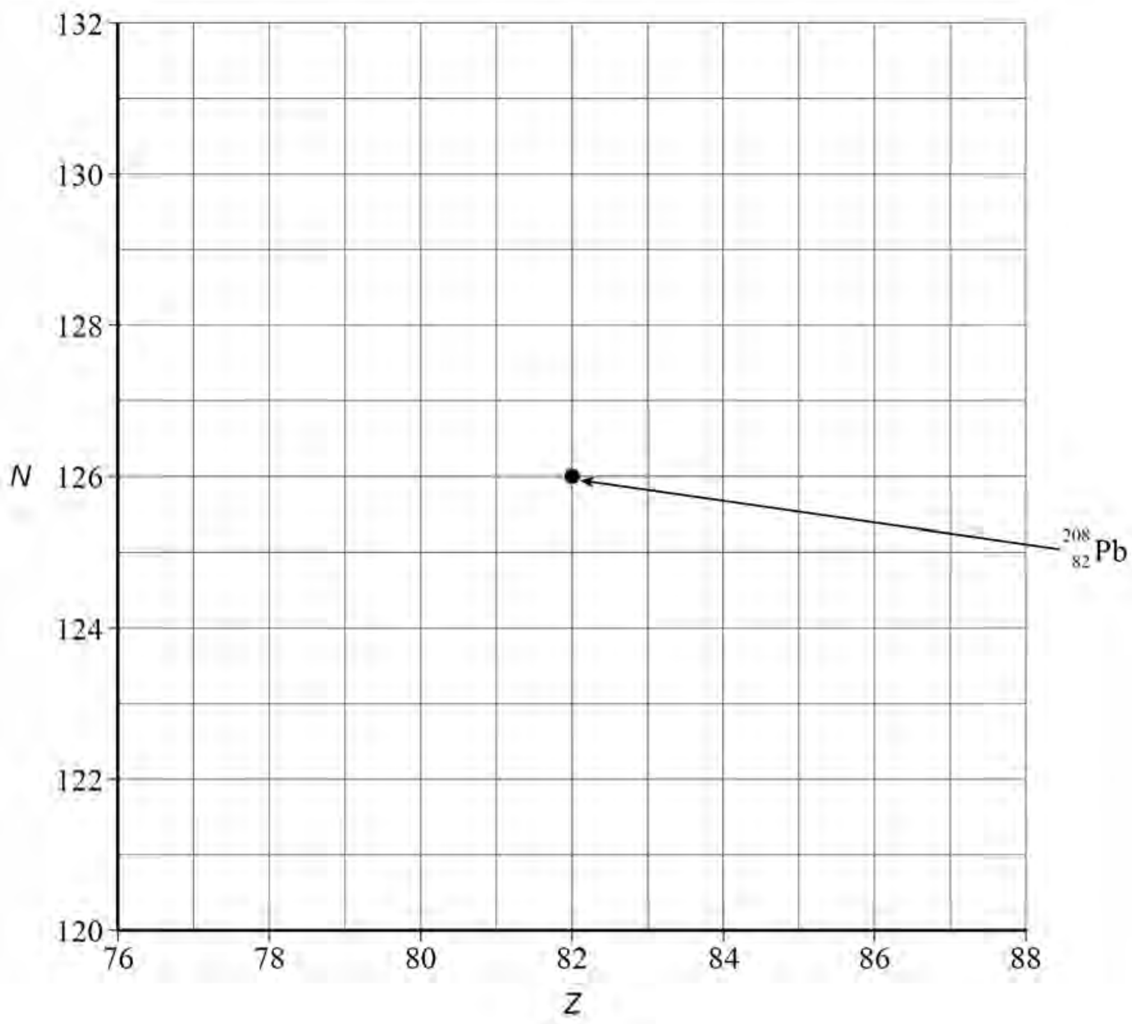
10

Do not write outside the box

0 7 A nucleus of polonium Po may decay to the stable isotope of lead $^{208}_{82}Pb$ through a chain of emissions following the sequence $\alpha\ \beta^-\ \beta^-\ \alpha$.

Figure 13 shows the position of the isotope $^{208}_{82}Pb$ on a grid of neutron number *N* against proton number *Z*.

Figure 13



0 7 . 1 Draw **four** arrows on **Figure 13** to show the sequence of changes to *N* and *Z* that occur as the polonium nucleus is transformed into $^{208}_{82}Pb$.

[2 marks]

Question 7 continues on the next page

Do not write outside the box

0 7 . 2 A nucleus of the stable isotope $^{208}_{82}\text{Pb}$ has more neutrons than protons.

Explain why there is this imbalance between proton and neutron numbers by referring to the forces that operate within the nucleus. Your explanation should include the range of the forces and which particles are affected by the forces.

[4 marks]

0 7 . 3 Many, but not all, isotopes of lead are stable. For example, $^{205}_{82}\text{Pb}$ decays by electron capture to become an isotope of thallium, Tl.

Write the equation to represent this decay, including the isotope of thallium produced.

[1 mark]

Do not write outside the box

0 7 . 4 The thallium nucleus is formed in an excited state. Electromagnetic radiation is emitted from the thallium atom following its formation.

Explain the origin and location of **two** sources of this radiation.

[2 marks]

Source 1

Source 2

0 7 . 5 Other nuclides also emit electromagnetic radiation.

Explain why the metastable form of the isotope of technetium ${}^{99}_{43}\mathrm{Tc}$ is a radioactive source suitable for use in medical diagnosis.

[2 marks]

11

END OF SECTION A

Section B

Each of Questions **08** to **32** 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.

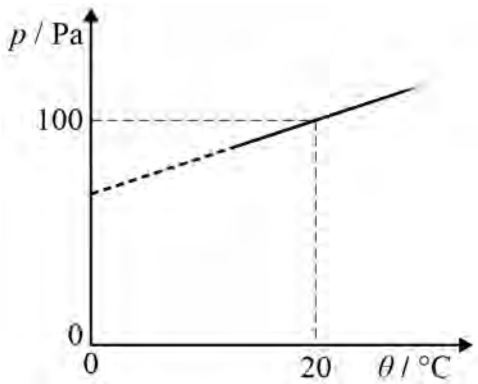
If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

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 8 The graph shows the variation of pressure p with temperature θ for a fixed mass of an ideal gas at constant volume.

What is the gradient of the graph?

[1 mark]



A 0.341

B 0.395

C 2.93

D 5.00

0 9 Two flasks **X** and **Y** are filled with an ideal gas and are connected by a tube of negligible volume compared to that of the flasks. The volume of **X** is twice the volume of **Y**. **X** is held at a temperature of $150\ \mathrm{K}$ and **Y** is held at a temperature of $300\ \mathrm{K}$

What is the ratio $\dfrac{\text{mass of gas in } \mathbf{X}}{\text{mass of gas in } \mathbf{Y}}$?

[1 mark]

A 0.125

B 0.25

C 4

D 8

1 0 The average mass of an air molecule is $4.8 \times 10^{-26}\ \mathrm{kg}$

What is the mean square speed of an air molecule at $750\ \mathrm{K}$?

[1 mark]

A $3.3 \times 10^{5}\ \mathrm{m^{2}\ s^{-2}}$

B $4.3 \times 10^{5}\ \mathrm{m^{2}\ s^{-2}}$

C $6.5 \times 10^{5}\ \mathrm{m^{2}\ s^{-2}}$

D $8.7 \times 10^{5}\ \mathrm{m^{2}\ s^{-2}}$

1 1 A transparent illuminated box contains small smoke particles and air.
The smoke particles are observed to move randomly when viewed through a microscope.

What is the cause of this observation of Brownian motion?

[1 mark]

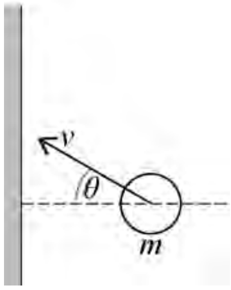
A Smoke particles gaining kinetic energy by the absorption of light

B Collisions between smoke particles and air molecules

C Smoke particles moving in convection currents caused by the air being heated by the light

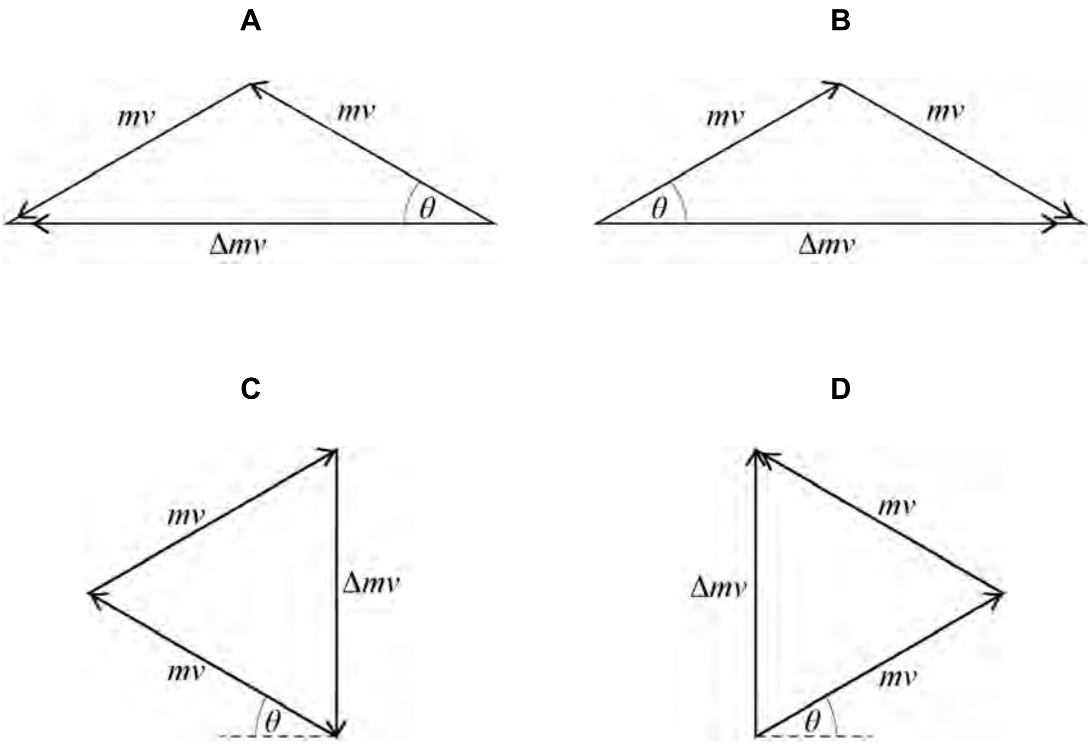
D The smoke particles moving randomly due to their temperature

1 2 The diagram shows a gas particle about to collide elastically with a wall.



Which diagram shows the correct change in momentum Δmv that occurs during the collision?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

1 3 The distance between the Sun and the Earth is 1.5×10^{11} m

What is the gravitational force exerted on the Sun by the Earth?

[1 mark]

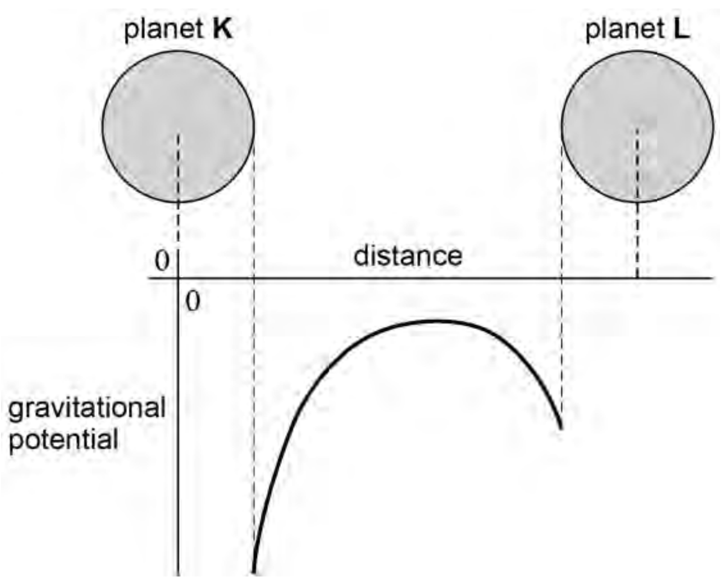
A 3.5×10^{22} N

B 1.7×10^{26} N

C 5.3×10^{33} N

D 8.9×10^{50} N

1 4 The graph shows how the gravitational potential varies with distance between two planets, **K** and **L**, that have the same radius.



Which statement is correct?

[1 mark]

A The mass of **L** is greater than the mass of **K**.

B The gravitational field strength at the surface of **L** is greater than that at the surface of **K**.

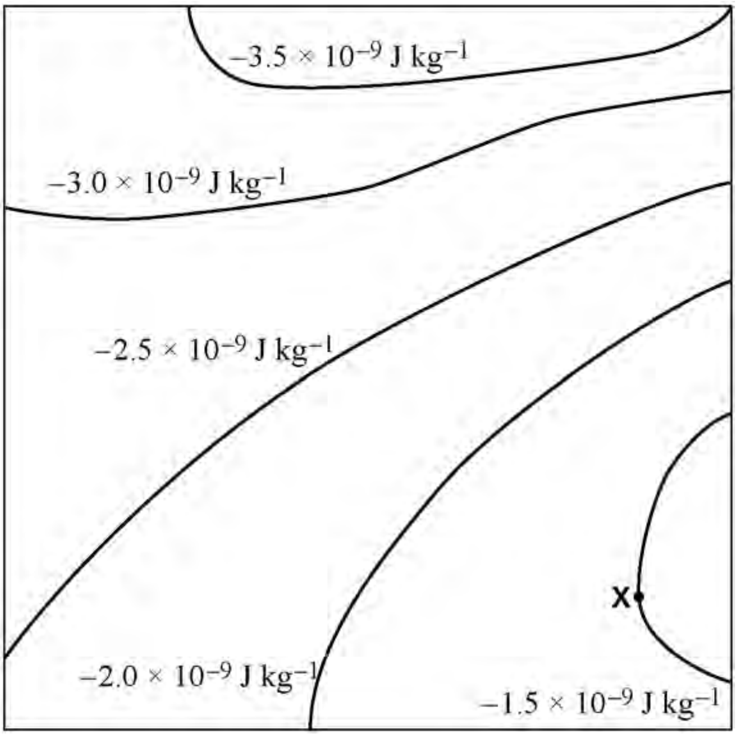
C The escape velocity from planet **L** is greater than that from planet **K**.

D More work must be done to move a mass of 1 kg from the surface of **K** to a distant point, than 1 kg from the surface of **L**.

Turn over ►

Do not write outside the box

1 5 The diagram shows equipotential lines near a group of asteroids.



Which arrow shows the direction of the gravitational field at **X**?

[1 mark]

A ↑ ⬭

B ↓ ⬭

C ← ⬭

D → ⬭

Do not write outside the box

1 6 Planet **N** has a gravitational potential $-V$ at its surface. Planet **M** has double the density and double the radius of planet **N**. Both planets are spherical and have uniform density.

What is the gravitational potential at the surface of planet **M**?

[1 mark]

A $-16V$ ⬭

B $-8V$ ⬭

C $-4V$ ⬭

D $-0.2V$ ⬭

1 7 A spacecraft of mass 1.0×10^{6} kg is in orbit around the Sun at a radius of 1.1×10^{11} m
The spacecraft moves into a new orbit of radius 2.5×10^{11} m around the Sun.

What is the total change in gravitational potential energy of the spacecraft?

[1 mark]

A -6.76×10^{14} J ⬭

B -3.38×10^{14} J ⬭

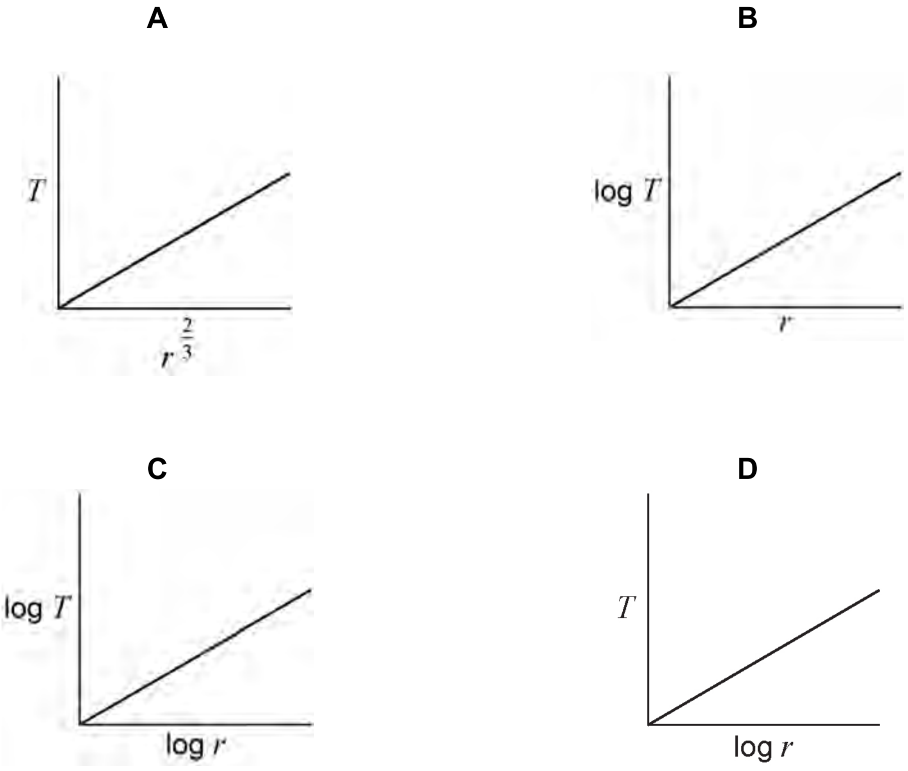
C 3.38×10^{14} J ⬭

D 6.76×10^{14} J ⬭

Turn over for the next question

1 8 Which graph shows the relationship between the time period T and the orbital radius r of a planet in orbit around the Sun?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

1 9 The Earth can be assumed to be a uniform sphere of radius R.

What is the mean density of the Earth?

[1 mark]

A $\frac{3g}{4\pi RG}$ ⬭

B $\frac{3RG}{4\pi g}$ ⬭

C $\frac{3G}{4\pi Rg}$ ⬭

D $\frac{3Rg}{4\pi G}$ ⬭

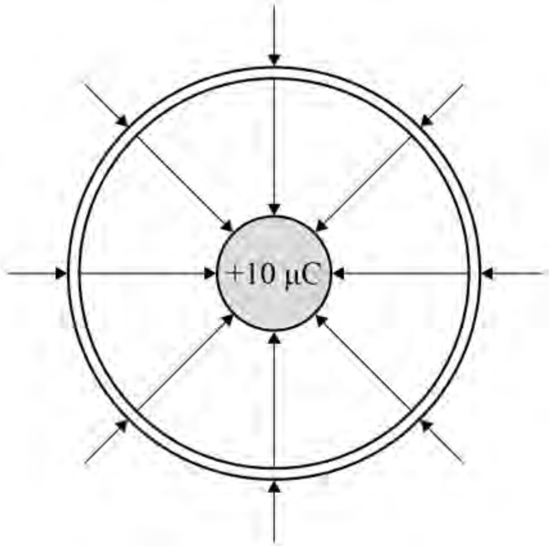
Turn over for the next question

2 0 A conducting sphere holding a charge of $+10\ \mu C$ is placed centrally inside a second uncharged conducting sphere.

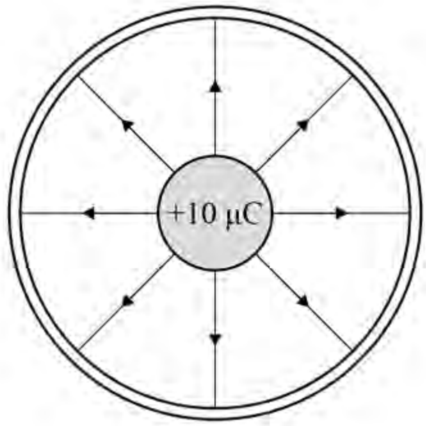
Which diagram shows the electric field lines for the system?

[1 mark]

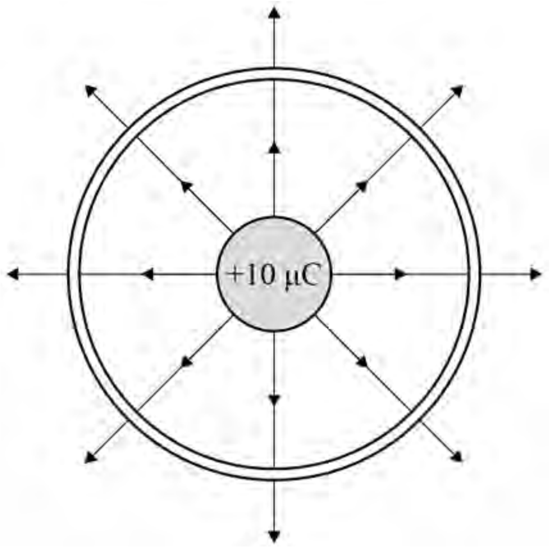
A



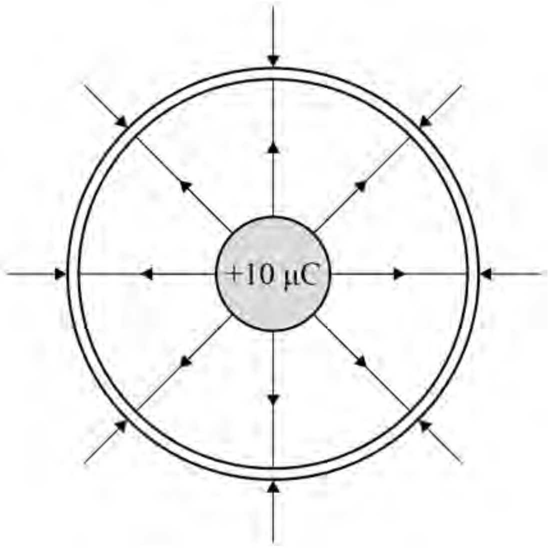
B



C



D



A ○

B ○

C ○

D ○

Do not write outside the box

2 1 A charged spherical conductor has a radius r. An electric field of strength E exists at the surface due to the charge.

What is the potential of the spherical conductor?

[1 mark]

A r^2E ⬭

B $r\,E^2$ ⬭

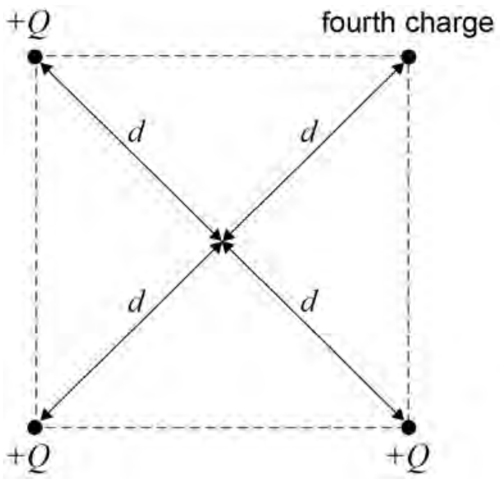
C $\frac{E}{r}$ ⬭

D $r\,E$ ⬭

Turn over for the next question

Do not write outside the box

2 2 Four positive charges are fixed at the corners of a square as shown.



The total potential at the centre of the square, a distance d from each charge, is $\frac{5Q}{4\pi\varepsilon_0 d}$.
Three of the charges have a charge of $+Q$.

What is the magnitude of the fourth charge?

[1 mark]

A $-\frac{7Q}{4}$ ⬭

B Q ⬭

C $\sqrt{2}Q$ ⬭

D $2Q$ ⬭

2 3 An air-filled parallel-plate capacitor is charged from a source of emf. The electric field has a strength E between the plates. The capacitor is disconnected from the source of emf and the separation between the isolated plates is doubled.

What is the final electric field between the plates?

[1 mark]

A $2E$ ⬭

B E ⬭

C $\frac{E}{2}$ ⬭

D $\frac{E}{4}$ ⬭

2 4 A parallel-plate capacitor has square plates of length l separated by distance d and is filled with a dielectric.

A second capacitor has square plates of length $2l$ separated by distance $2d$ and has air as its dielectric.

Both capacitors have the same capacitance.

What is the relative permittivity of the dielectric in the first capacitor?

[1 mark]

A $\frac{1}{2}$ ⬭

B 1 ⬭

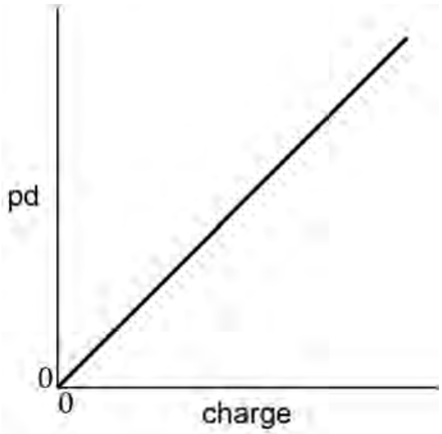
C 2 ⬭

D 8 ⬭

Turn over for the next question

Do not write outside the box

2 5 The graph shows the variation of potential difference (pd) with charge for a capacitor while it is charging.



Which statement can be deduced from the graph?

[1 mark]

A The charging current is constant.

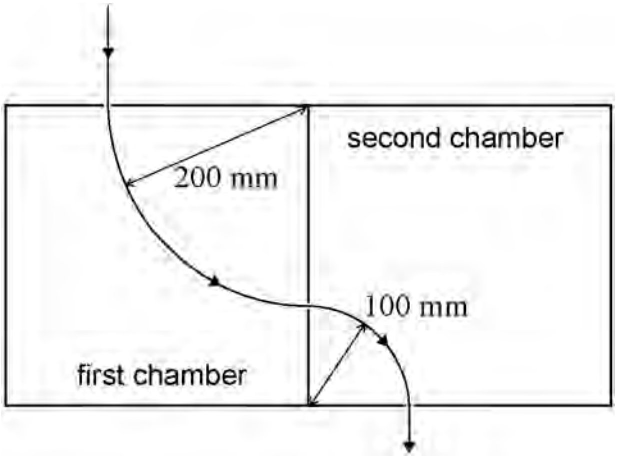
B The energy stored in the capacitor increases uniformly with time.

C The capacitance of the capacitor is constant.

D The power supply used to charge the capacitor had a constant terminal pd.

Do not write outside the box

2 6 Different magnetic fields are present in the two chambers shown. A particle enters the first chamber at a velocity of 80 m s^{-1} and is deflected into a circular path of radius 200 mm
In the second chamber it follows a circular path of radius 100 mm



The particle leaves the second chamber at a speed of

[1 mark]

A 20 m s^{-1} ⬭

B 40 m s^{-1} ⬭

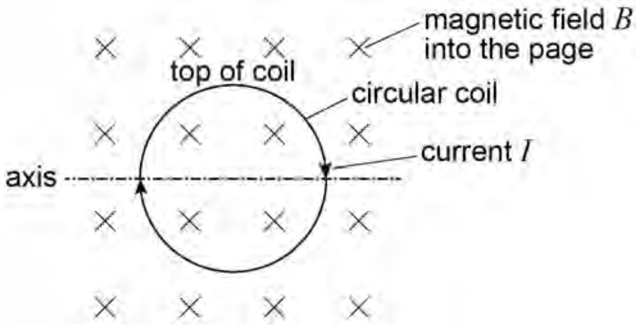
C 80 m s^{-1} ⬭

D 160 m s^{-1} ⬭

Turn over for the next question

Do not write outside the box

2 7 The diagram shows a clockwise current I in a circular coil placed in a uniform magnetic field B with the plane of the coil perpendicular to the magnetic field.



What is the effect on the coil of the interaction between the current and the magnetic field?

[1 mark]

A It rotates about the axis with the top moving out of the page. ⬭

B It rotates about the axis with the top moving into the page. ⬭

C It causes an increase in the diameter of the coil. ⬭

D It causes a decrease in the diameter of the coil. ⬭

2 8 A transformer has an efficiency of 80%
It has 7000 turns on its primary coil and 175 turns on its secondary coil. When the primary of the transformer is connected to a 240 V ac supply, the secondary current is 8.0 A

What are the primary current and secondary voltage?

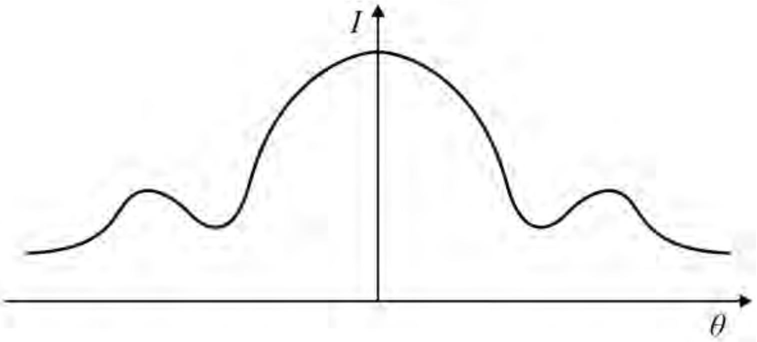
[1 mark]

	Primary current / mA	Secondary voltage / V	
A	250	6.0	⬭
B	160	6.0	⬭
C	250	9600	⬭
D	160	9600	⬭

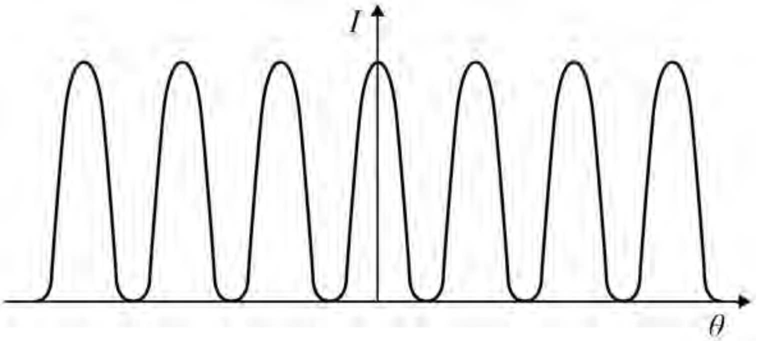
2 9 Which graph shows how intensity I varies with angle θ when electrons are diffracted by a nucleus?

[1 mark]

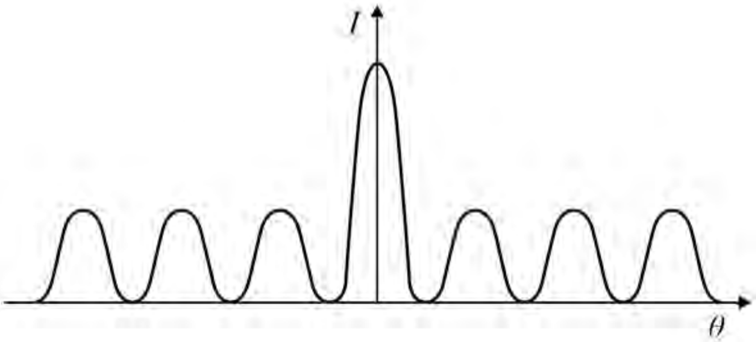
A



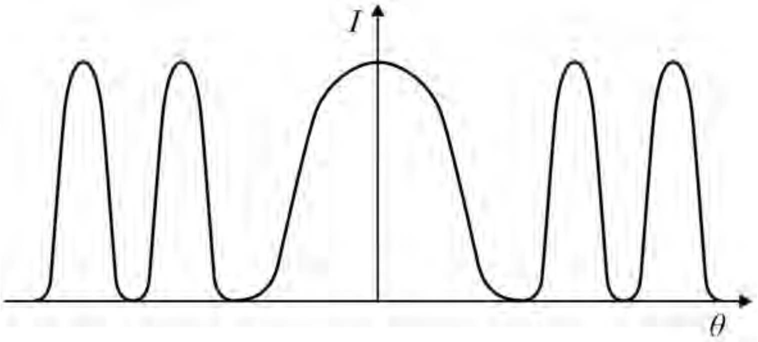
B



C



D



Do not write outside the box

3 0 The radius of a uranium $^{238}_{92}U$ nucleus is 7.75×10^{-15} m

What is the radius of a $^{12}_{6}C$ nucleus?

[1 mark]

A 1.10×10^{-18} m

B 3.91×10^{-16} m

C 2.86×10^{-15} m

D 3.12×10^{-15} m

3 1 During a single fission event of uranium-235 in a nuclear reactor the total mass lost is 0.23 u. The reactor is 25% efficient.

How many events per second are required to generate 900 MW of power?

[1 mark]

A 1.1×10^{14}

B 6.6×10^{18}

C 1.1×10^{20}

D 4.4×10^{20}

3 2 Which of the following substances can be used as a moderator in a nuclear reactor?

[1 mark]

A Boron

B Concrete

C Uranium-238

D Water

25

END OF QUESTIONS

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED