Please write clearly in block capitals.

Centre number		Candidate number	

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________

A-level PHYSICS

Paper 2

Wednesday 21 June 2017 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	

Kinetic theory model assumptions:
VINCE
→ volume of gas molecules << volume of container

Section A

Answer **all** questions in this section.

0 1 . 1 A number of assumptions are made when explaining the behaviour of a gas using the molecular kinetic theory model.

State **one** assumption about the size of molecules.

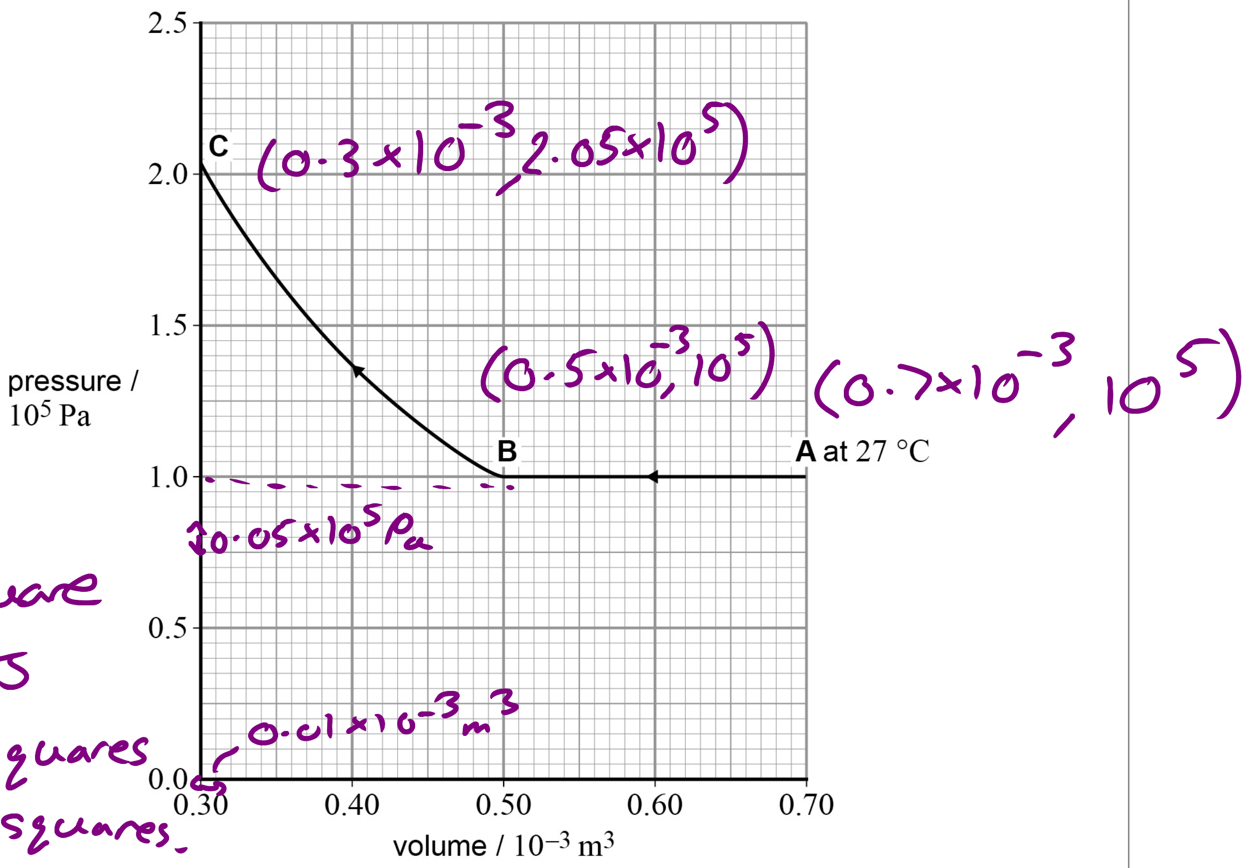
[1 mark]

Volume of the gas molecules is much smaller than the volume of the container.

Figure 1 shows how the pressure changes with volume for a fixed mass of an ideal gas.

At **A** the temperature of the gas is 27 °C. The gas then undergoes two changes, one from **A** to **B** and then one from **B** to **C**.

Figure 1



Area of one square
→ 0.05 J
Count squares
~170 squares.

Do not write outside the box

T_A in kelvin is $27+273=300K$

0 1 . 2 Calculate the number of gas molecules trapped in the cylinder using information from the initial situation at **A**.

[2 marks]

$T_A = 27°C =$

$P_A = 10^5 Pa$

$V_A = 0.7 \times 10^{-3} m^3$

$(pV = Nk_BT)$

$N = \frac{pV}{k_BT}$

$N = \frac{10^5 \times 0.7 \times 10^{-3}}{1.38\times10^{-23}\times300} = 1.691... \times10^{22}$

number of molecules = 1.7×10^{22}

0 1 . 3 Calculate, in K, the change in temperature of the gas during the compression that occurs between **A** and **B**.

[2 marks]

$pV = Nk_BT$

$\frac{pV}{T} = Nk_B$ ← Fixed mass of gas, N constant

$\frac{P_AV_A}{T_A} = Nk_B = \frac{P_BV_B}{T_B} \rightarrow \frac{T_B}{T_A} = \frac{P_BV_B}{P_AV_A} \rightarrow T_B = \frac{P_BV_B}{P_AV_A} \times T_A$

$P_A = P_B$

$T_B = \frac{V_B}{V_A} \times T_A = \frac{0.5\times10^{-3}}{0.7\times10^{-3}} \times 300 = 214.285...$

$T_B - T_A = 300 - 214.285... \approx -86K$

change in temperature = -86 K

0 1 . 4 Deduce whether the temperature of the gas changes during the compression from **B** to **C**.

[2 marks]

Isothermal: same temperature

$pV = Nk_BT$, T is constant, N is constant

Isothermal: $P_BV_B = P_CV_C$

$P_BV_B = 10^5 \times 0.5 \times 10^{-3} = 50 Pam^3$

$P_CV_C = 2.05\times10^5 \times 0.3\times10^{-3} = 61 Pam^3$

$P_BV_B \neq P_CV_C$, so the temperature of the gas changes since the change is not isothermal.

Question 1 continues on the next page

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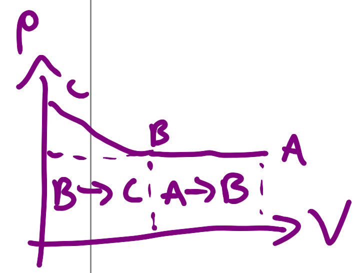
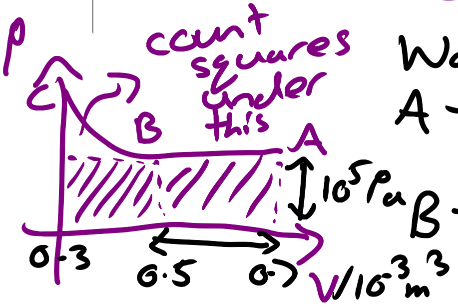
0 1 . 5 Compare the work done on the gas during the change from **A** to **B** with that from **B** to **C** on **Figure 1**.

[3 marks]



Work done on gas is the area under the pV graph.

	$V/10^{-3}m^3$	$p/10^5$ Pa
A	0.7	1
B	0.5	1
C	0.3	2.05



Work done is area under the graph

A→B: height $= 10^5$ Pa, length $= (0.7-0.5)\times10^{-3} = 0.2\times10^{-3}m^3$

Area $= 10^5 \times 0.2\times10^{-3} = 20$ J

B→C: rectangle: height $= 10^5$ Pa, length $= (0.5-0.3)\times10^{-3} = 0.2\times10^{-3}m^3$

Area of rectangle $= 20$ J

Area between rectangle and curve B→C is $0.05\times170 = 8.5$ J

Work done from B→C $= 20+8.5 = 28.5$ J

So work done from B→C is greater than the work done from A→B by 8.5 J.

10

Turn over for the next question

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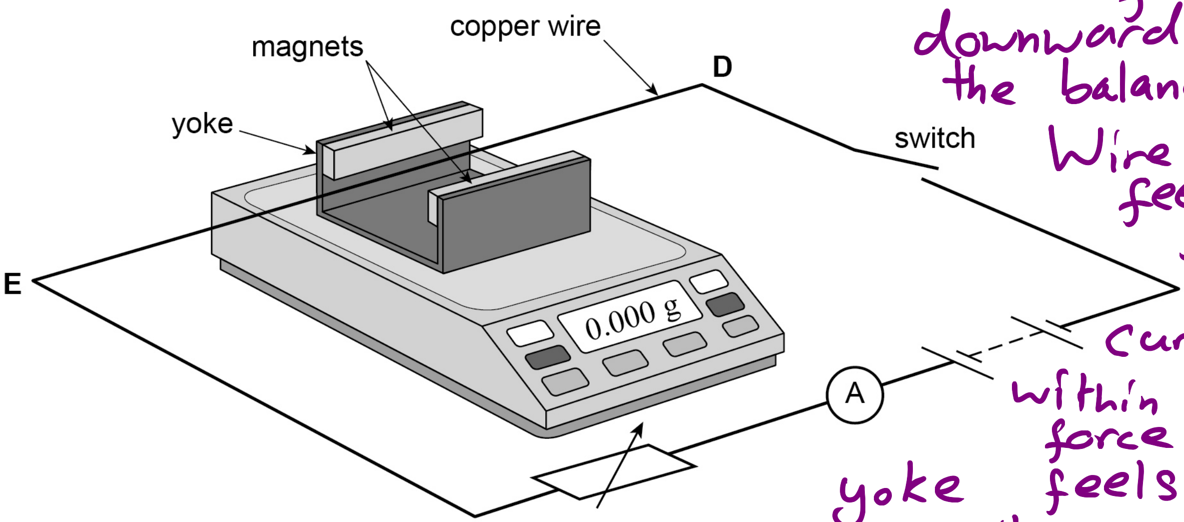
ANSWER IN THE SPACES PROVIDED

0 2 **Figure 2** shows two magnets, supported on a yoke, placed on an electronic balance.

Figure 2



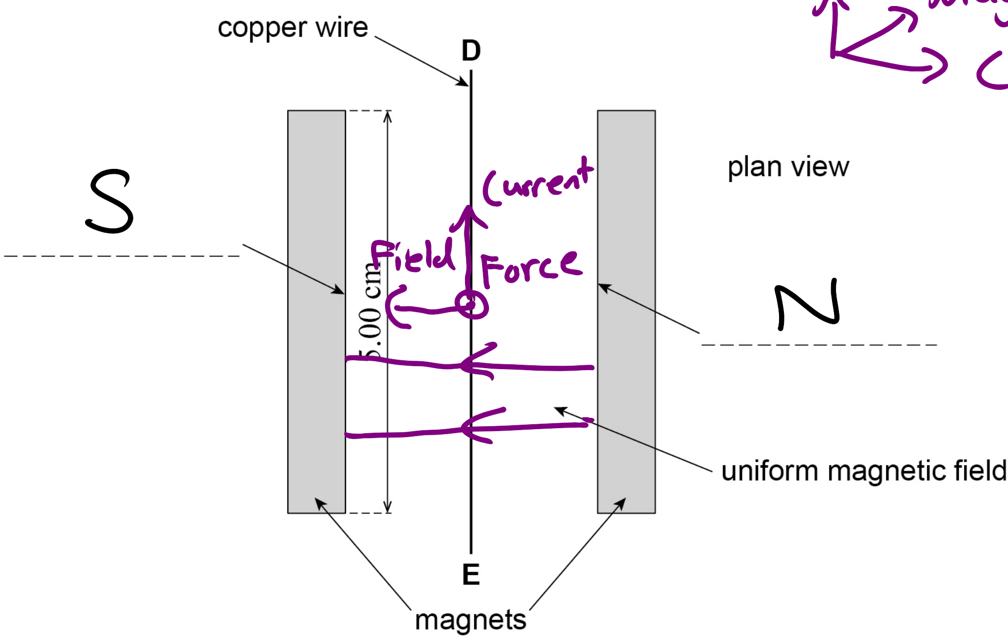
yoke is applying extra force downwards onto the balance. Wire must feel a force, since current within magnetic force. yoke feels equal and opposite force to wire

The magnets produce a uniform horizontal magnetic field in the region between them. A copper wire **DE** is connected in the circuit shown in **Figure 2** and is clamped horizontally at right angles to the magnetic field.

Figure 3 shows a simplified plan view of the copper wire and magnets.

Fleming Left hand rule:
Force
Magnetic Field
Current

Figure 3



When the apparatus is assembled with the switch open, the reading on the electronic balance is set to 0.000 g. This reading changes to a positive value when the switch is closed.

Do not write outside the box

0 2 . 1 Which of the following correctly describes the direction of the force acting on the wire **DE** due to the magnetic field when the switch is closed?

Tick (✓) the correct box.

[1 mark]

towards the left magnet in **Figure 3**	☐
towards the right magnet in **Figure 3**	☐
vertically up	☑
vertically down	☐

yoke pushed downwards, by Newton's 3rd law wire is pulled upwards.

0 2 . 2 Label the poles of the magnets by putting **N** or **S** on each of the two dashed lines in **Figure 3**.

[1 mark]

0 2 . 3 Define the tesla.

$F = BIL$ → length inside magnetic flux density.

$1N = 1T \times 1A \times 1m$

[1 mark]

1T is the magnetic flux density for which a wire of length 1m carrying a current 1A experiences a force of 1N, when the current is perpendicular to the field.

$F = BIL\sin\theta$

θ angle between current and field

$\sin 90° = 1$

0 2 . 4 The magnets are 5.00 cm long. When the current in the wire is 3.43 A the reading on the electronic balance is 0.620 g. F (indirectly)

$F = mg$ (what balance does)

Assume the field is uniform and is zero beyond the length of the magnets.

Calculate the magnetic flux density between the magnets.

[2 marks]

$F = BIL\sin\theta$, $\theta = 90°$, $\sin\theta = 1$

$F = BIL$

Force received by balance (same as the force on wire in magnitude)

$F = 0.620 \times 10^{-3} \times 9.81$ g → kg

$B = \frac{F}{IL}$.

$B = \frac{0.620 \times 10^{-3} \times 9.81}{3.43 \times 0.05}$ cm → m

magnetic flux density = 0.0355 T (3 s.f.)

$B = 0.0354647...$

5

Turn over ▶

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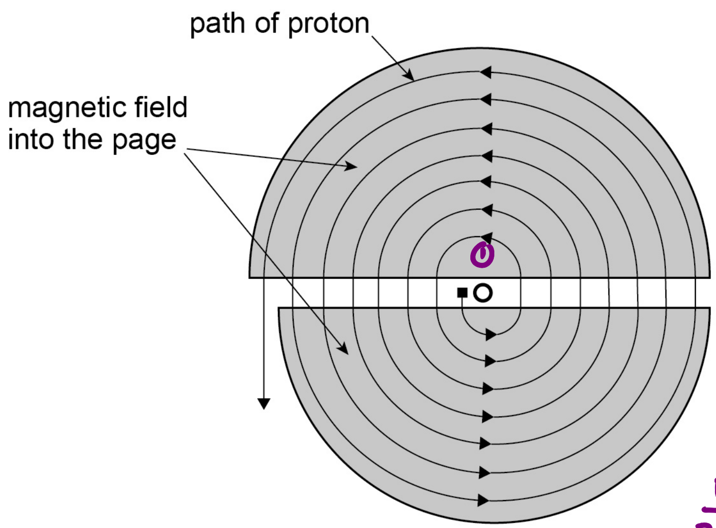
0 3

A cyclotron has two D-shaped regions where the magnetic flux density is constant. The D-shaped regions are separated by a small gap.
An alternating electric field between the D-shaped regions accelerates charged particles. The magnetic field causes the charged particles to follow a circular path.

Figure 4 shows the path followed by a proton that starts from **O**.

Figure 4



Fleming: Flux, Current, Force

So force perpendicular to velocity

For speed to change: $\frac{1}{2}mv^2$ changes

Must do work: apply force over a distance *

0 3 . 1 Explain why it is **not** possible for the magnetic field to alter the speed of a proton while it is in one of the D-shaped regions.

[1 mark]

The magnetic force is perpendicular to the direction of the proton's velocity, so it cannot do any work on the proton and thus cannot change its speed.

* Force must be applied with a component in the direction of motion for work done.

0 3 . 2 Derive an expression to show that the time taken by a proton to travel round one semi-circular path is independent of the radius of the path.

[3 marks]

– Moving under a magnetic flux density
⇒ $F = Bqv\sin\theta$ $(q = e)$, $\theta = 90°$, $F = Bev$
– Circular motion $F = \frac{mv^2}{r}$, $v = \omega r$, $\omega = \frac{\theta}{t}$

Circular motion + under magnetic field

$Bev = \frac{mv^2}{r} \rightarrow v = \frac{Ber}{m}$

$v = \omega r$, $\omega = \frac{\pi}{t} \rightarrow v = \frac{\pi r}{t}$

time taken to move round semi-circle → t

$\frac{Ber}{m} = \frac{\pi r}{t} \rightarrow t = \frac{\pi m}{Be}$

Independent of r

0 3 . 3 The maximum radius of the path followed by the proton is 0.55 m and the magnetic flux density of the uniform field is 0.44 T.

Ignore any relativistic effects.

We know proton mass

Calculate the maximum speed of a proton when it leaves the cyclotron.

[2 marks]

$v = \frac{Ber}{m}$

maximum speed is at maximum radius $(v \propto r)$

maximum speed $v = \frac{0.44 \times 1.60 \times 10^{-19} \times 0.55}{1.673 \times 10^{-27}}$

↑ proton mass

$v = 2.3144... \times 10^7$
$\simeq 2.3 \times 10^7$

maximum speed = 2.3×10^7 m s^{-1} (2 s.f.)

6

0 4 The core of a thermal nuclear reactor contains a number of components that are exposed to moving neutrons.

0 4 . 1 State what happens to a neutron that is incident on the moderator.

[1 mark]

The neutron collides with atoms in the moderator and loses speed.

0 4 . 2 State what happens to a neutron that is incident on a control rod.

[1 mark]

The neutron is absorbed.

0 4 . 3 A slow-moving neutron is in collision with a nucleus of an atom of the fuel which causes fission.

Describe what happens in the process.

[3 marks]

The neutron is absorbed, causing the uranium nucleus to decay into daughter nuclei, as well as into several neutrons.

$^{1}_{0}n + {}^{235}U \rightarrow {}^{236}U \rightarrow$ daughter nuclei $+ 3\,^{1}_{0}n$

unstable!

Do not write outside the box

0 4 . 4 A thermal nuclear reactor produces radioactive waste.

State the source of this waste and discuss some of the problems faced in dealing with the waste at various stages of its treatment.

Your answer should include:

- the main source of the most dangerous waste
- a brief outline of how waste is treated
- problems faced in dealing with the waste, with suggestions for overcoming these problems.

[6 marks]

The source of the waste is the radioactive daughter nuclei from fission of uranium-235. In treatment, first the waste is cooled in ponds (or other sources of water). Then, the plutonium/uranium are separated, before the high level waste is vitrified (made into solid glass). This is then placed in lead barrels and stored deep underground. During treatment, several problems are encountered. Firstly, the waste is very hot when removed from the reactor and so is cooled in water. Secondly, to prevent the high level waste from leaking, it is vitrified. Finally, the waste is put into lead containers since this attenuates the radiation it produces.

2 marks from here (treatment process)

3 marks from here (problems/solutions)

NB: Only 2 spelling/grammatical errors allowed otherwise marks are deducted.

Extra space is available on the next page if needed

Turn over ▶

Do not write outside the box

11

Do not write outside the box

0 5 . 1 Calculate the binding energy, in MeV, of a nucleus of $^{59}_{27}\text{Co}$.

nuclear mass of $^{59}_{27}\text{Co}$ = 58.93320 u → amu

[3 marks]

Mass defect Δm

Total mass > Total mass

Lost some mass

$\Delta E = \Delta m c^2$ ← binding energy

Mass of nucleons (in amu)

$= 27 \times 1.00728$ (protons) $+ (59-27) \times 1.00867$

$= 59.474$ u

Mass defect $\Delta m = 59.474 - 58.93320 = 0.5408$ u

1 u is equivalent to 931.5 MeV (4 s.f.)

$\Delta E = \Delta m \text{ in u} \times 931.5 \text{ MeV} = 931.5 \times \Delta m$ MeV

$\Delta E = 931.5 \times 0.5408 = 503.7552$

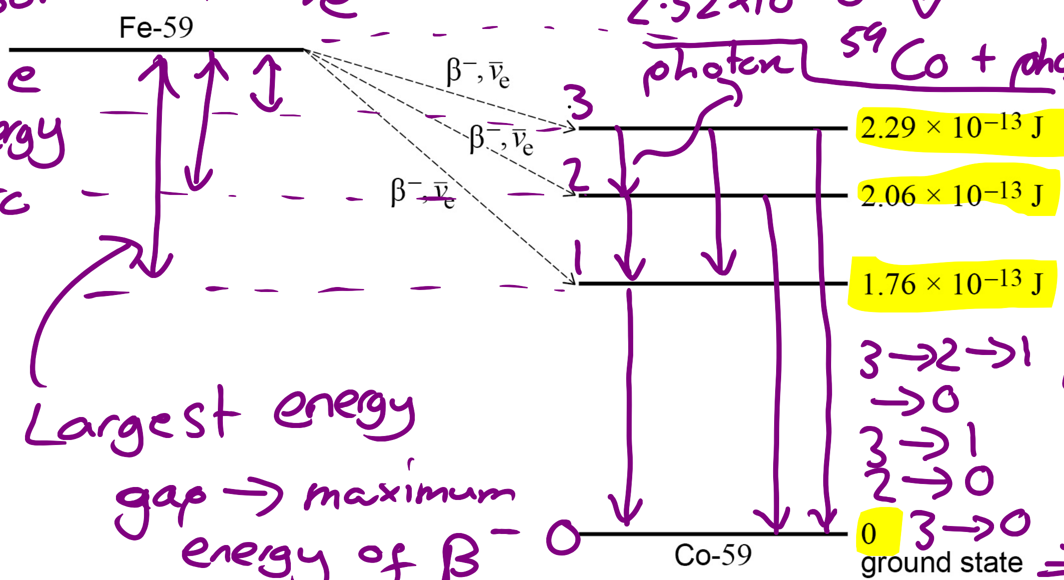
binding energy = 503.8 MeV (4 s.f.)

0 5 . 2 A nucleus of iron Fe-59 decays into a stable nucleus of cobalt Co-59. It decays by β^- emission followed by the emission of γ-radiation as the Co-59 nucleus de-excites into its ground state.

The total energy released when the Fe-59 nucleus decays is 2.52×10^{-13} J.

The Fe-59 nucleus can decay to one of three excited states of the cobalt-59 nucleus as shown in **Figure 5**. The energies of the excited states are shown relative to the ground state.

Figure 5



Calculate the maximum possible kinetic energy, in MeV, of the β^- particle emitted when the Fe-59 nucleus decays into an excited state that has energy above the ground state.

[2 marks]

maximum kinetic energy = 0.48 MeV

Do not write outside the box

0 5 . 3 Following the production of excited states of $^{59}_{27}Co$, γ-radiation of discrete wavelengths is emitted.

State the maximum number of discrete wavelengths that could be emitted.

[1 mark]

maximum number = 6

0 5 . 4 Calculate the longest wavelength of the emitted γ-radiation.

[3 marks]

$E = \frac{hc}{\lambda}$ Longest wavelength ⇒ lowest energy.

Smallest energy difference is between levels 3 and 2.

Therefore $E = 2.29 \times 10^{-13} - 2.06 \times 10^{-13}$

$= 0.23 \times 10^{-13}$

$E = \frac{hc}{\lambda} \rightarrow \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{0.23 \times 10^{-13}}$

$= 8.649593... \times 10^{-12}$

longest wavelength = 8.65×10^{-12} m

(3s.f.)

9

Turn over ►

Do not write outside the box

0 6 . 1 State what is represented by gravitational field lines.

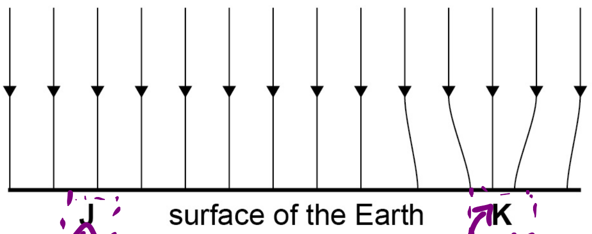
[1 mark]

Gravitational field lines represent the direction and relative size of the force acting upon an object with mass in a gravitational field.

following field line Force massive object density of lines → strength of force

0 6 . 2 **Figure 6** shows the gravitational field above a small horizontal region on the surface of the Earth.

Figure 6



Denser field lines → stronger field

source of gravitational field is mass ⇒ more mass

Suggest why the field lines converge over a small area at **K**.

[2 marks]

Since field lines at K are closer together, the field is stronger. Therefore the material at K has a higher density than the surrounding material.

Gravitational force F_g has component to right

0 6 . 3 A ball travelling at constant speed passes position **J** moving towards position **K** in **Figure 6**.

Assume friction is negligible.

Explain any change in the speed of the ball as it approaches **K**.

[2 marks]

The ball accelerates and increases its speed, since there is a component of the gravitational force acting to the right.

At K, the ball experiences a force. (F=ma)

Forces at K: vertically balanced, unbalanced force to right.

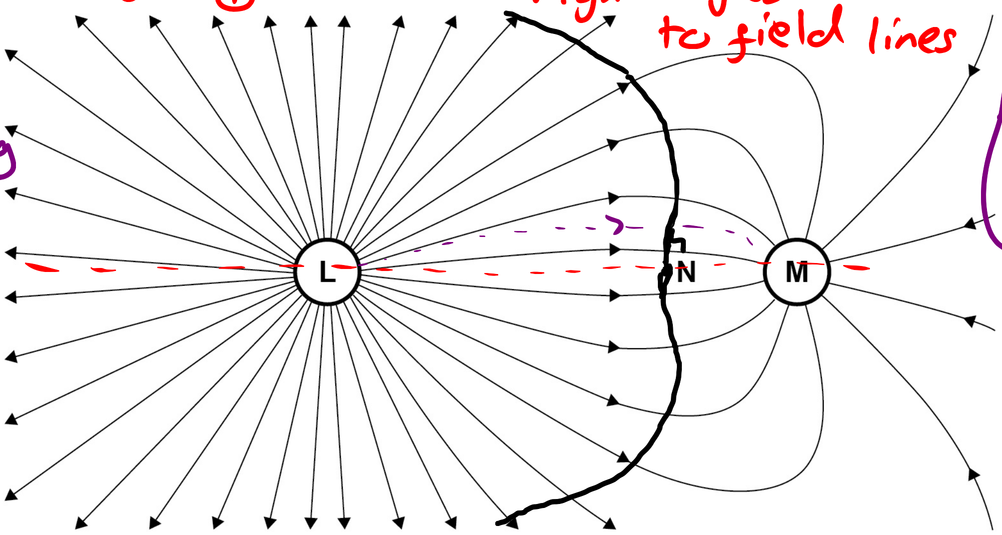
Do not write outside the box

0 6 . 4 **Figure 7** shows lines of force for the electric field surrounding two charged objects **L** and **M**.

Criteria: [Line had to bend to the left. Line is symmetrical about 1 [Line at right angles to field lines

Gravity attracts only.

Figure 7



Field lines leaving L

Field lines are more dense around L

Object repelled. Field lines cannot flow out of object

Equipotential: Part of space where potential is constant

Field lines show gradient of potential

Explain why the lines of force shown in **Figure 7** cannot represent a gravitational field.

[1 mark]

Lines of gravitational force must always point into a massive object

0 6 . 5 State which object **L** or **M** has a charge with the greater magnitude.

E field lines represent direction a small, positive test charge moves*

Larger magnitude charge → force of larger magnitude

object L

State which object **L** or **M** has a positive charge.

+ve – repel other +ve charges so leave object

– ve – attract +ve charges (enter object)

object L

[1 mark]

0 6 . 6 Draw, on **Figure 7**, an equipotential line that passes through point **N**.
Do **not** extend your line beyond the given field lines.

[2 marks]

9

* This comes from the direction of the electric force, since the electric force causes motion in the direction of the electric field.

Turn over ►

0 7 . 1 Derive an expression to show that for satellites in a circular orbit

$$T^2 \propto r^3$$

where T is the period of orbit and r is the radius of the orbit.

[2 marks]

Satellites orbit under gravitational force $F = \frac{GmM}{r^2}$ $m \leftarrow r \rightarrow M$ Eliminate F, get two eqns including v, r, and T

Circular orbits: – Centripetal force $F = \frac{mv^2}{r}$

– $v = \frac{2\pi r}{T}$ (2πr → radius of orbit; T → time taken to orbit)

gravitational force $\frac{GmM}{r^2} = \frac{mv^2}{r}$ ✓ $\rightarrow v^2 = \frac{GM}{r}$

circular motion $v = \frac{2\pi r}{T}$ $\rightarrow \left(\frac{2\pi r}{T}\right)^2 = \frac{GM}{r}$ ✓

$\Rightarrow T^2 \times GM = 4\pi^2 r^3$

$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$ $\left(\frac{4\pi^2}{GM}\right)$ is constant $\rightarrow$ $T^2 \propto r^3$

0 7 . 2 Pluto is a dwarf planet. The mean orbital radius of Pluto around the Sun is 5.91×10^9 km compared to a mean orbital radius of 1.50×10^8 km for the Earth.

Calculate in years the orbital period of Pluto.

[2 marks]

$T^2 \propto r^3$ $\left(T^2 = \left(\frac{4\pi^2}{GM}\right) r^3\right)$ → don't know the mass of the sun

S • E • P

Earth: $T_e^2 = \frac{4\pi^2}{GM} r_e^3$

Pluto: $T_p^2 = \frac{4\pi^2}{GM} r_p^3$

$\frac{T_p^2}{T_e^2} = \frac{\frac{4\pi^2}{GM}}{\frac{4\pi^2}{GM}} \frac{r_p^3}{r_e^3}$

$\left(\frac{T_p}{T_e}\right)^2 = \left(\frac{r_p}{r_e}\right)^3$

$T_e = 1$ year

$T_p^2 = \left(\frac{r_p}{r_e}\right)^3 \times (1y)^2$

$T_p = \left(\frac{r_p}{r_e}\right)^{3/2} \times 1y$

$T_p = \left(\frac{5.91 \times 10^9 \text{ km}}{1.50 \times 10^8 \text{ km}}\right)^{3/2} \times 1y$ ✓

$T_p = 247.3\ldots$ yr

orbital period of Pluto = 247 ✓ yr (3 s.f.)

Do not write outside the box

0 7 . 3 A small mass released from rest just above the surface of Pluto has an acceleration of $0.617\ \text{m s}^{-2}$.

Assume Pluto has no atmosphere that could provide any resistance to motion.

Calculate the mass of Pluto.

Give your answer to an appropriate number of significant figures.

radius of Pluto = 1.19×10^{6} m

[3 marks]

(no air resistance)

small mass

Gravitational Force or potential

$F = \frac{GMm}{r^2}$

acceleration $F = ma$? → Force

$F = ma$

G to 3s.f.

$ma = \frac{GMm}{r^2}$

$a = \frac{GM}{r^2}$

$M = \frac{ar^2}{G} = \frac{0.617 \times (1.19 \times 10^{6})^2}{6.67 \times 10^{-11}}$

$M = 1.3099455\ldots \times 10^{22}$ kg

mass of Pluto = 1.31×10^{22} kg (3s.f.)

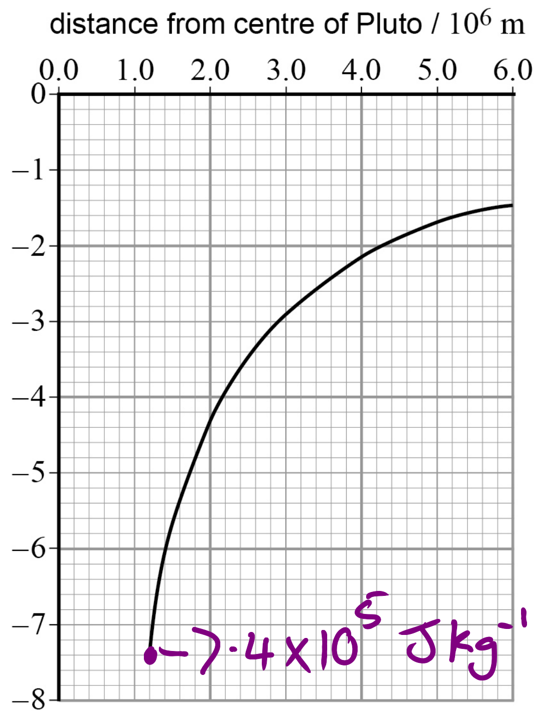
Turn over ▶

Do not write outside the box

0 7 . 4 **Figure 8** shows the variation in gravitational potential with distance from the centre of Pluto for points at and above its surface.

Figure 8

To escape, enough kinetic energy must be converted into potential energy such that there gravitational potential energy has increased V_p from a negative value to zero.



note: if there's less E_k than the value of E_p, can't escape.

0 escaped from pluto, no gravitational potential enegy

A meteorite hits Pluto and ejects a lump of ice from the surface that travels vertically at an initial speed of 1400 m s^{-1}.

Determine whether this lump of ice can escape from Pluto.

[3 marks]

E_k, E_p, $E_k = \frac{1}{2}mv^2$, E_p from graph above.

$E_p = V_p \times m$

lump at pluto surface

$E_k, E_p < 0$

kinetic energy:

$E_k = \frac{1}{2} \times m \times (1400)^2 = 9.8 \times 10^5 \times m$

energy needed to escape: $E_p = +7.4 \times 10^5 \times m$

$9.8 \times 10^5 \times m > 7.4 \times 10^5 \times m$

Yes, the lump can escape pluto as it has enough kinetic energy to escape.

10

END OF SECTION A

Do not write outside the box

Section B

Each of Questions **8** 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.

100m ↑ Gravitational potential energy
↓ Kinetic energy (from downwards velocity)
↓ Thermal energy

0 8 A continuous stream of water falls through a vertical distance of 100 m. = h
Assume no thermal energy is transferred to the surroundings.
The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the temperature difference of the water between the top and bottom of the waterfall?

[1 mark]

Gravitational potential energy = Thermal energy added to a water particle.

- **A** 0.023 K ○
- **B** 0.23 K ⬬
- **C** 2.3 K ○
- **D** 4.3 K ○

Conservation of energy:

$E_p = mgh = mc\Delta\theta$ ~ energy gain of a substance if heated through $\Delta\theta$

$\Delta\theta = \frac{mgh}{mc} = \frac{gh}{c}$

$\Delta\theta = \frac{9.81 \times 100}{4200} = 0.23357\ldots \approx 0.23\text{K}$

Turn over ▶

0 9 A student measures the power of a microwave oven. He places 200 g of water at 23 °C into the microwave and heats it on full power for 1 minute. When he removes it, the temperature of the water is 79 °C.

The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the average rate at which thermal energy is gained by the water?

[1 mark]

A 780 W

B 840 W

C 1.1 kW

D 4.6 kW

1 0 The composition of a carbon dioxide (CO_2) molecule is one atom of $^{12}_{6}C$ and two atoms of $^{16}_{8}O$.

What is the number of molecules of CO_2 in 2.2 kg of the gas?

[1 mark]

A 1.0×10^{22}

B 3.0×10^{22}

C 3.0×10^{25}

D 4.7×10^{25}

1 1 What is the total internal energy of 2.4 mol of an ideal gas which has a temperature of 15 °C?

[1 mark]

A 6.0×10^{-21} J

B 1.4×10^{-20} J

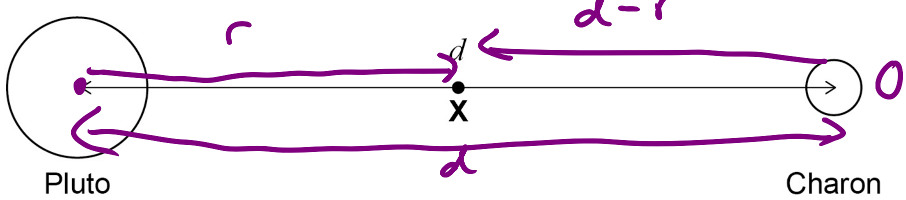
C 4.5×10^{2} J

D 8.6×10^{3} J

Do not write outside the box

1 2 Charon is a moon of Pluto that has a mass equal to $\frac{1}{9}$ that of Pluto.

The distance between the centre of Pluto and the centre of Charon is d.
X is the point at which the resultant gravitational field due to Pluto and Charon is zero.



What is the distance of **X** from the centre of Pluto?

[1 mark]

A $\frac{2}{9}d$

B $\frac{2}{3}d$

C $\frac{3}{4}d$

D $\frac{8}{9}d$

1 3 The distance between the Sun and Mars varies from 2.1×10^{11} m to 2.5×10^{11} m.
When Mars is closest to the Sun, the force of gravitational attraction between them is F.

What is the force of gravitational attraction between them when they are furthest apart?

[1 mark]

A $0.71F$

B $0.84F$

C $1.2F$

D $1.4F$

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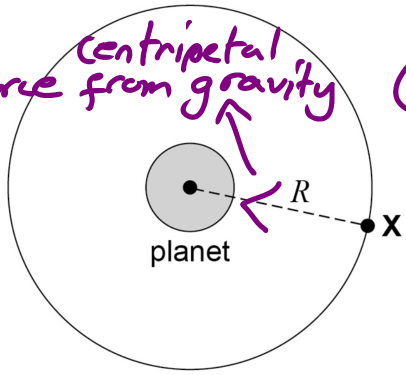
1 4 A satellite **X** of mass m is in a concentric circular orbit of radius R about a planet of mass M.



- Circular orbit $\frac{mv^2}{R}$
(centripetal Force / circular motion)
- Gravitational Force $\frac{GMm}{R^2}$
- Kinetic energy is goal $\rightarrow E_k = \frac{1}{2}mv^2$

What is the kinetic energy of **X**?

[1 mark]

E_k contains v, must use centripetal force = gravitational force to get an equation for v.

A $\frac{GMm}{2R}$ ■

B $\frac{GMm}{R}$ ○

C $\frac{2GMm}{R}$ ○

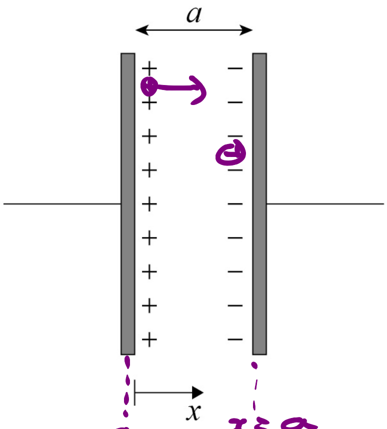
D $\frac{4GMm}{R}$ ○

$$\frac{mv^2}{R} = \frac{GMm}{R^2}$$

$$v^2 = \frac{GM}{R}$$

$$E_k = \frac{1}{2}m \times v^2 = \frac{1}{2}m\frac{GM}{R} = \frac{GMm}{2R}$$

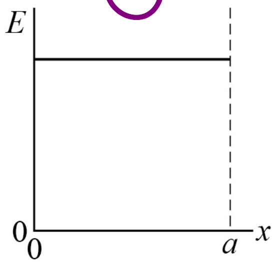
1 5 Two parallel metal plates of separation a carry equal and opposite charges.



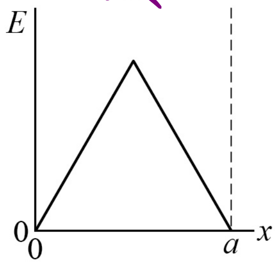
Which graph best represents how the electric field strength E varies with the distance x in the space between the two plates?

[1 mark]

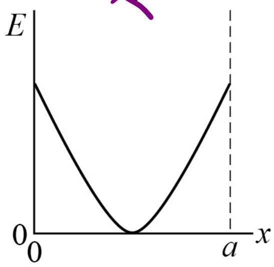
A



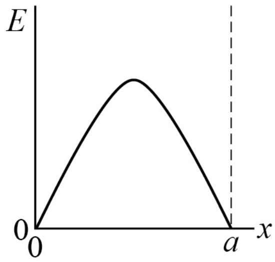
B



C



D



- **A** ☐
- **B** ☐
- **C** ☐
- **D** ☐

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1 6 A particle of mass m and charge q is accelerated through a potential difference V over a distance d.

What is the average acceleration of the particle?

[1 mark]

A	$\frac{qV}{md}$	■
B	$\frac{mV}{qd}$	○
C	$\frac{V}{mqd}$	○
D	$\frac{dV}{mq}$	○

1 7 An electron moves through a distance of $0.10\ \text{m}$ parallel to the field lines of a uniform electric field of strength $2.0\ \text{kN C}^{-1}$.

What is the work done on the electron?

[1 mark]

A	zero	○
B	$1.6 \times 10^{-17}\ \text{J}$	○
C	$3.2 \times 10^{-17}\ \text{J}$	■
D	$1.6 \times 10^{-21}\ \text{J}$	○

1 8 A parallel-plate capacitor is fully charged and then disconnected from the power supply. A dielectric is then inserted between the plates.

Which row correctly identifies the charge on the plates and the electric field strength between the plates?

[1 mark]

	Charge	Electric field strength	
A	Stays the same	Increases	⬭
B	Increases	Decreases	⬭
C	Increases	Increases	⬭
D	Stays the same	Decreases	⬭

1 9 A capacitor of capacitance C has a charge of Q stored on the plates. The potential difference between the plates is doubled.

What is the change in the energy stored by the capacitor?

[1 mark]

A $\dfrac{Q^2}{2C}$ ⬭

B $\dfrac{Q^2}{C}$ ⬭

C $\dfrac{3Q^2}{2C}$ ⬭

D $\dfrac{2Q^2}{C}$ ⬭

Turn over ▶

2 0 A capacitor consists of two parallel square plates of side l separated by distance d. The capacitance of the arrangement is C.

What is the capacitance of a capacitor with square plates of side $2l$ separated by a distance $\frac{d}{2}$?

[1 mark]

A C ○

B $2C$ ○

C $4C$ ○

D $8C$ ○

2 1 A capacitor of capacitance $120\ \mu\text{F}$ is charged and then discharged through a $20\ \text{k}\Omega$ resistor.

What fraction of the original charge remains on the capacitor $4.8\ \text{s}$ after the discharge begins?

[1 mark]

A 0.14 ○

B 0.37 ○

C 0.63 ○

D 0.86 ○

2 2 A coil with 20 circular turns each of diameter 60 mm is placed in a uniform magnetic field of flux density 90 mT.

Initially the plane of the coil is perpendicular to the magnetic field lines as shown in **Figure X**.

Figure X

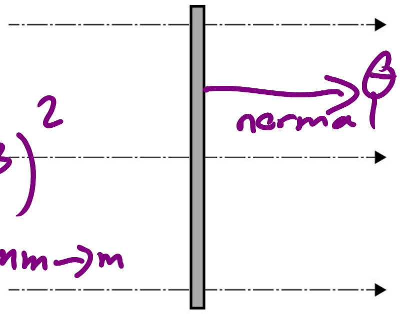
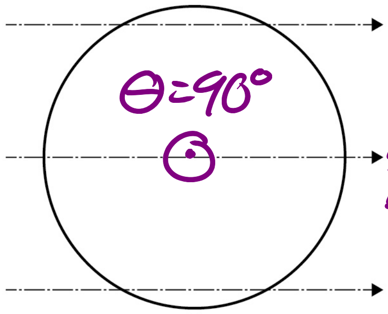


Figure Y



The coil is rotated about a vertical axis by 90° in a time of 0.20 s so that its plane becomes parallel to the field lines as shown in **Figure Y**.
Assume that the rate of change of flux linkage remains constant.

What is the emf induced in the coil?

[1 mark]

A zero

B 1.3 mV

C 25 mV

D 100 mV

2 3 The mean power dissipated in a resistor is 47.5 μW when the root mean square (rms) voltage across the resistor is 150 mV.

What is the peak current in the resistor?

[1 mark]

A 2.3×10^{-4} A

B 4.5×10^{-4} A

C 2.3×10^{3} A

D 4.5×10^{3} A

2 4 The National Grid is used to transfer electrical energy from power stations to consumers.

What conditions for the transmission voltage and the transmission current give the most efficient transfer of energy through the National Grid?

[1 mark]

	Transmission voltage	Transmission current	
A	High	High	○
B	High	Low	○
C	Low	High	○
D	Low	Low	○

2 5 A mains transformer has a primary coil of 2500 turns and a secondary coil of 130 turns.
The primary coil is connected to a mains supply where V_{rms} is 230 V.
The secondary coil is connected to a lamp of resistance 6.0 Ω.
The transformer is 100% efficient.

What is the peak power dissipated in the lamp?

[1 mark]

A 12 W ○

B 24 W ○

C 48 W ○

D 96 W ○

2 6 The Rutherford scattering experiment led to

[1 mark]

A the discovery of the electron. ○

B the quark model of hadrons. ○

C the discovery of the nucleus. ○

D evidence for wave-particle duality. ○

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2 7 A Geiger counter is placed near a radioactive source and different materials are placed between the source and the Geiger counter.

The results of the tests are shown in the table.

Material	Count rate of Geiger counter / s^{-1}
None	1000
Paper	1000
Aluminium foil	250
Thick steel	50

What is the radiation emitted by the source?

[1 mark]

A α only ○

B α and γ ○

C α and β ○

D β and γ ●

2 8 Nobelium-259 has a half-life of 3500 s.

What is the decay constant of nobelium-259?

[1 mark]

A $8.7 \times 10^{-5}\ s^{-1}$ ○

B $2.0 \times 10^{-4}\ s^{-1}$ ●

C $1.7 \times 10^{-2}\ s^{-1}$ ○

D $1.2 \times 10^{-2}\ s^{-1}$ ○

Turn over ►

Do not write outside the box

2 9 A pure sample of nuclide **X** containing N nuclei has an activity A.
The half-life of **X** is 6000 years.

A pure sample of nuclide **Y** containing $3N$ nuclei has an activity $6A$.

What is the half-life of nuclide **Y**?

[1 mark]

A 1000 years ○

B 3000 years ●

C 12 000 years ○

D 18 000 years ○

$X: A = \lambda_x N \rightarrow \lambda_x = \frac{A}{N}$

Half-life: $T_{\frac{1}{2},x} = \frac{1}{\lambda_x} \ln 2$

$T_{\frac{1}{2}} \propto \frac{1}{\lambda}$

$Y: A_y = 6A = \lambda_y N_y = \lambda_y \times 3N$

$\rightarrow \lambda_y = \frac{A}{N} \times 2 \rightarrow \lambda_y = 2\lambda_x$

$\rightarrow T_{\frac{1}{2}} \propto \frac{1}{\lambda}$, $\lambda_y = 2\lambda_x$, $T_{\frac{1}{2},y} = \frac{1}{2} T_{\frac{1}{2},x}$ (inversely proportional)

$T_{\frac{1}{2},y} = \frac{6000}{2} = 3000$ years

3 0 Cobalt-60 has a half-life of 5.27 years. $T_{\frac{1}{2}}$ 60u

What is the total activity of 1.0 g of cobalt-60?

[1 mark]

A 4.2×10^{13} Bq ●

B 2.2×10^{14} Bq ○

C 2.5×10^{15} Bq ○

D 1.3×10^{21} Bq ○

$A = \lambda N \simeq 4.2 \times 10^{13}$ Bq

$T_{\frac{1}{2}} = \frac{1}{\lambda} \ln 2$

$\lambda = \frac{1}{T_{\frac{1}{2}}} \ln 2$

$N = \frac{\text{total mass}}{\text{mass of one Co-60}} = \frac{1 \times 10^{-3}}{60 \times 1.661 \times 10^{-27}}$ (g → kg)

$N = 1.003411... \times 10^{22}$ radioactive nuclei

$\lambda = \frac{\ln 2}{5.27 \times 365 \times 24 \times 60 \times 60} = 4.170693... \times 10^{-9}\ s^{-1}$

(days in year, hours in a day, seconds in an hour)

$A = 1.003... \times 10^{22} \times 4.170693... \times 10^{-9} = 4.18598 \times 10^{13}$

3 1 The radius of a nucleus of the iron nuclide $^{56}_{27}\mathrm{Fe}$ is 4.35×10^{-15} m.

What is the radius of a nucleus of the uranium nuclide $^{238}_{92}\mathrm{U}$?

[1 mark]

A 2.69×10^{-15} m

B 2.89×10^{-15} m

C 6.55×10^{-15} m

D 7.05×10^{-15} m

3 2 Uranium-236 undergoes nuclear fission to produce barium-144, krypton-89 and three free neutrons.

What is the energy released in this process?

Nuclide	Binding energy per nucleon / MeV
$^{236}_{92}\mathrm{U}$	7.5
$^{144}_{56}\mathrm{Ba}$	8.3
$^{89}_{36}\mathrm{Kr}$	8.6

[1 mark]

A 84 MeV

B 106 MeV

C 191 MeV

D 3730 MeV

END OF QUESTIONS

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