Do not write outside the box

2 3 A coil is rotated at frequency f in a uniform magnetic field.
The magnetic flux linking the coil is a maximum at time t_1 and the emf induced in the coil is a maximum at time t_2.

What is the smallest value of $t_1 - t_2$?

[1 mark]

A 0 ☐

B $\frac{1}{4f}$ ☐

C $\frac{1}{2f}$ ☐

D $\frac{3}{4f}$ ☐

2 4 Power P is dissipated in a resistor of resistance R carrying a direct current I.

A second resistor of resistance $2R$ carries an alternating current with peak value I.

What is the power dissipated in the second resistor?

[1 mark]

A $\sqrt{2}P$ ☐

B P ☐

C $2P$ ☐

D $4P$ ☐

2 5 What was deduced or observed in the Rutherford scattering experiment?

[1 mark]

A All gold atoms are not alike. ☐

B Alpha particles are helium nuclei. ☐

C Some particles were deflected through angles greater than $90°$. ☐

D The motion of most alpha particles was reversed. ☐

Turn over ►

2 6 Which row is correct for α, β and γ radiation?

[1 mark]

		α	β	γ	
A	Is it deflected by a magnetic field?	yes	yes	no	⬭
B	Is it deflected by an electric field?	yes	yes	yes	⬭
C	Does it have a positive charge?	yes	no	yes	⬭
D	Does it come from outside the nucleus?	no	yes	no	⬭

2 7 A sample of radioactive material consists of 200 g of nuclide **P** and 100 g of nuclide **Q**.

Nuclide **P** has a half-life of 2 days and nuclide **Q** has a half-life of 4 days.

What is the total mass of nuclides **P** and **Q** after 12 days?

[1 mark]

A 3.1 g ⬭

B 12.5 g ⬭

C 15.6 g ⬭

D 18.8 g ⬭

2 8 A nuclide has a half-life of 10 ms.

The decay constant for this nuclide lies between

[1 mark]

A 1 s^{-1} and 10 s^{-1}. ⬭

B 10 s^{-1} and 10^2 s^{-1}. ⬭

C 10^2 s^{-1} and 10^3 s^{-1}. ⬭

D 10^3 s^{-1} and 10^6 s^{-1}. ⬭

Do not write outside the box

2 9 Which provides evidence for the existence of energy levels in nuclei?

[1 mark]

A the Rutherford alpha particle scattering experiment ✗

B the existence of X-ray line spectra ✗

C the existence of gamma radiation ✓ ← v. high freq so high energy ☒

D electron diffraction by crystals ✗

3 0 Which is **not** true for gamma radiation?

[1 mark]

A It is more penetrating than alpha or beta radiation of the same energy through the same material. ✓

B Its intensity is inversely proportional to the square of the distance from its source. ✓

C It is emitted with discrete frequencies. ✓

D When it is absorbed it makes the absorber radioactive. ✗ ☒

3 1 In a thermal reactor, induced fission occurs when a $^{235}_{92}\mathrm{U}$ nucleus captures a neutron.

Which statement is true?

[1 mark]

A The moderator absorbs excess neutrons. ✗ (slows down)

B A large number of neutrons should be produced per fission to sustain the reaction. ✗

C Slow neutrons are required for this induced fission. ✓ (Thermal) ☒

D The control rods slow down neutrons. ✗

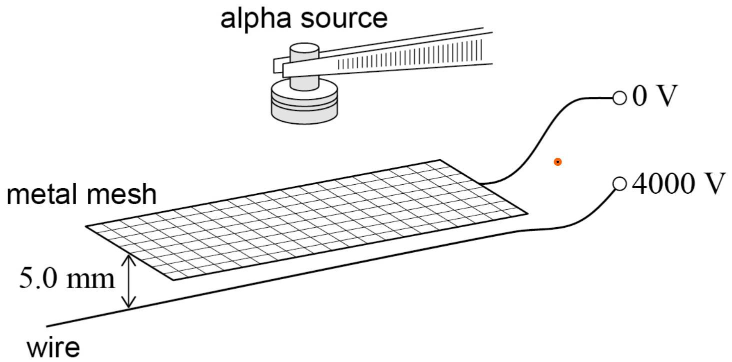
END OF QUESTIONS

25

Do not write outside the box

0 4 **Figure 4** shows a spark detector used to detect alpha particles.

Figure 4



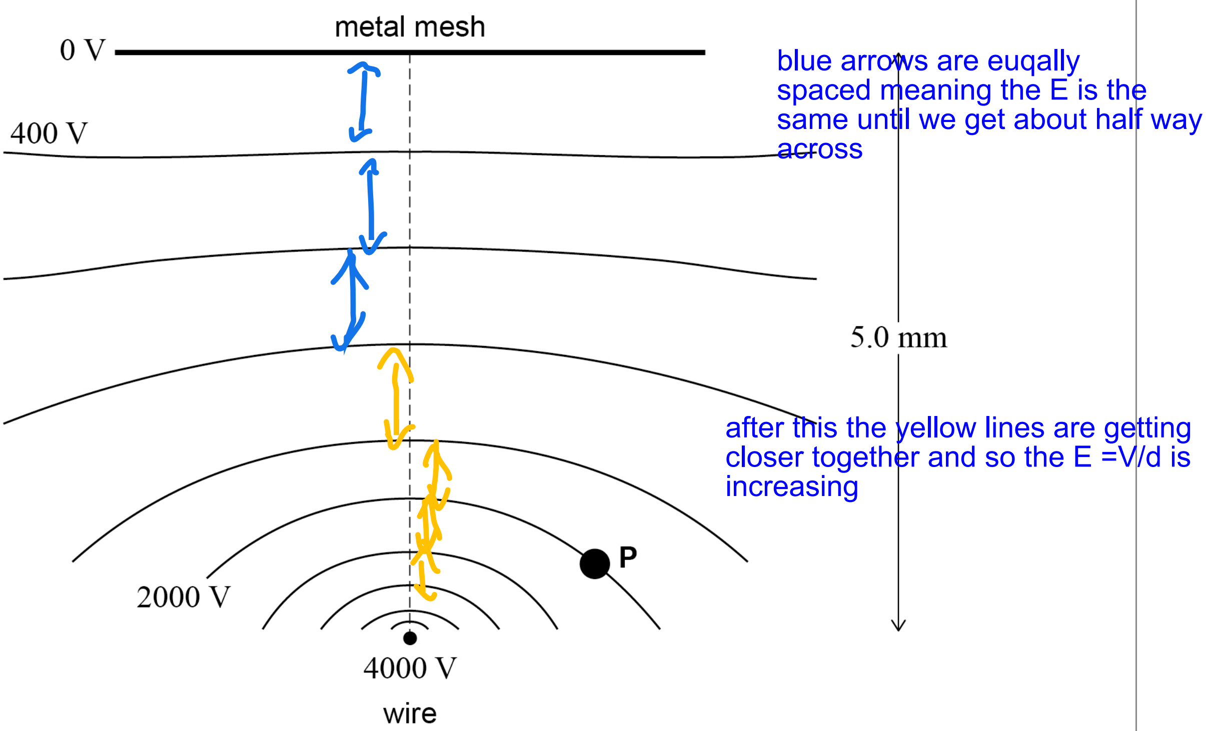
The detector consists of a metal mesh placed 5.0 mm above a wire.
A potential difference of 4000 V is applied between the mesh and the wire.

Molecules in the air between the mesh and the wire are ionised by an alpha particle and a spark is produced.

Figure 5 shows equipotentials between the mesh and the wire.

Figure 5

z



the gadient of a V vs r graph is V/r - which is the electric field strength. So we need to consider the gradient - in otherwords the consider the distance between the equipotentials

Do not write outside the box

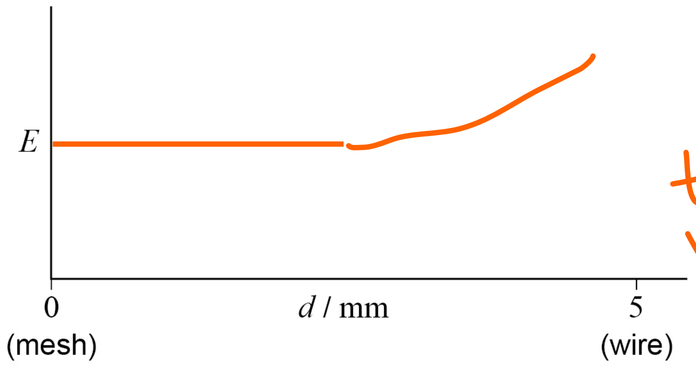
0 4 . 1 **Figure 5** shows a dashed line between the mesh and the wire.

Sketch on **Figure 6** a graph to show how the magnitude E of the electric field strength varies with the distance d from the mesh along this dashed line.
No values are required on the E axis.

[2 marks]

see above

Figure 6



straight till about half way, then increasing grad^n

An alpha particle passes through the mesh.
The alpha particle ionises an argon atom at **P** on **Figure 5**, releasing one electron.
The electron and the argon ion have no kinetic energy at **P**.
The electron then travels to the wire and the argon ion travels to the mesh.

0 4 . 2 Calculate the ratio $\dfrac{\text{speed of electron when it reaches the wire}}{\text{speed of argon ion when it reaches the mesh}}$.

Assume that the air has no effect on the motion of the electron or on the motion of the argon ion.

mass of argon ion = 6.64×10^{-26} kg

[2 marks]

both will gain the same energy

ie 4000 − 2000 = 2000 eV

$\therefore \frac{1}{2} m_e v_e^2 = \frac{1}{2} m_a v_a^2 \Rightarrow \frac{v_e^2}{v_a^2} = \frac{m_a}{m_e}$

$\frac{v_e^2}{v_a^2} = \frac{6.64 \times 10^{-26}}{9.11 \times 10^{-31}} \Rightarrow \frac{v_e}{v_a} = 270$

ratio = ____________________

Question 4 continues on the next page

Turn over ▶

Do not write outside the box

0 4 . 3 In practice, the air **does** affect the motion of the electron and the motion of the argon ion.

Suggest how the presence of air between the mesh and the wire changes the ratio in Question **04.2**.
No numerical detail is required.

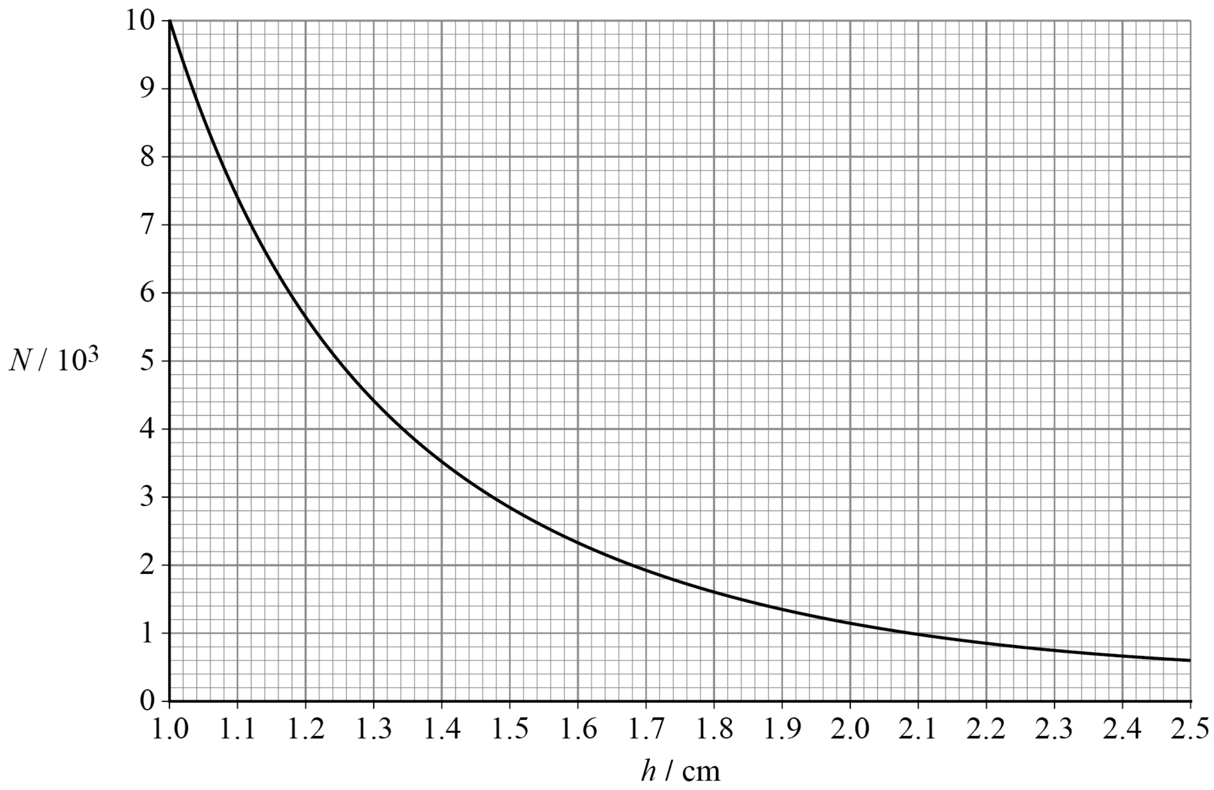
[1 mark]

argon ions ar bigger so will collide more losing Ek so will arrive slower meaning that the ratio is larger.

0 4 . 4 The alpha source in **Figure 4** is moved to different heights h above the mesh.

Figure 7 shows how the number of sparks N produced in 10 minutes varies with h.
No sparks are produced when the source is not present.

Figure 7



Do not write outside the box

Student **A** suggests that the spark rate obeys an inverse-square law.
Student **B** suggests that the spark rate decreases exponentially with h.

Determine whether either student is correct.

[3 marks]

if inverse square the Nh^2 = constant. Take three values

→ $10 \times 1^2 = 10$
→ $1.9 \times 1.7^2 = 5.4$
→ $1 \times 2.1^2 = 4.4$

not constant

if exponential should be a constant "half life"

10→5 1.24 − 1 = 0.24
8→4 1.34 − 1.08 = 0.26
6→3: 1.46 − 1.18 = 0.28
2→1 2.2 − 1.66 = 0.54

not const

both students are sadly mistaken in their proposals

8

Turn over for the next question

Turn over ►

Do not write outside the box

0 6 . 1 Nuclear radii can be estimated using either alpha particles or high-energy electrons.

State **two** advantages of using high-energy electrons rather than alpha particles for this estimate.

[2 marks]

1 as attractive need less energy to get towards the nucleus

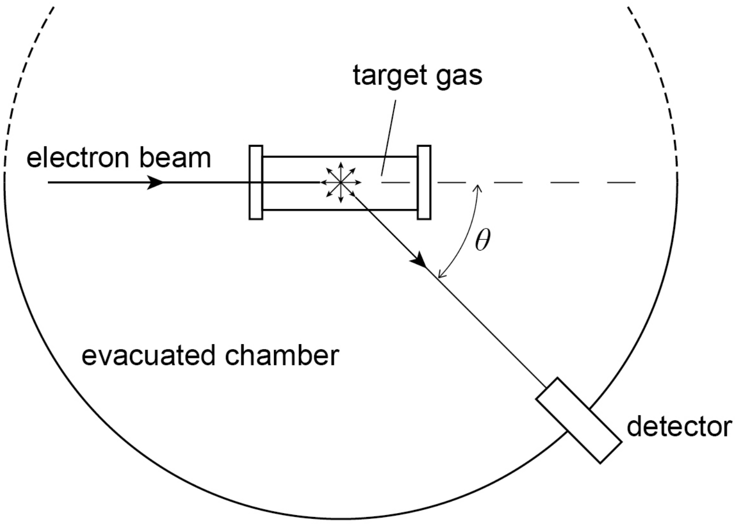
2 easier to get to high speeds needed for a short wavelength meaning better resolution

Question 6 continues on the next page

Do not write outside the box

0 6 . 2 **Figure 11** shows a beam of electrons, each with the same high energy, incident on a target gas.
The electrons are diffracted by the nuclei in the gas.
The intensities of these diffracted electrons are measured at various angles θ.
The data are used to determine the nuclear radius R of the atoms in the gas.

Figure 11

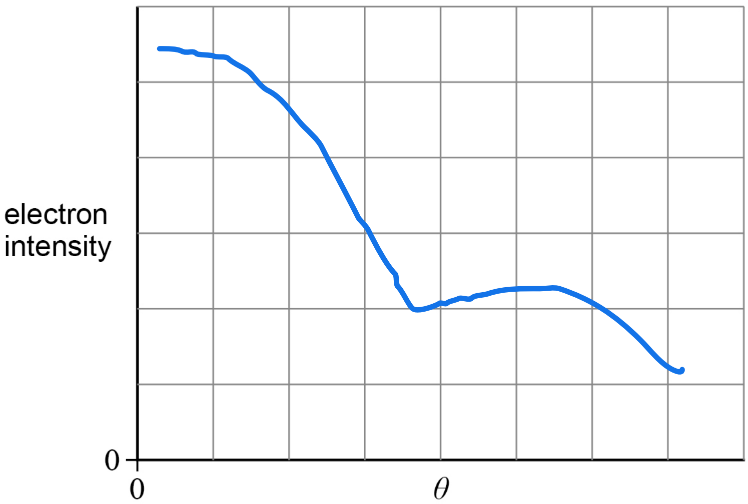


Sketch on **Figure 12** a graph showing how the electron intensity varies with θ.

[2 marks]

Figure 12

curved line, with a single minimum that is not zero.



Do not write outside the box

0 6 . 3 The radius R of a nucleus is related to its nucleon number by $R = R_0 A^{\frac{1}{3}}$.

Show that this equation is consistent with the idea that all nuclei have the same density.

[2 marks]

$\rho = \frac{m}{V}$

there are A nucleons in the nucleus. So work out a formula for density of the nucleus. $M_{nucleon}$ is mass of a nucleon

$\rho = \frac{A m_{nuc}}{\frac{4}{3}\pi (R_0 A^{1/3})^3} = \frac{A m_{nuc}}{\frac{4}{3}\pi R_0^3 A} = \frac{3 m_{nucleon}}{4\pi R_0^3}$

which has no depednece on A and ony constants in it

0 6 . 4 The equation $R = R_0 A^{\frac{1}{3}}$ is derived from experimental data.

Suggest **one** reason why the constant density of nuclear material derived from this equation is only approximate.

[1 mark]

assumed that there is no binding energy which will reduce the mass

that there are no gpas between the particles

assumed P and N have the smae mass

0 6 . 5 The measured radius R of $^{35}_{17}Cl$ is 4.02×10^{-15} m.

Calculate an estimate of

- the constant R_0
- the density of nuclear material.

[3 marks]

$R = R_0 A^{\frac{1}{3}}$

$R_0 = \frac{R}{A^{\frac{1}{3}}} = \frac{4.02 \times 10^{-15}}{35^{1/3}} = 1.23 \times 10^{-15}$ m

$\rho = \frac{3 m_{nuc}}{4\pi R_0^3}$ ($m_{nuc} = 1.67 \times 10^{-27}$)

$\rho = 2.1(5) \times 10^{27}$ Kg m^{-3}

R_0 = ______________ m   density = ______________ kg m^{-3}

10

Turn over ►

Do not write outside the box

0 7 . 1 Carbon is used as the moderator in some thermal nuclear reactors.

Identify **one** other material commonly used as a moderator.

[1 mark]

water, heavy water, Be

0 7 . 2 State **two** benefits of slowing down the neutrons released during fission.

[2 marks]

1 more likely neutron is absorbed

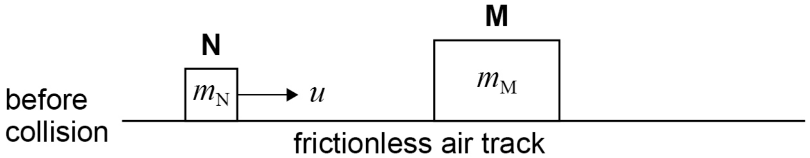
2 faster neutrons more likely to damage structure

0 7 . 3 The collision of a neutron with the nucleus of a moderator atom is modelled using two gliders on a horizontal frictionless air track.

In **Figures 13** and **14** the glider **N** of mass m_N represents the neutron and the glider **M** of mass m_M represents the moderator nucleus.

Figure 13 shows glider **N** travelling with initial speed u towards the stationary glider **M**.

Figure 13



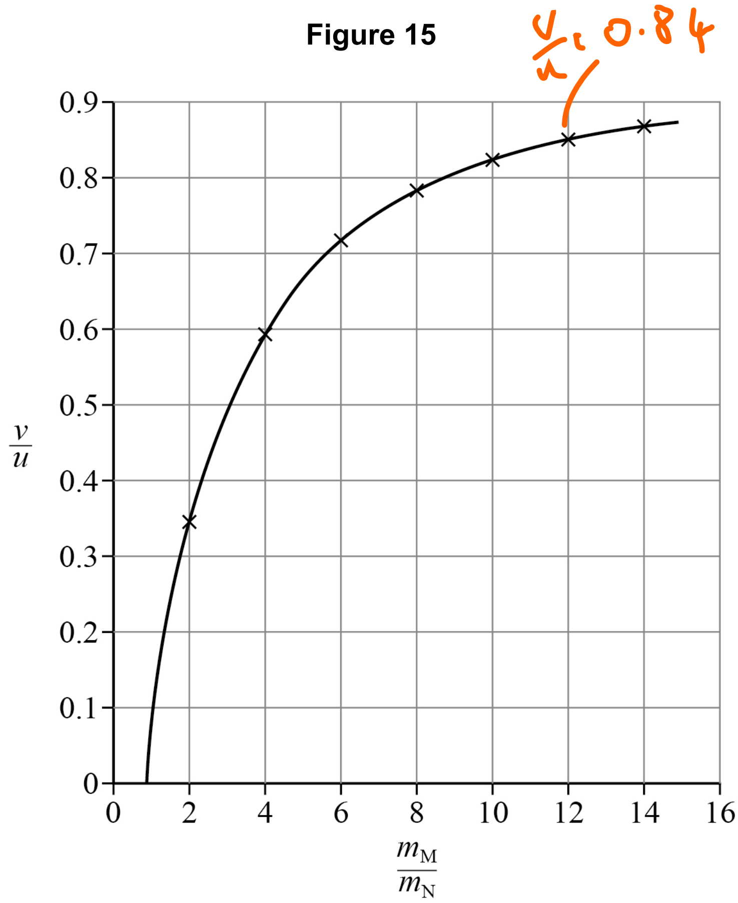
The gliders collide. **N** rebounds with speed v as shown in **Figure 14**.

Figure 14

Do not write outside the box

Figure 15 shows the variation of the ratio $\frac{v}{u}$ with the ratio $\frac{m_M}{m_N}$.

Figure 15



Show that when $\frac{m_M}{m_N}$ is 12, **N** loses about 30% of its initial kinetic energy in the collision.

[2 marks]

$\frac{v}{u}$ = 0.84 ∴ energy loss (E_k change) depends on $\left(\frac{v}{u}\right)^2 = 0.84^2$

= 0.71

so has dropped 0.3 = 30%

Question 7 continues on the next page

Turn over ▶

Do not write outside the box

0 7 . 4 In a reactor, the speed of a fast-moving neutron is reduced by a series of y random collisions with carbon-12 nuclei.

The final kinetic energy E_f of the neutron is

$$E_f = E_0 e^{-by}$$

where E_0 is the initial kinetic energy of the neutron and $b = 0.73$

A thermal neutron has kinetic energy equivalent to that of the average particle of an ideal gas with a temperature of 350 K.

One neutron has an initial kinetic energy of 1.0 MeV. $= 1.6 \times 10^{-13}$ J

Calculate the minimum value of y required so that this neutron becomes a thermal neutron.

[3 marks]

Energy at 350 K = $\frac{3}{2}kT = 7.245 \times 10^{-21}$ J (1.38×10^{-23})

$$\frac{E_f}{E_0} = e^{-by} \Rightarrow \ln\left(\frac{E_f}{E_0}\right) = -by$$

$$\frac{\ln\left(\frac{7.245 \times 10^{-21}}{1.6 \times 10^{-13}}\right)}{0.73} = -y \Rightarrow y = 23$$

$y =$ ______________________

Do not write outside the box

0 7 . 5 Explain, with reference to **Figure 15**, why elements with a small nucleon number are preferred as moderator materials.

[2 marks]

smaller nuclei loose more energy/velocity per collision
therefore we need fewer collions and so the moderator can be thinner

10

END OF SECTION A

Do not write outside the box

1 9 An alpha particle is moving towards a stationary gold nucleus. The alpha particle has a kinetic energy of 9.0×10^{-13} J when it is a large distance from the gold nucleus.
The gold nucleus contains 79 protons.

What is the closest possible distance of approach of the alpha particle to the gold nucleus?

[1 mark]

All Ek → EPE

$r = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r E_k}$ ⇒ r

A 2.5×10^{-16} m ○

B 2.0×10^{-14} m ○

C 4.0×10^{-14} m ☒

D 2.0×10^{-7} m ○

2 0 A wire is at right angles to a uniform magnetic field and carries an electric current.
The wire is 150 mm in length.

When the current in the wire is increased by 4.0 A, the force acting on the wire increases by 3.6×10^{-3} N.

What is the magnetic flux density of the field?

[1 mark]

F = BIL ~ 150 mm

$\Delta F = B \Delta I L$

$\frac{\Delta F}{\Delta I L} = B = 6 \times 10^{-3}$ T

A 6.0×10^{-6} T ○

B 6.0×10^{-3} T ☒

C 1.7×10^{2} T ○

D 1.7×10^{5} T ○

Turn over for the next question

Do not write outside the box

2 3 The distance between the wing tips of a metal aircraft is 30 m.
The aircraft flies horizontally at a steady speed of 100 m s^{-1}.
The aircraft passes through a vertical magnetic field of flux density 2.0×10^{-7} T.

What is the emf induced between its wing tips?

[1 mark]

A 0.2 μV

B 20 μV

C 300 μV

D 600 μV

2 4 A circular coil with a radius of 0.10 m has 200 turns.
The coil rotates at 50 revolutions per second about an axis which is perpendicular to a uniform magnetic field and in the plane of the coil.
The magnetic flux density of the field is 0.20 T.

What is the maximum emf induced in the coil?

[1 mark]

A 63 V

B 126 V

C 195 V

D 395 V

2 5 After radioactive waste is removed from a cooling pond, it is often stored in underground caves.
This is to protect workers from the effects of

A alpha particles from nuclides with a large decay constant.

B alpha particles from nuclides with a small decay constant.

C gamma radiation from nuclides with a large decay constant.

D gamma radiation from nuclides with a small decay constant.

alpha wont penetrate so not a problem. Gamma with a small decay constant will decay away over a longer time and so be a threat for longer

Do not write outside the box

2 6 Alpha particle scattering can be demonstrated using a thin gold foil.

Which statement about this demonstration is **not** true?

[1 mark]

A The foil is thin enough to assume that alpha particles are deflected only once. ☐

B Nuclei are more massive than alpha particles which allows the alpha particles to be deflected by more than 90°. ☐

C The number of alpha particles deflected backwards is greater than the number that pass straight through the foil. ☐

D Deflections of alpha particles by electrons in the foil are much smaller than deflections due to nuclei. ☐

2 7 A transformer for use in a 230 V ac supply is 90% efficient.
The transformer provides a current of 3.00 A at 12.0 V.

What is the current in the primary coil?

[1 mark]

A 0.141 A

B 0.156 A

C 0.174 A

D 5.75 A

2 8 The random nature of radioactive decay means that it is never possible to predict

[1 mark]

A when a particular nucleus will decay. ☐

B whether a β^- particle or a β^+ particle is emitted. ☐

C the approximate time taken for the activity to decrease to a specified value. ☐

D the approximate thickness of an absorber needed to reduce the count rate to a specified value. ☐

Turn over ▶

Do not write outside the box

2 9 Radiation is used to measure the thickness of an aluminium sheet accurately.
The thickness of the sheet is about 0.5 mm.

Which type of radiation is most appropriate for the measurement?

[1 mark]

A α

B β^-

C β^+ — will anihilate

D γ

3 0 Tritium is a radioactive nuclide used in 'Exit' signs.
When a sign was manufactured the activity of the tritium in it was 37 MBq.
After 10 years the tritium in the sign has an activity of 21 MBq.

What will the activity be 15 years after it was manufactured?

[1 mark]

A 12 MBq

B 13 MBq

C 16 MBq

D 17 MBq

3 1 The mass of fuel in a nuclear reactor decreases at a rate of 4.0×10^{-6} kg per hour.

What is the rate at which energy is transferred due to nuclear fission?

[1 mark]

A 4.0×10^{7} W

B 1.0×10^{8} W

C 6.0×10^{8} W

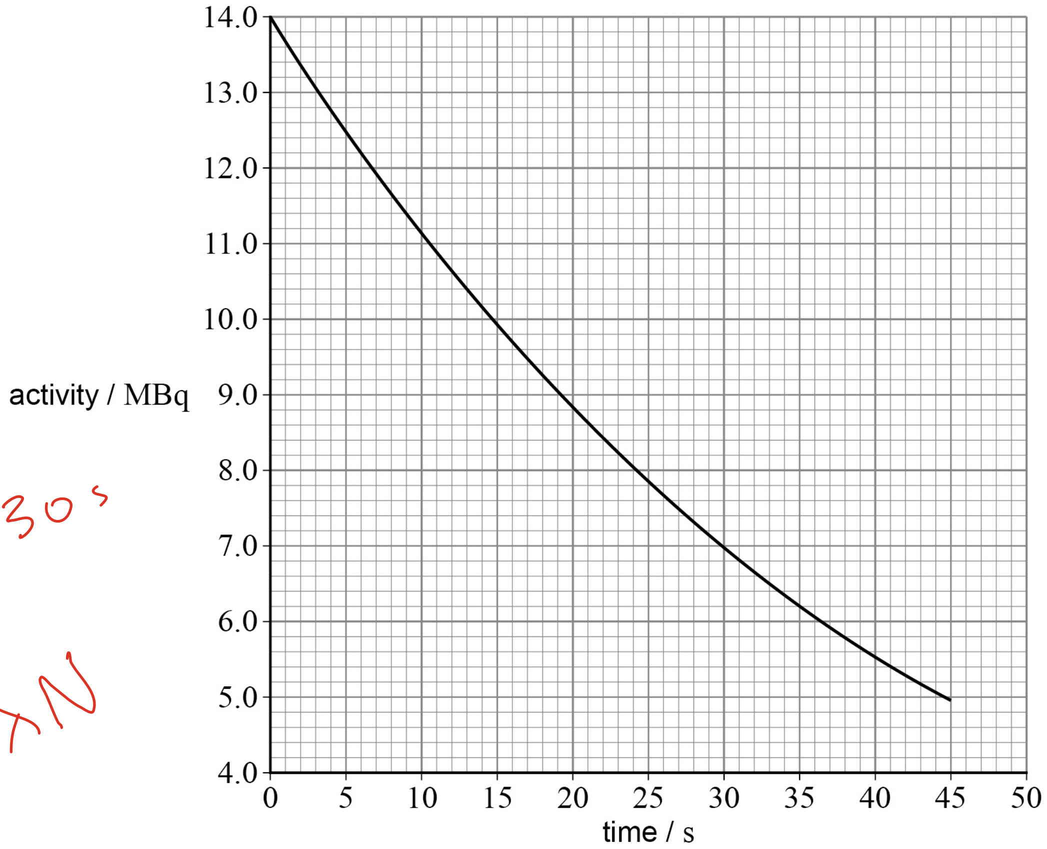
D 3.6×10^{10} W

$\Delta E = \Delta m c^2$

Don't forget to convert to seconds

Do not write outside the box

3 2 The graph shows the variation of activity with time for a sample of a nuclide **X**.



What was the initial number of nuclei of **X** in the sample?

[1 mark]

A 4.67×10^{5} ○

B 3.0×10^{8} ○

C 4.2×10^{8} ○

D 6.1×10^{8} ○

25

END OF QUESTIONS