L-Università ta' Malta

MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

INTERMEDIATE MATRICULATION LEVEL
2022 FIRST SESSION

SUBJECT:	**Physics**
DATE:	28th May 2022
TIME:	4:00 p.m. to 7:05 p.m.

A list of useful formulae and equations is provided. Take the acceleration due to gravity $g = 9.81\ ms^{-2}$ unless otherwise stated.

SECTION A
Attempt ALL 8 questions in this section. This section carries 50% of the total mark for this paper.

1. a) A minivan of mass 2900 kg bumps into the back of a car of mass 1100 kg. Assuming that, during the collision, a constant force of 62000 N acts for 0.19 s, calculate the change in velocity of:
   i) the car; (2)
   ii) the minivan. (1)

   b) Briefly explain how, for the same mass and velocity change, changing the time of impact for the collision described in part (a) would affect the impact force. (1)

(Total: 4 marks)

2. A satellite of mass m, orbits the Earth at a distance 4.5×10^5 m above the Earth's surface. A centripetal force acts on the satellite.

   a) What is the origin of the centripetal force acting on the satellite? (1)

   b) State Newton's law of universal gravitation. (1)

   c) The satellite lies within the Earth's gravitational field. Distinguish between gravitational field and gravitational field strength. (2)

   d) Sketch a graph to show how the Earth's gravitational field strength varies with distance from the Earth's centre. Only the variation above the Earth's surface is required in your sketch. (1)

   e) Write down the mathematical expression that describes the relationship between the gravitational field strength and distance from the Earth's centre, for the variation indicated in part (d) (1)

   f) Show that the orbital speed, v, of the satellite is given by the equation $v = \sqrt{\frac{G\,M_{Earth}}{r}}$, where *r* is the distance of the satellite from the Earth's centre and M_{Earth} is the mass of the Earth. (2)

   g) Calculate the orbital speed for the satellite. (2)

   (mass of the Earth: 5.97×10^{24} kg; radius of the Earth: 6.37×10^6 m)

(Total: 10 marks)

3. Figure 1 shows a simplified pot-in-pot cooler which acts as an electricity free evaporative cooling device. A porous outer pot is soaked with water and carries a smaller waterproof pot in it. The space between the pots is filled with water. The food which needs to be kept at a low temperature is placed in the waterproof pot – the food container. As water evaporates from the porous pot surface, the food in the inner pot is kept cool.

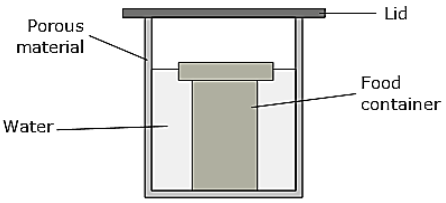

Figure 1

[rate of evaporation of water: 1.9×10^{-4} kgs^{-1};
specific latent heat of vaporisation of water: 2.264×10^{6} J kg^{-1}]

a) Explain how the evaporation of water from the surface of the porous pot keeps the water inside the cylinder at a lower temperature. (2)

b) Use the given data to show that the rate of heat transfer due to evaporation is around 430 W. (2)

c) Mention the main process that would allow heat to enter the system. (1)

d) State **TWO** properties of the environment that would likely affect the rate of evaporation of water from the porous pot surface. (2)

(Total: 7 marks)

4. Figure 2 shows how pressure of a fixed mass of ideal gas changes with volume, as it is taken through a cycle of changes from A to B, to C to D and back again to A.

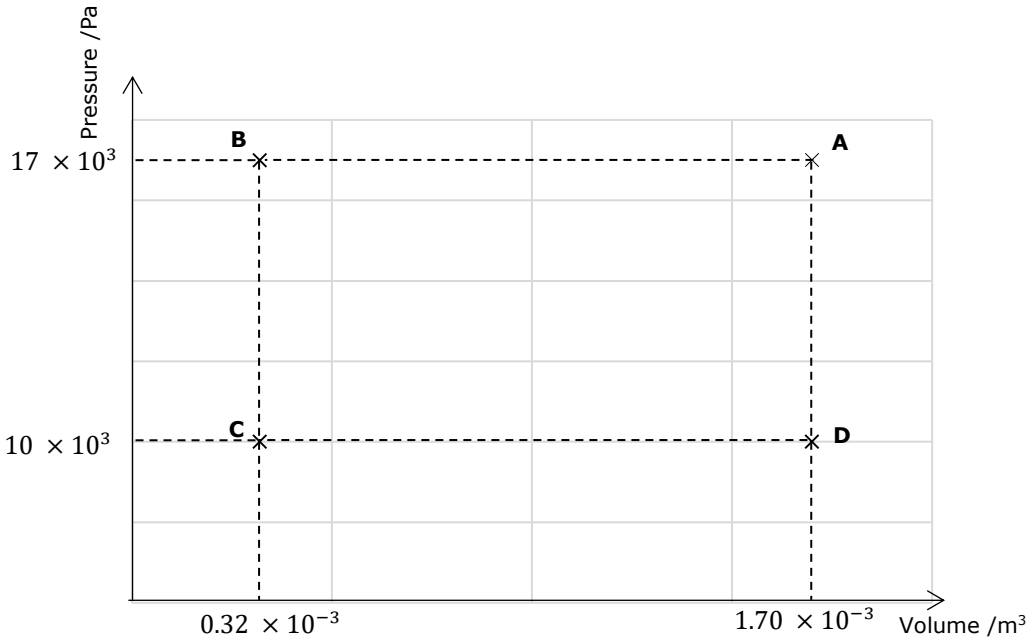

Figure 2

Answer the following questions, showing all your working:

a) Find the work done on the gas in going from A to B. (1)

b) Find the work done by the gas in going from B to C. (1)

c) Find the net work done on the gas in going through the whole cycle ABCDA. (1)

d) In going from A to B, does the gas experience any temperature change? Explain. (1)

e) Calculate the change in internal energy going from D to A, if 13 J of heat energy are supplied to the gas during this process. (2)

(Total: 6 marks)

5. Figure 3 shows the apparatus used by a student to investigate the elastic properties of materials in the form of a wire.

a) Wire A is inclined at 2° with reference to the bench surface being used.

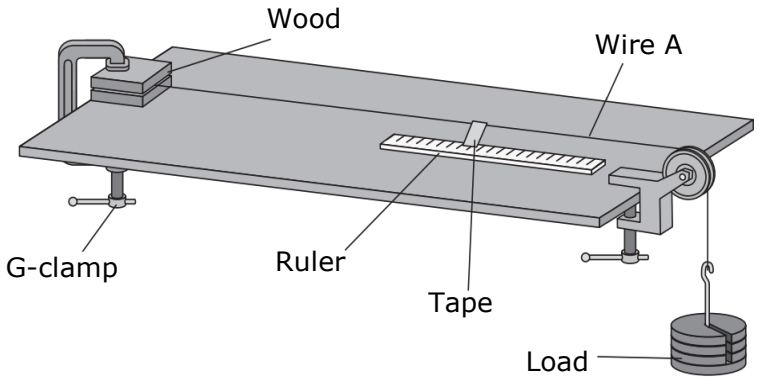

Figure 3

i) Calculate the actual extension of the wire, when an extension of 4.0 mm is recorded from the ruler. (2)

ii) The stiffness constant of the wire is 5920 Nm^{-1}. Calculate the extension of the wire when a mass of 1.98 kg is being used. (1)

Question continues on next page.

b) During another experiment, various loads were added to another wire B and the resulting extensions were noted. A graph of Force/N against Extension/mm was plotted (see Figure 4). The wire has a length of 2.0 m and a cross sectional area of $1.8 \times 10^{-7} \mathrm{m}^2$.

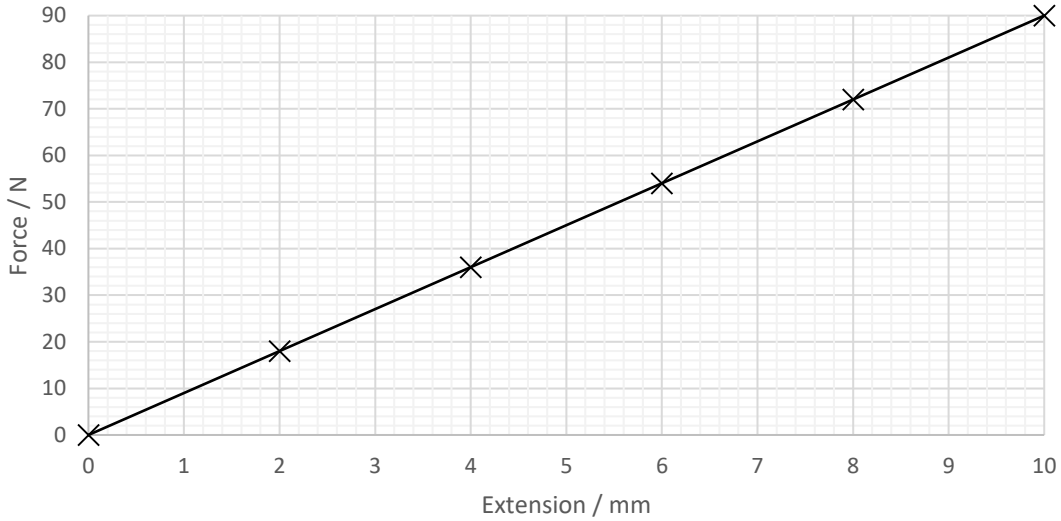

Figure 4

Calculate:

i) the Young modulus for the wire; (2)
ii) the work done in stretching the wire by 7.8 mm. (2)

(Total: 7 marks)

6. a) A small electromagnet is placed on an electronic digital balance and a stiff wire AB is clamped in the space between its poles (see Figure 5). The length of wire between the poles of the electromagnet is 6 cm and the wire forms part of a simple series circuit. The reading on the balance increases by 240 g when a current of 4 A flows through the wire AB.

i) Calculate the magnetic flux density between the poles of the electromagnet. (2)
ii) State **TWO** assumptions that you made in your calculation in part (i). (2)

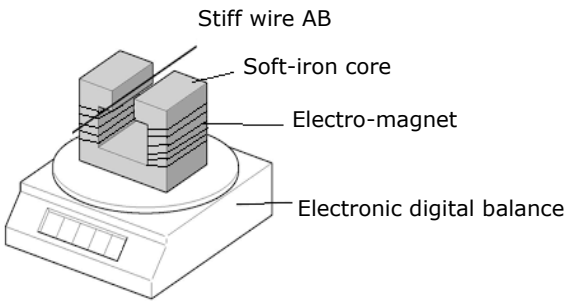

Figure 5

b) A narrow circular coil of 60 turns has a cross sectional area of 100 cm^2. The coil is connected to a galvanometer and stands in a uniform magnetic field of flux density 2 T so that the flux links the turns normally. The coil is now completely removed from the magnetic field region in 3 seconds.

Calculate the average induced e.m.f. in the coil. (2)

(Total: 6 marks)

7. Fibre optic illuminators are used to transmit light rays into fibre optic lighting systems. Figure 6 shows a ray of light incident on the fibre optic cable. The light travels into the fibre plastic core and hits the core's boundary with the cladding.
$[n_{illuminator} = n_{air};\ n_{cladding} = 1.44;\ n_{plastic\ core} = 1.52]$

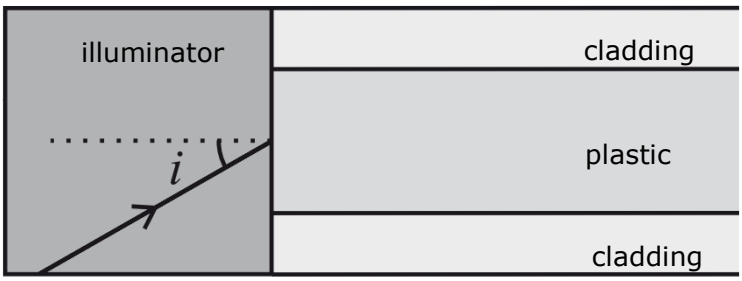

Figure 6

Calculate:

a) the critical angle for light at the boundary between the plastic core and the cladding; (2)

b) the value of angle *i* for the light ray to hit the boundary between the plastic core and the cladding at the critical angle. (3)

(Total: 5 marks)

8. A student is conducting an experiment to measure the focal length of a converging lens. He measures a number of object distances and the corresponding image distances and plots a graph of object distance (u) versus image distance (v). Figure 7 shows the graph obtained.

a) Suggest what can be plotted on the y and x axes for a linear graph to be obtained by the student.
Include a sketch of the graph that would be obtained, as part of your answer. (3)

b) Explain how the focal length of the lens can be found from the linear graph suggested in part (a). (2)

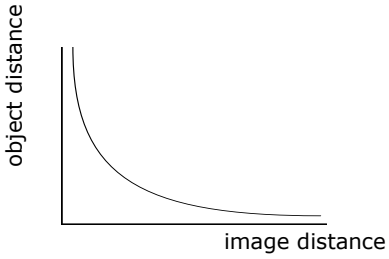

Figure 7

(Total: 5 marks)

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SECTION B
This question carries 14% of the total mark of this paper and must be attempted.

9. A student uses the apparatus shown in Figure 8 to find the value of g, the acceleration due to gravity.

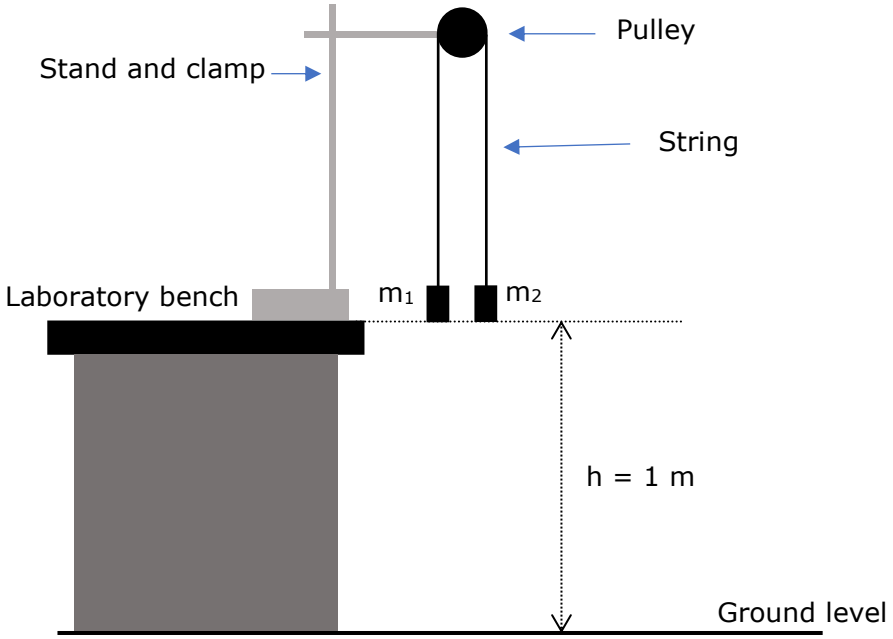

Figure 8

When m_2 and m_1 are equal, each having a mass of 1 kg, the system remains stationary with the masses at the same horizontal level, as shown. When m_2 is greater than m_1, m_2 moves down a distance *h* which is equal to 1 m.

100 g masses are added to m_2, one by one. For every 100 g added, the student records the time, *t,* taken for the mass m_2 to reach the ground. The results are recorded and shown in Table 1. It is assumed that the pulley is frictionless and that the string does not stretch.

In Table 1 $M = \frac{m_2 - m_1}{m_1 + m_2}$. *M* varies with *t* according to the equation $M = \frac{2h}{gt^2}$

Table 1

m_1 / kg	m_2 / kg	$m_1 + m_2$ / kg	$m_2 - m_1$ / kg	M	t / s	t^2 / s^2	t^{-2} / s^{-2}
1	1.1				2.1		
1	1.2				1.5		
1	1.3				1.2		
1	1.4				1.1		
1	1.5				1.0		

a) Copy Table 1 and complete the missing values. (5)

b) Plot a graph of M versus t^{-2} / s^{-2}. (4)

c) Use the graph to determine the value of g, the acceleration due to gravity. (3)

d) If *M* is kept constant, what straight line graph should be plotted to find g? Sketch the graph indicating the x and y variables. (2)

(Total: 14 marks)

SECTION C

Answer any TWO questions from this section. Each question carries 18 marks. This section carries 36% of the total mark for this paper.

10.a) State the principle of conservation of linear momentum. (2)

b) Laura was provided with the following apparatus – an air track, a glider with pin, a glider with cork and 2 photogates (see Figure 9).

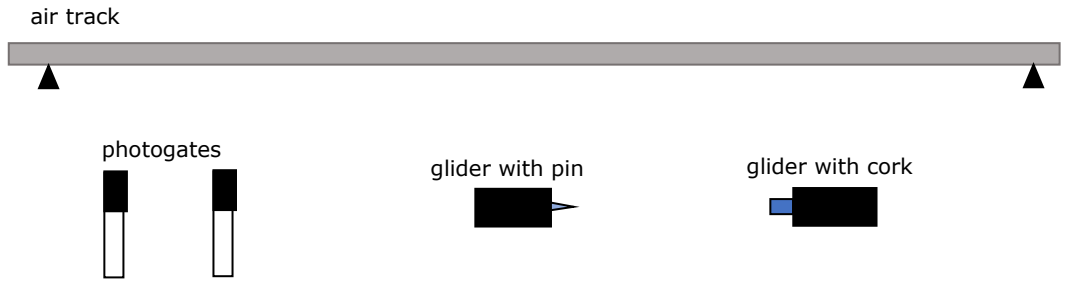

Figure 9

i) Describe how the apparatus made available to Laura can be used to confirm the principle of conservation of linear momentum in a completely inelastic collision between the two gliders. Your answer should include a diagram of how the given apparatus is set up for use, a description of the procedure to follow and the calculations necessary to confirm the conservation of linear momentum. In your description include **TWO** precautions needed to make the experiment more reliable. (8)

ii) Briefly describe how the apparatus can be altered to investigate conservation of linear momentum in an elastic collision. (2)

c) A ball A of mass 0.1 kg, moving with a linear velocity of 6 ms^{-1}, collides directly with a ball B of mass 0.2 kg which is at rest.

i) Calculate the common velocity, assuming that both balls move off together. (2)

ii) If ball A had rebounded with a velocity of 2ms^{-1} in the opposite direction after collision, what would be the new velocity of ball B? (2)

iii) Determine whether the collision in part (ii) is elastic or inelastic, showing all your working. (2)

(Total: 18 marks)

11. a) Distinguish between potential difference and electromotive force (e.m.f.). (2)

b) A 6.0 V battery has an internal resistance of 8.0 Ω.

i) Calculate the potential difference across its terminals when it is supplying a current of 42 mA. (1)

ii) Determine the maximum current that this battery can supply. (1)

iii) Explain why the headlamps of a car go dim when starting a car. (2)

Question continues on next page.

c) A battery is connected in series with a variable resistor and an ammeter. A voltmeter is connected across the variable resistor. When the resistance of the variable resistor is 2.0 Ω the current reading is 0.25 A. When the resistance value is changed to 1.3 Ω, the current reading becomes 0.37 A.

i) Draw a circuit diagram of the setup. (2)

ii) Calculate the e.m.f. and the internal resistance of the battery. (3)

d) The rear window defogger of a car consists of six thin wires, each of resistance 20 Ω. The wires are connected in parallel to each other and across a 12 V battery of negligible internal resistance (see Figure 10).

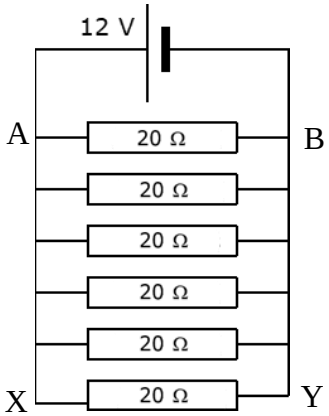

Figure 10

i) Calculate the total resistance in the circuit. (2)

ii) Calculate the current flowing through the battery. (1)

iii) Determine the current flowing through the branch AB. (1)

iv) Is the current flowing through the branch XY, larger, the same or smaller than the current flowing through the branch AB? Explain. (1)

v) The manufacturer of the car wanted to have less current flowing in each of the branches. Instead of six 20 Ω resistors he started using three. Explain whether the change implemented by the manufacturer would reduce the current in the branches. (2)

(Total: 18 marks)

12. a)

i) Sketch the field lines (flux lines) for:

- a uniform electric field; (1)
- an electric field due to a positively charged sphere; (1)
- an electric field surrounding two equal positive point charges, placed in a vacuum. (1)

ii) Describe **TWO** common characteristics of the field lines drawn in part (a)(i). (2)

iii) Define electric field strength and state its units. (2)

iv) Two vertical parallel metal plates have a potential difference, *V,* across them. A uniform electric field results between the plates. An amount of work equal to 7.68×10^{-15} J is needed to accelerate a proton from rest, moving it from one plate to the other. Calculate the potential difference between the plates, expressing your answer in kV. (2)
(Charge of proton = 1.6×10^{-19} C)

b) In the following diagram, two point charges, M and N, are situated 3.20 m apart in a vacuum. M has a charge of +12 μC and N has a charge of +6 μC. At point O, which is at a distance x away from M, the resultant electric field strength is zero.

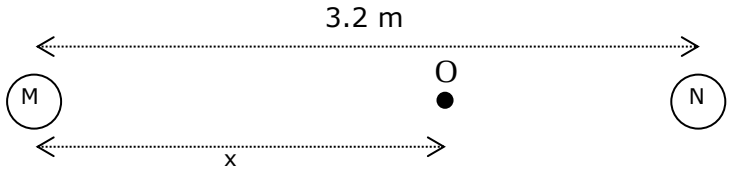

Figure 11

i) Determine the value of x. (2)

ii) What change can be made to the arrangement so that the distance x becomes equal to 1.6 m? (2)

c) A capacitor, of capacitance C, is discharged through a 125 kΩ resistor. Figure 12 shows the voltage–time graph obtained during the discharging process.

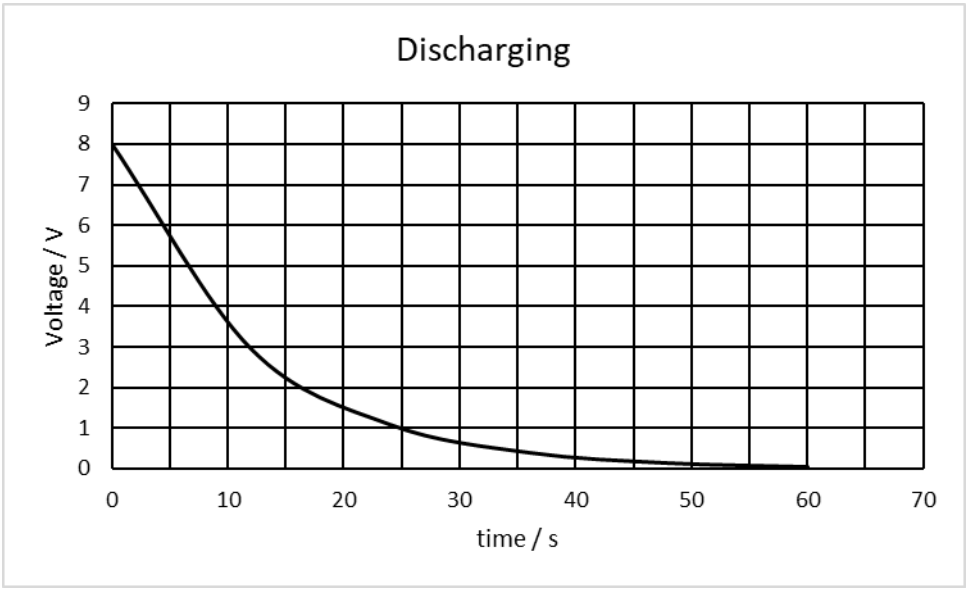

Figure 12

Use the graph to determine:

i) an approximate value of the time constant of the circuit; (3)

ii) an approximate value of the capacitance C. (2)

(Total: 18 marks)

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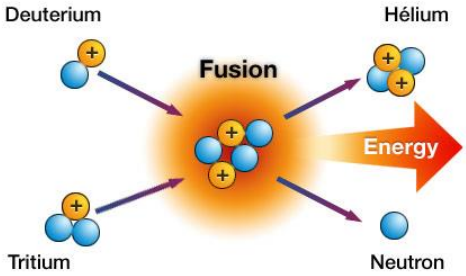
13. Cynthia's physics textbook included a diagram similar to that in Figure 13. The diagram shows a nuclear fusion reaction of Deuterium and Tritium - both isotopes of Hydrogen.



(https://fusionforpower.weebly.com/)

Figure 13

a. Explain the terms isotopes and nuclear fusion. (2)

b. This nuclear fusion reaction may be represented by the following equation:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

Table 2 shows the mass of the particles involved in the nuclear fusion reaction.

Table 2

Particle	Mass (kg)
Deuterium	3.344×10^{-27} kg
Tritium	5.008×10^{-27} kg
Helium	6.646×10^{-27} kg
Neutron	1.675×10^{-27} kg

i) Explain why energy is released in this reaction. (1)

ii) Calculate the energy released, giving your answer in MeV. (4)

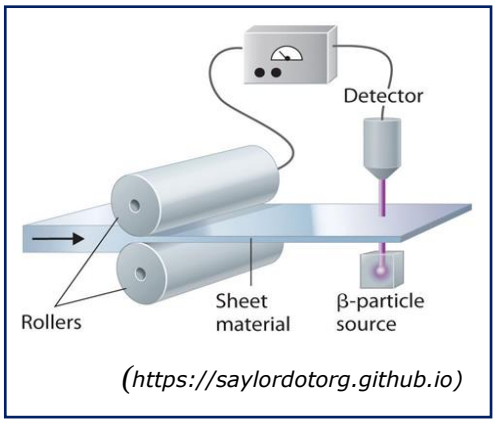
c. A Uranium-235 nucleus undergoes fission by absorbing a neutron. The nucleus splits into two lighter nuclei producing free neutrons and releasing energy. A typical reaction is:

$$^{235}_{92}U + ^{1}_{0}n = ^{148}_{57}La + ^{85}_{35}Br + neutrons$$

i) Calculate the number of neutrons released in this reaction, showing your working. (2)

ii) Use the given equation to explain how nuclear chain reactions arise. (2)

d. The equipment shown in Figure 14 is used in the paper manufacturing industry as a gauge to ensure that paper of the same thickness is produced.
A beta (β)-particle source is preferred over an alpha (α) or a gamma (γ) source for this arrangement.



(https://saylordotorg.github.io)

Figure 14

i) Explain why alpha (α) and gamma (γ) sources are **not** suitable for this arrangement. (2)

ii) Cobalt-60, which has a half-life of 1930 days, is a common β-particle source used in such gauges. A newly installed source of Cobalt-60 would typically contain 4.8×10^{20} radioactive atoms.
Determine the initial activity of the source. (4)

iii) For the gauge to function properly the β-particle source is replaced regularly. As it is being replaced, the detector still gives a reading. Explain. (1)

(Total: 18 marks)