THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

2824

Forces, Fields and Energy

Candidates answer on the Question Paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Friday 18 June 2010
Morning

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **90**.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	12	
2	13	
3	11	
4	13	
5	12	
6	14	
7	15	
TOTAL	**90**	

Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J K^{-1}\ mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

refractive index, $n = \dfrac{1}{\sin C}$

capacitors in series, $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\dfrac{Nm}{V} <c^2>$

radioactive decay, $x = x_0\, e^{-\lambda t}$

$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \dfrac{3H_0^{\,2}}{8\pi G}$

relativity factor, $= \sqrt{}\,(1 - \dfrac{v^2}{c^2})$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10\lg\left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

1 **(a)** Show that the relationship between the mechanical power P, the velocity v and the constant applied force F is given by

$$P = Fv.$$

Start from the definition of work, W.

[3]

(b) Fig. 1.1 shows how the force F produced by a railway locomotive varies with velocity v.

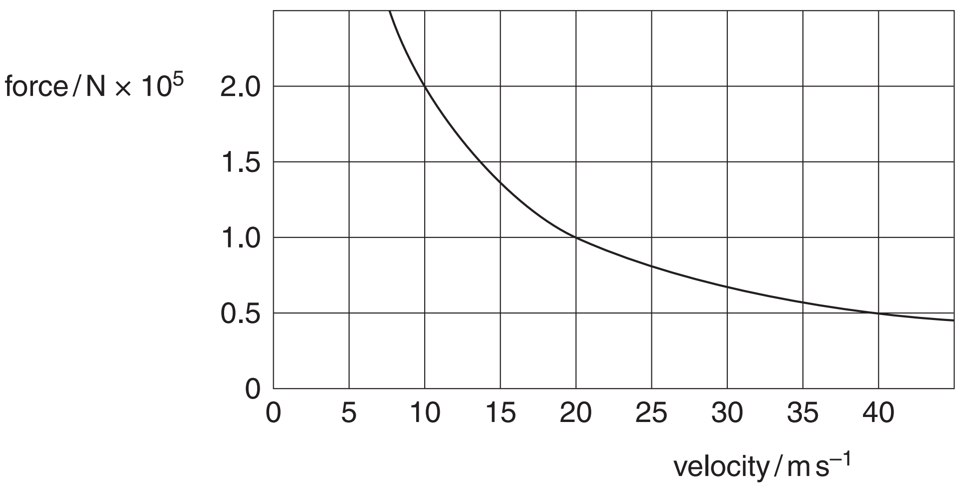

Fig. 1.1

Use data from Fig. 1.1 to

(i) calculate the power developed by the locomotive when travelling at 10 m s^{-1}

power = ... W **[2]**

(ii) show that the power developed by the locomotive is constant

[1]

(iii) calculate the force produced at a velocity of $5\,m\,s^{-1}$.

force = ... N **[1]**

(c) The locomotive in **(b)** pulls a train of total mass 3.0×10^5 kg against a constant frictional force of 5.0×10^4 N. Use Fig. 1.1 and this data to calculate

(i) the acceleration of the train when travelling at $10\,m\,s^{-1}$

acceleration = ... $m\,s^{-2}$ **[3]**

(ii) the maximum speed that the train can achieve on a level track.

speed = ... $m\,s^{-1}$ **[2]**

[Total: 12]

2 This question is about a mass-spring system.

Fig. 2.1 shows a mass attached to two identical springs. The mass moves along a horizontal tube with one spring stretched and the other compressed. An arrow marked on the mass indicates its position on a scale. Fig. 2.1 shows the situation when the mass is displaced through a distance x from its equilibrium position. The mass is experiencing an acceleration a in the direction shown. Fig. 2.2 shows a graph of the magnitude of the acceleration a against the displacement x.

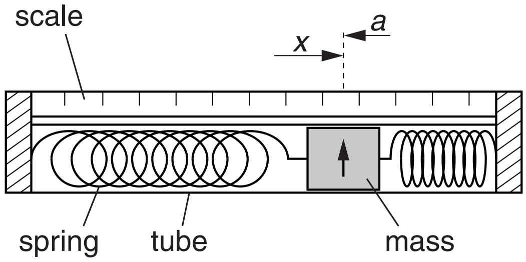

Fig. 2.1

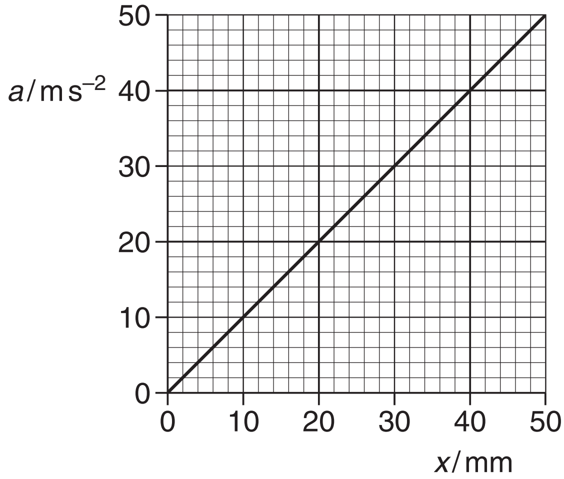

Fig. 2.2

(a) **(i)** State **one** feature from each of Fig. 2.1 and Fig. 2.2 which shows that the mass performs simple harmonic motion when released.

....

....

.... **[2]**

(ii) Use data from Fig. 2.2 to show that the frequency of simple harmonic oscillations of the mass is about 5 Hz.

[3]

(iii) The mass oscillates in damped harmonic motion before coming to rest. On the axes of Fig. 2.3 sketch a graph of the damped harmonic oscillation of the mass, from an initial displacement of 25.0 mm. **[3]**

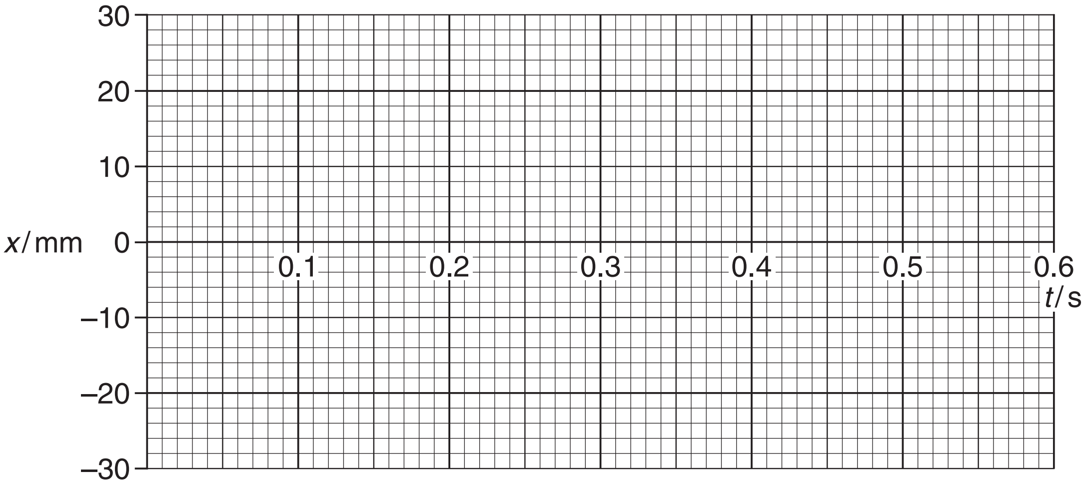

Fig. 2.3

(b) The mass-spring system of Fig. 2.1 can be used as a device to measure acceleration, called an accelerometer. It is mounted on a rotating test rig, used to simulate large g-forces for astronauts. Fig. 2.4 shows the plan view of a long beam rotating about axis **A** with the astronaut seated at end **B**, facing towards **A**. The accelerometer is parallel to the beam and is fixed under the astronaut's seat 10 m from **A**.

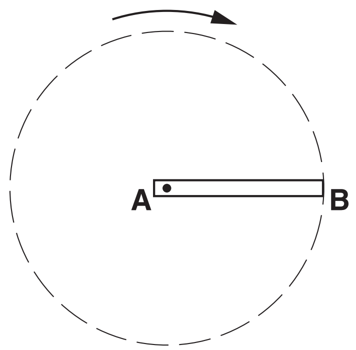

Fig. 2.4

(i) When the astronaut is rotating at a constant speed the mass has a constant deflection. Explain why.

....

....

.... **[2]**

(ii) Calculate the speed v of rotation of the astronaut when the deflection is 50 mm.

v = ... m s^{-1} **[3]**

[Total: 13]

3 This question is about the atmosphere treated as an ideal gas.

(a) The equation of state of an ideal gas is $pV = nRT$. Data about gases are often given in terms of density ρ rather than volume V. Show that the equation of state for a gas can be written as

$$p = \frac{\rho RT}{M}$$

where M is the mass of one mole of gas.

[3]

(b) One simple model of the atmosphere assumes that air behaves as an ideal gas at a constant temperature. Using this model the pressure p of the atmosphere at a temperature of 20 °C varies with height h above the Earth's surface as shown in Fig. 3.1.

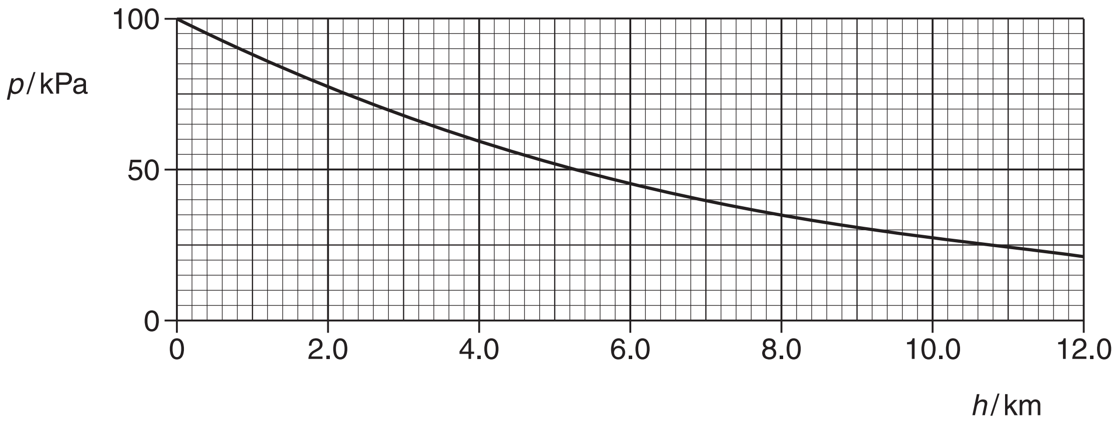

Fig. 3.1

Use data from the graph to show that the variation of pressure with height follows an exponential relationship.

[2]

(c) The ideal gas equation in **(a)** shows that, at constant temperature, pressure p is proportional to density ρ. Use data from Fig. 3.1 to find the density of the atmosphere at a height of 8.0 km.

density ρ of air at $h = 0$ is $1.3\,\text{kg}\,\text{m}^{-3}$

ρ = ... $\text{kg}\,\text{m}^{-3}$ **[3]**

(d) In the real atmosphere the density, pressure and temperature all decrease with height. At the summit of Mt. Everest, $h = 8.0$ km, pressure is only 0.30 of that at sea level, $h = 0$. Take the temperature at the summit to be –23 °C and at sea level to be 20 °C.

Calculate, using the ideal gas equation and data from Fig. 3.1, the density of the air at the summit.

density ρ of air at sea level = $1.3\,\text{kg}\,\text{m}^{-3}$

ρ = ... $\text{kg}\,\text{m}^{-3}$ **[3]**

[Total: 11]

4 Two very small identical conducting balls, each of mass 8.0×10^{-4} kg, are suspended from a single point by insulating threads of negligible mass as shown in Fig. 4.1. Each sphere has been given the same charge of 3.0×10^{-8} C so that they repel each other and are in equilibrium with their centres a distance 6.0×10^{-2} m apart.

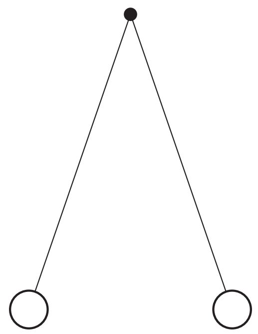

Fig. 4.1

(a) **(i)** On Fig. 4.1, draw **two** arrows, each labelled F_e, to show the direction of the electrostatic force on each ball. **[1]**

(ii) Show that the value of F_e is about 2.3×10^{-3} N.

[3]

(b) Each ball experiences three forces. On Fig. 4.1, draw and label arrows to represent the other **two** forces acting on one ball. **[1]**

(c) Using the data above, calculate the angle between the threads.

angle = ... ° **[4]**

(d) The gravitational force F_g between the two balls is much smaller than the electrostatic force F_e between them.

Calculate $\frac{F_g}{F_e}$.

$\frac{F_g}{F_e}$ = ... **[4]**

[Total: 13]

5 Fig. 5.1 shows a simple transformer used for demonstrations in the laboratory. It consists of two coils linked by a laminated soft iron core. The primary coil is connected to a signal generator and the secondary coil to a voltage sensor and computer. The number of turns on the secondary coil is double that on the primary coil.

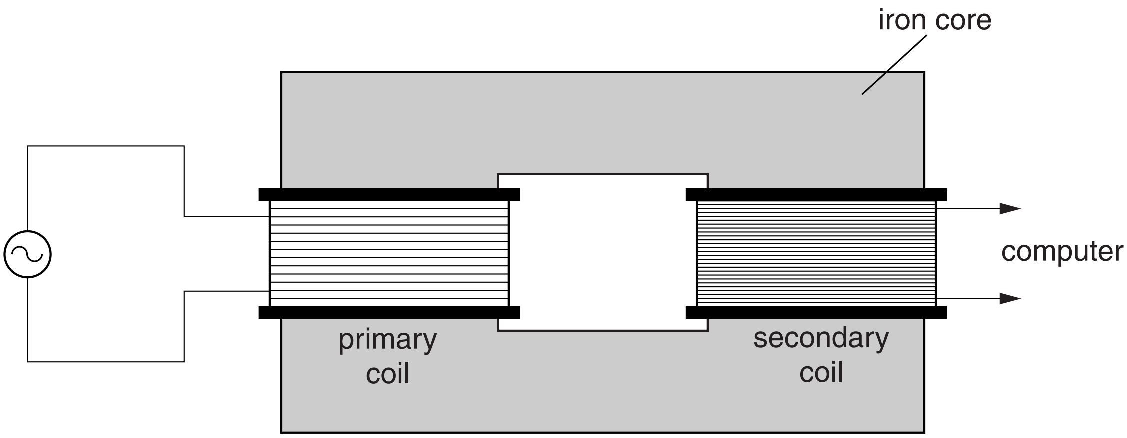

Fig. 5.1

(a) **(i)** Draw on Fig. 5.1 the complete paths of **two** lines of magnetic flux linked with the current in the primary coil. **[2]**

(ii) Define the term *magnetic flux*.

....

....

.... **[2]**

(iii) Explain how the term *magnetic flux linkage* differs from *magnetic flux*.

....

....

.... **[2]**

(iv) Use Faraday's law of electromagnetic induction to explain why an alternating current is necessary in the primary coil for a voltage to be detected across the secondary coil.

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.... **[3]**

(b) Fig. 5.2 shows the computer screen in the demonstration where the number of turns on the secondary coil is double that on the primary coil.

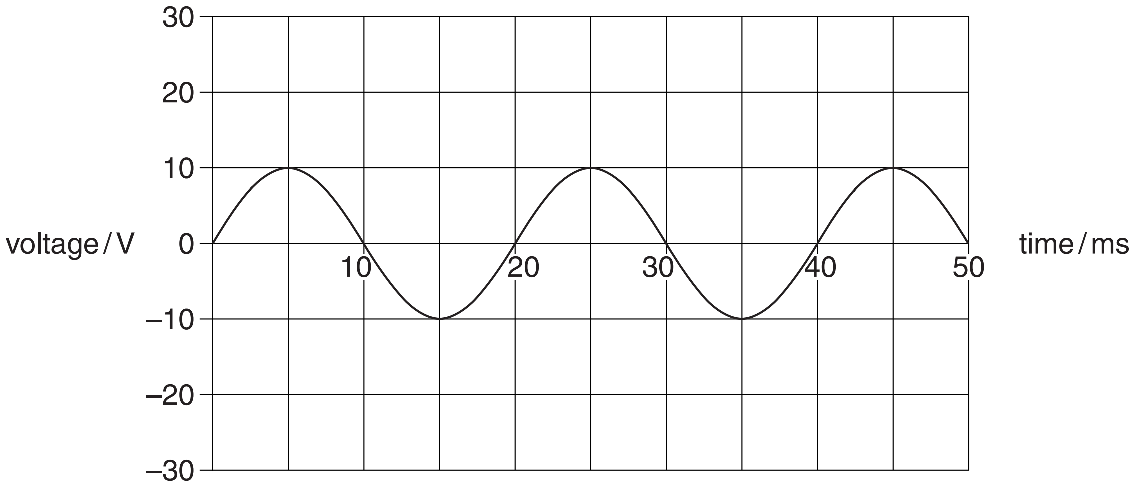

Fig. 5.2

(i) Show that the frequency of the supply is 50 Hz.

[1]

(ii) Calculate the amplitude of the **supply** voltage.

amplitude = ... V **[2]**

[Total: 12]

6 Two radioactive isotopes which are serious health hazards to human beings are strontium-90 and caesium-137. Both decay by β^--emission.

(a) The nuclear equations for each of the decays are shown below with letters substituted for some of the numbers.

$$^{90}_{38}\text{Sr} \rightarrow \, ^{90}_{\text{Z}}\text{Y} + \beta^-$$

$$^{137}_{55}\text{Cs} \rightarrow \, ^{\text{A}}_{\text{A-N}}\text{Ba} + \beta^-$$

Write down the numerical values of the two letters Z and N. State what each represents.

(i) Z ....

.... **[2]**

(ii) N ....

.... **[2]**

(b) The radioactive decay law can be written in the form

$$A = \lambda N$$

where A is the activity, λ is the decay constant and N is the number of undecayed nuclei.

(i) Define the term *activity*.

....

.... **[1]**

(ii) Caesium-137 has a half-life of 30 years. Calculate the decay constant.

1 year = 3.15×10^7 s

λ = ... s^{-1} **[2]**

(c) The radioactive dust cloud from the Chernobyl explosion in 1986 contained caesium-137. Fig. 6.1 shows the graph of the number of undecayed nuclei of caesium-137 remaining in a dust particle against time after the explosion.

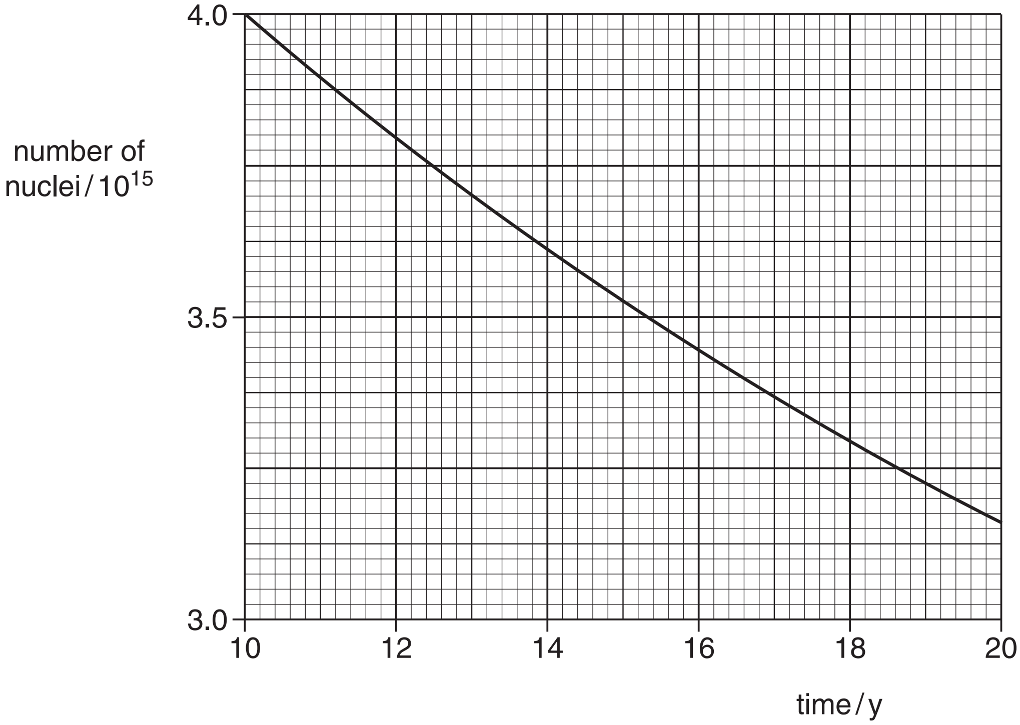

Fig. 6.1

(i) Use Fig. 6.1 to calculate the activity of the caesium dust particle after 15 years.

activity = ... Bq **[2]**

(ii) Use data from the graph to show that the initial number of caesium-137 nuclei in the dust particle is about 5.0×10^{15}.

[3]

(iii) Hence show that the original mass of caesium-137 in the dust particle is about 1 μg.

[2]

[Total: 14]

7 In this question, four marks are available for the quality of written communication.

(a) Describe the processes of fission and fusion of nuclei. Distinguish clearly between them by highlighting **one** similarity and **one** difference between the two processes. State the conditions required for each process to occur in a sustained manner.

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.... **[7]**

(b) The fission of a uranium-235 nucleus releases about 200 MeV of energy, whereas the fusion of four hydrogen-1 nuclei releases about 28 MeV. However the energy released in the fission of one kilogramme of uranium-235 is less than the energy released in the fusion of one kilogramme of hydrogen-1. Explain this by considering the number of particles in one kilogramme of each.

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.... **[4]**

Quality of Written Communication **[4]**

[Total: 15]

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