29959601

OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2824

Forces, Fields and Energy

Thursday **17 JUNE 2004** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name

Centre Number

Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
  DO NOT ANSWER IN PENCIL. **DO NOT** WRITE IN THE BARCODE.
  DO NOT WRITE IN THE GREY AREAS BETWEEN THE PAGES.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- 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.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	13	
2	13	
3	14	
4	10	
5	11	
6	13	
7	16	
TOTAL	90	

This question paper consists of 18 printed pages and 2 blank pages.

[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,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
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,	$n = \frac{1}{\sin C}$
capacitors in series,	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \frac{3H_0^2}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\frac{I}{I_0}\right)$

Answer **all** the questions.

1 **(a)** Define *simple harmonic motion*.

....

....

.... [2]

(b) Fig. 1.1 shows a simple pendulum with the bob at the amplitude of its swing.

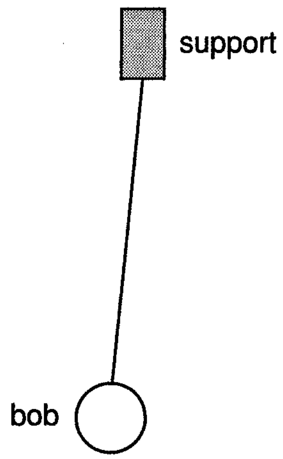

Fig. 1.1

On Fig. 1.1, draw and label arrows to represent the forces acting on the bob. [2]

(c) Fig. 1.2 shows the graph of displacement of the bob against time.

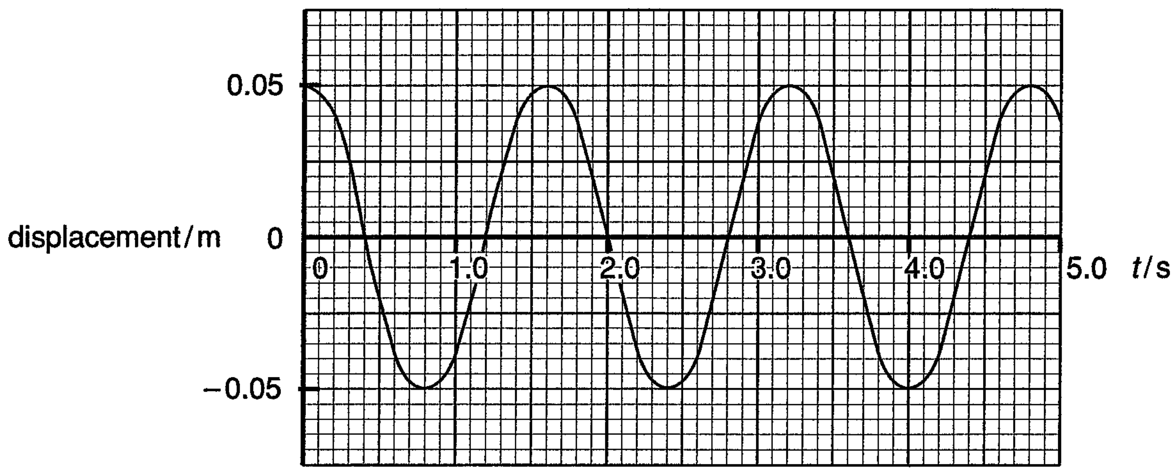

Fig. 1.2

(i) Use Fig. 1.2 to determine the frequency of oscillation of the pendulum. Give a suitable unit for your answer.

frequency = ... unit .... [3]

(ii) Use Fig. 1.2 or otherwise to determine the maximum speed of the bob. Show your method clearly.

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

(d) The bob is now made to oscillate with twice its previous amplitude. The pendulum is still moving in simple harmonic motion.

State with a reason the change, if any, in

(i) the period

....

....

.... [2]

(ii) the maximum speed of the bob.

....

....

.... [2]

[Total: 13]

For Examiner's Use

2 A binary star is a pair of stars which move in circular orbits around their common centre of mass. For stars of equal mass, they move in the same circular orbit, shown by the dotted line in Fig. 2.1. In this question, consider the stars to be point masses situated at their centres at opposite ends of a diameter of the orbit.

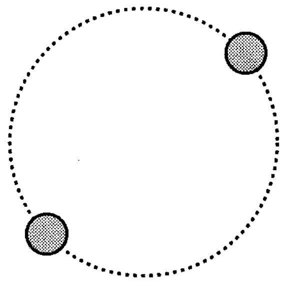

Fig. 2.1

(a) **(i)** Draw on Fig. 2.1 arrows to represent the force acting on each star. [2]

(ii) Explain why the stars must be diametrically opposite to travel in the circular orbit.

....

....

....

....

.... [2]

(b) Newton's law of gravitation applied to the situation of Fig. 2.1 may be expressed as

$$F = \frac{GM^2}{4R^2}.$$

State what each of the four symbols listed below represents.

F ....

G ....

M ....

R .... [2]

For Examiner's Use

(c) **(i)** Show that the orbital period T of each star is related to its speed v by $v = 2\pi R/T$.

[1]

(ii) Show that the magnitude of the centripetal force required to keep each star moving in its circular path is

$$F = \frac{4\pi^2 MR}{T^2} .$$

[2]

(iii) Use equations from **(b)** and **(ii)** above to show that the mass of each star is given by

$$M = 16\pi^2 \frac{R^3}{GT^2} .$$

[2]

(d) Binary stars separated by a distance of 1 x 10^{11} m have been observed with an orbital period of 100 days. Calculate the mass of each star.

1 day = 86 400 s

mass = ... kg [2]

[Total: 13]

[Turn over

For Examiner's Use

3 **(a)** Define the *capacitance* of a capacitor.

....

.... [1]

(b) Fig. 3.1 shows a circuit where a 0.47 μF capacitor may be connected by a two-way switch S either to an 11.0 V d.c. supply or to a 2200 Ω resistor.

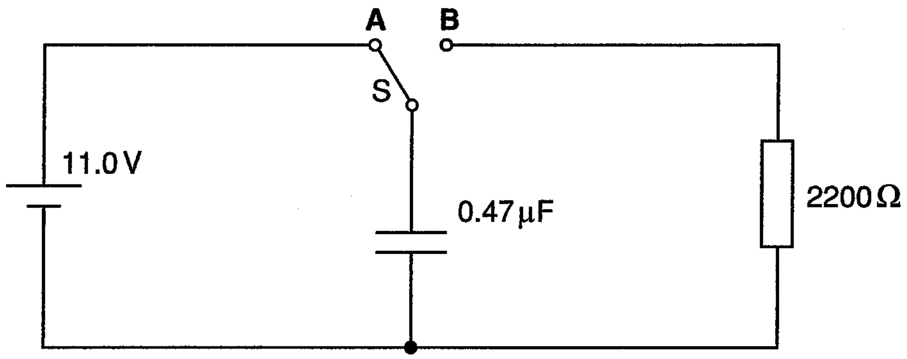

Fig. 3.1

(i) The capacitor is charged with switch S in position **A**. Calculate

1. the charge stored in the capacitor

charge = ... C [2]

2. the energy stored in the capacitor.

energy = ... J [2]

(ii) The switch is moved to position **B** at time $t = 0$ to discharge the capacitor.

Calculate

1. the initial current in the resistor

current = ... A [2]

2. the time constant of the circuit.

time constant = ... s [2]

(c) Fig. 3.2 shows the variation in current in the resistor with time for part of the discharge.

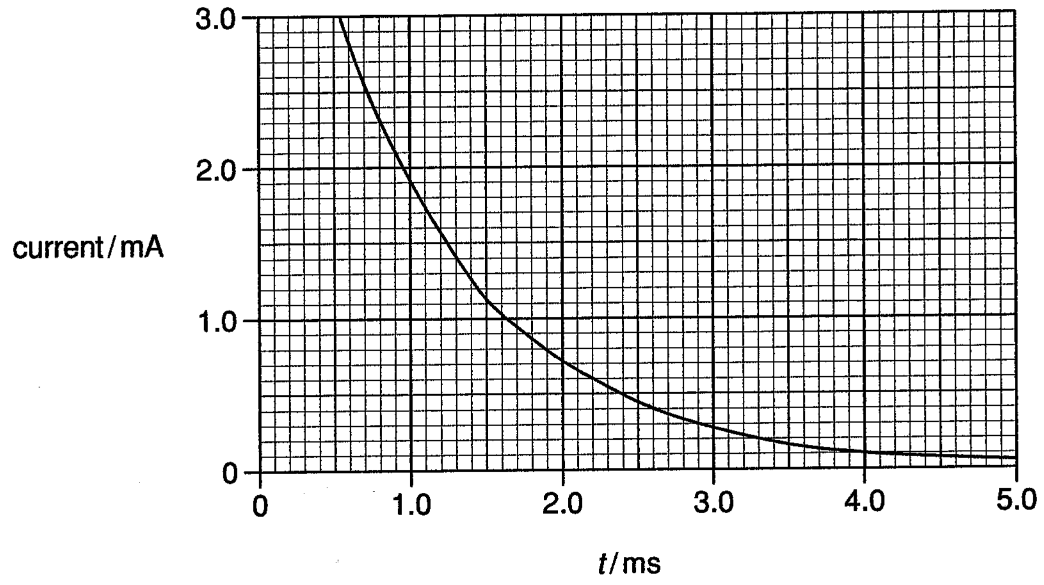

Fig. 3.2

(i) Show that the shape of the graph is exponential.

....

....

....

.... [2]

(ii) Estimate the charge which flows from the capacitor during the time t = 1.0 ms to t = 2.0 ms.

charge = ... C [3]

[Total: 14]

For Examiner's Use

4 Fig. 4.1 shows a square flat coil of insulated wire placed in a region of uniform magnetic field of flux density B. The direction of the field is vertically out of the paper. The coil of side x has N turns.

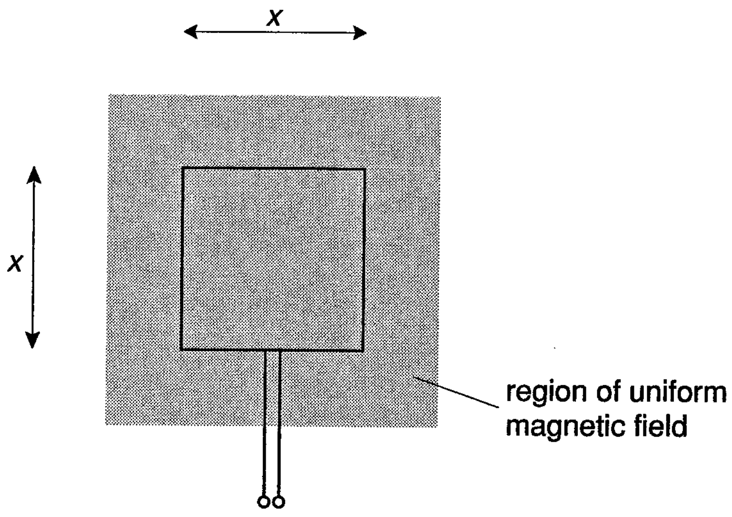

Fig. 4.1

(a) **(i)** Define the term *magnetic flux*.

....

....

.... [1]

(ii) Show that the magnetic flux linkage of the coil in Fig. 4.1 is NBx^2.

....

....

.... [2]

(b) The coil of side x = 0.020 m is placed at position **Y** in Fig. 4.2. The ends of the 1250 turn coil are connected to a voltmeter. The coil moves sideways steadily through the region of magnetic field of flux density 0.032 T at a speed of 0.10 m s^{-1} until it reaches position **Z**. The total motion takes 1.0 s.

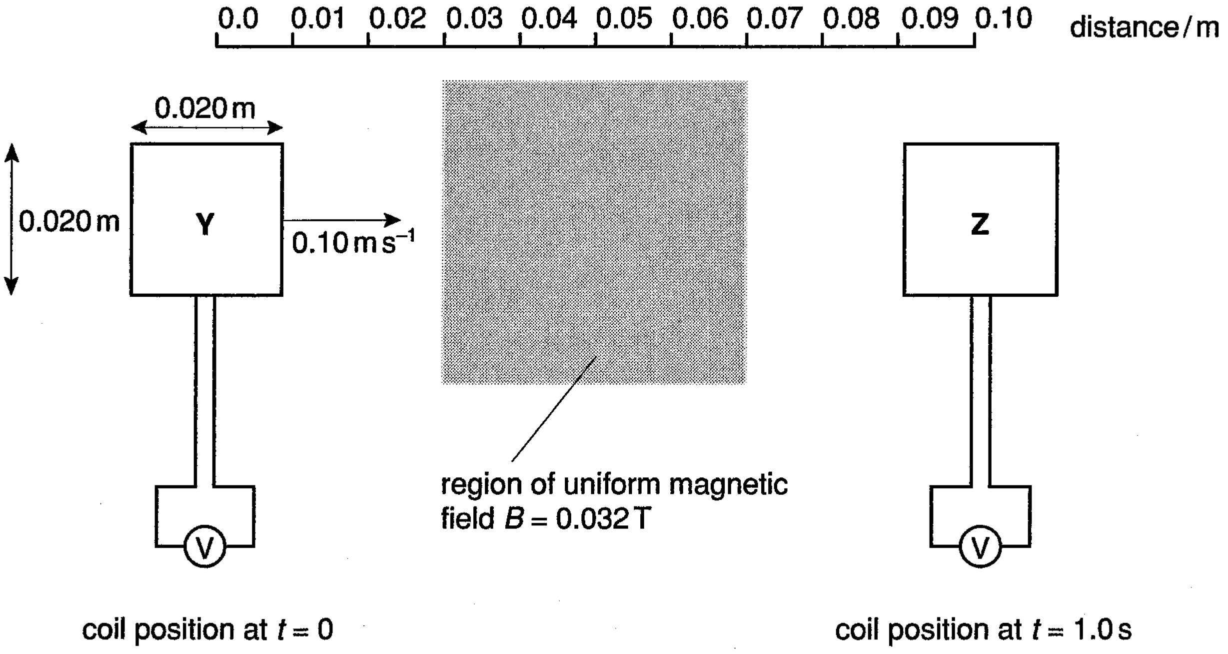

Fig. 4.2

(i) Show that the voltmeter reading as the coil enters the field region, after $t = 0.2$ s, is 80 mV. Explain your reasoning fully.

[3]

(ii) On Fig. 4.3, draw a graph of the voltmeter reading against time for the motion of the coil from **Y** to **Z**. Label the y-axis with a suitable scale. [4]

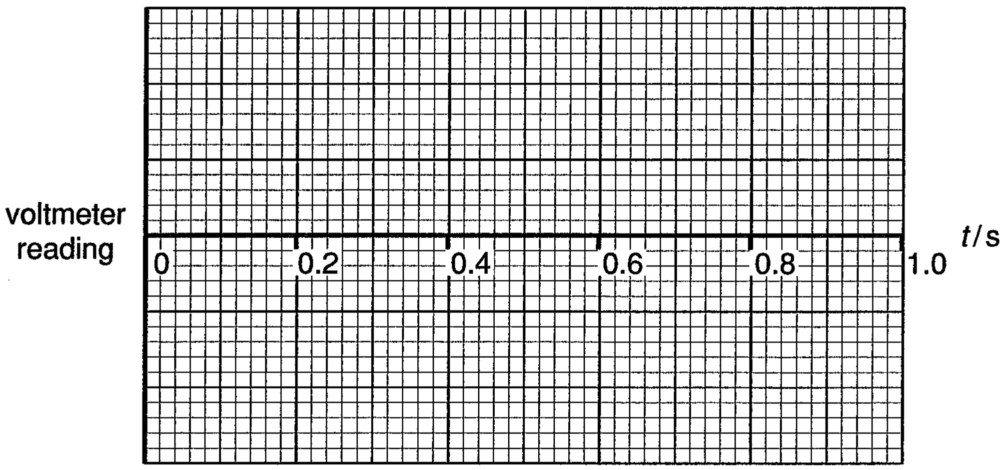

Fig. 4.3

[Total: 10]

[Turn over

For Examiner's Use

5 (a) Explain what is meant by *nuclear fission*.

....

.... [1]

(b) A possible fission reaction is

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{98}_{*}Sr + ^{*}_{54}Xe + 2^{1}_{0}n$$

(i) The two asterisks (*) represent two numbers missing from the right hand side of the nuclear reaction.

Write down the missing nucleon (atomic mass) number ....

and the missing proton (atomic) number .... [2]

(ii) The total mass of the compound nucleus $^{236}_{92}U$ before fission is 236.053 u. The total mass of the fission products is 235.840 u. Show that the energy released in the fission process is about 3×10^{-11} J.

[3]

(c) Suppose that 0.001 kg of uranium-235 could be persuaded to fission completely.

(i) Show that the energy released would be about 8×10^{10} J.

[2]

(ii) Estimate the mass of water that the released energy could raise from 20 °C to its normal boiling point.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

mass = ... kg [3]

[Total: 11]

6 **(a)** The charge and mass of each of the three types of ionising radiations emitted by radioactive substances can be given in terms of the fundamental charge e and the mass m_e of an electron or the mass m_p of a proton. Using these symbols, complete the table below.

radiation	charge	mass
α		
β		
γ		

[3]

(b) Alpha particles do not penetrate more than a few centimetres of air. Fig. 6.1 shows how the mean range of alpha particles depends on their kinetic energy at emission.

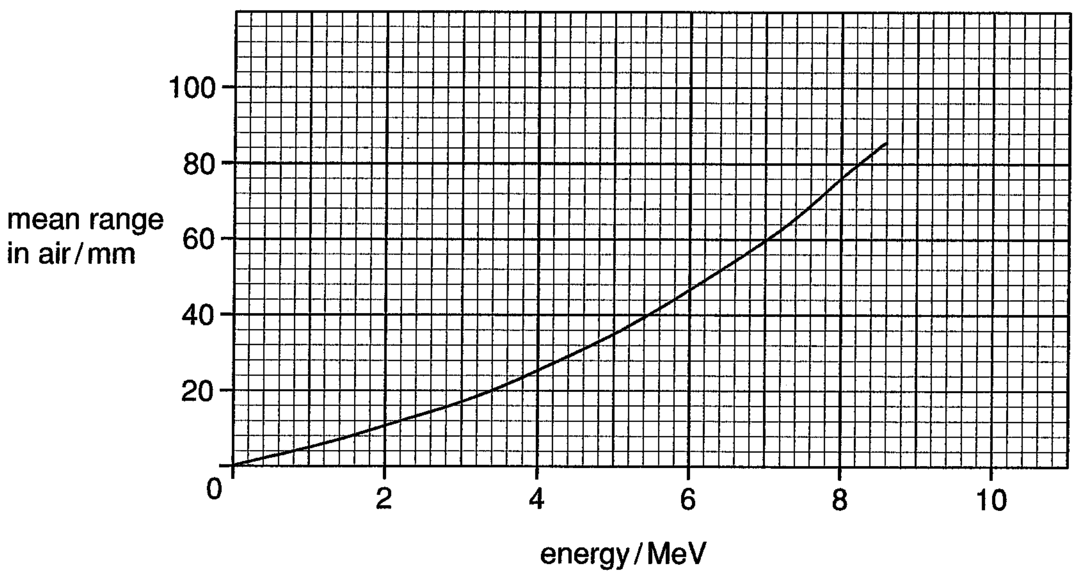

Fig. 6.1

(i) Use the graph to find the range of alpha particles emitted with an energy of 5.0 MeV.

range = ... mm [1]

(ii) Calculate the initial speed of a 5 MeV alpha particle.

1 MeV = 1.6 x 10^{-13} J

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

For Examiner's Use

(iii) Explain how alpha particles lose kinetic energy as they travel through the air.

....

....

....

.... [2]

(c) Fig. 6.2 shows a film badge which is worn by people who work with ionising radiation, such as beta particles, X-rays and gamma rays. The film is wrapped in a light-tight paper wrapper. It is placed in a plastic holder which has a wide slot or 'window' cut through the plastic. The holder also contains a number of metallic and plastic filters. The amount of darkening in different regions of the film indicate the exposure to different types of radiation.

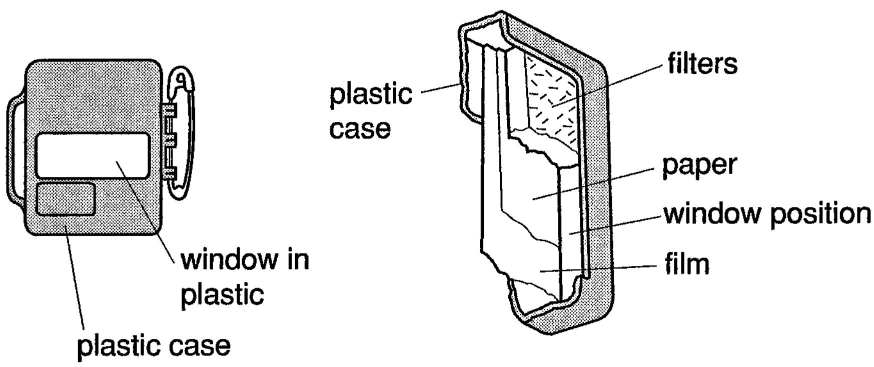

Fig. 6.2

Suggest why film badges are **not** suitable for monitoring alpha radiation, and why the window and the different types of filter are provided.

....

....

....

....

....

....

.... [4]

[Total: 13]

For Examiner's Use

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

(a) Define the momentum of a particle. State the principles of the conservation of linear momentum and the conservation of energy as applied to head-on collisions between particles. Explain the conditions under which linear momentum and kinetic energy are conserved.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

.... [6]

For Examiner's Use

(b) Use one or both of the principles in **(a)** to explain why in elastic collisions a small particle bounces back from a massive stationary particle, Fig. 7.1, whereas a large massive particle incident on a small particle does not bounce back, Fig. 7.2.

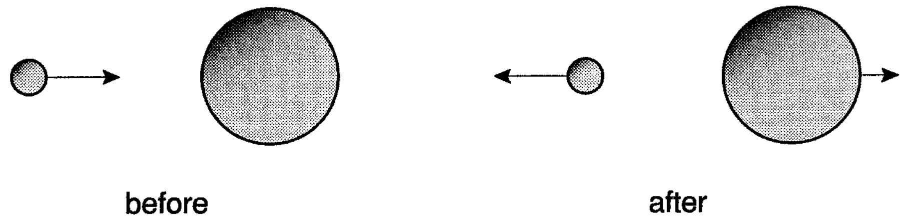

Fig. 7.1

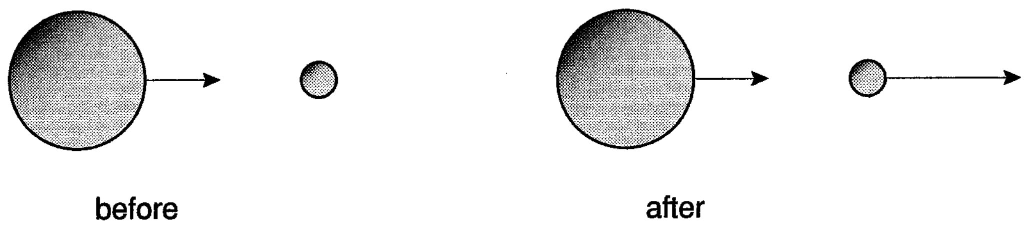

Fig. 7.2

....

....

....

....

....

....

....

....

....

....

....

....

.... [6]

Quality of Written Communication [4]

[Total: 16]

END OF QUESTION PAPER

BLANK PAGE

BLANK PAGE