RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2864/01

Field and Particle Pictures

Thursday **16 JUNE 2005** Morning 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 15 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.
- 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.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The number of marks is given in brackets [ ] at the end of each question or part question.
- Four marks are available for the quality of written communication in Section B.
- The values of standard physical constants are given in the Data, Formulae and Relationship Booklet. Any additional data required are given in the appropriate question.

FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**20**	
B	**50**	
TOTAL	**70**	

This question paper consists of 14 printed pages and 2 blank pages.

[Turn over

Answer **all** the questions.

Section A

1 Here is a list of units.

NC^{-1} **JC^{-1}** **$Wb\,s^{-1}$** **$Wb\,m^{-2}$**

Choose the correct unit for

(a) electric field strength ....

(b) magnetic field strength ....
[2]

2 Fig. 2.1 shows the path followed by an alpha particle as it is deflected by a gold nucleus.

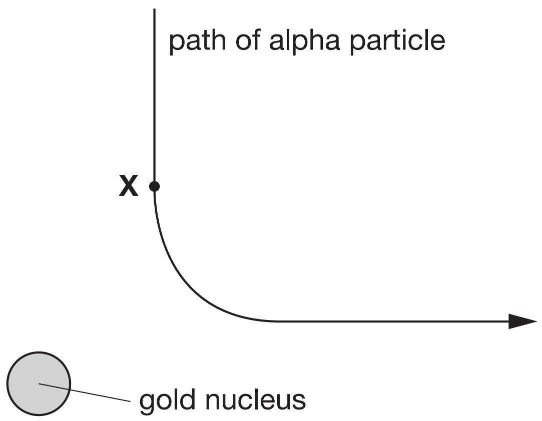


Fig. 2.1

(a) Mark with an arrow the direction of the force on the alpha particle when it is at point **X**.
[1]

(b) At point **X**, the alpha particle is 1.2×10^{-13} m from the centre of the gold nucleus. A gold nucleus and an alpha particle contain 79 and 2 protons respectively.

Calculate the magnitude of the force on the alpha particle when it is at point **X**.

$e = 1.6 \times 10^{-19}$ C

$k = \dfrac{1}{4\pi\varepsilon_0} = 9.0 \times 10^{9}\ N\,m^{2}\,C^{-2}$

force = ... N [3]

3 The graph of Fig. 3.1 shows how the flux in the secondary coil of a transformer varies with time.

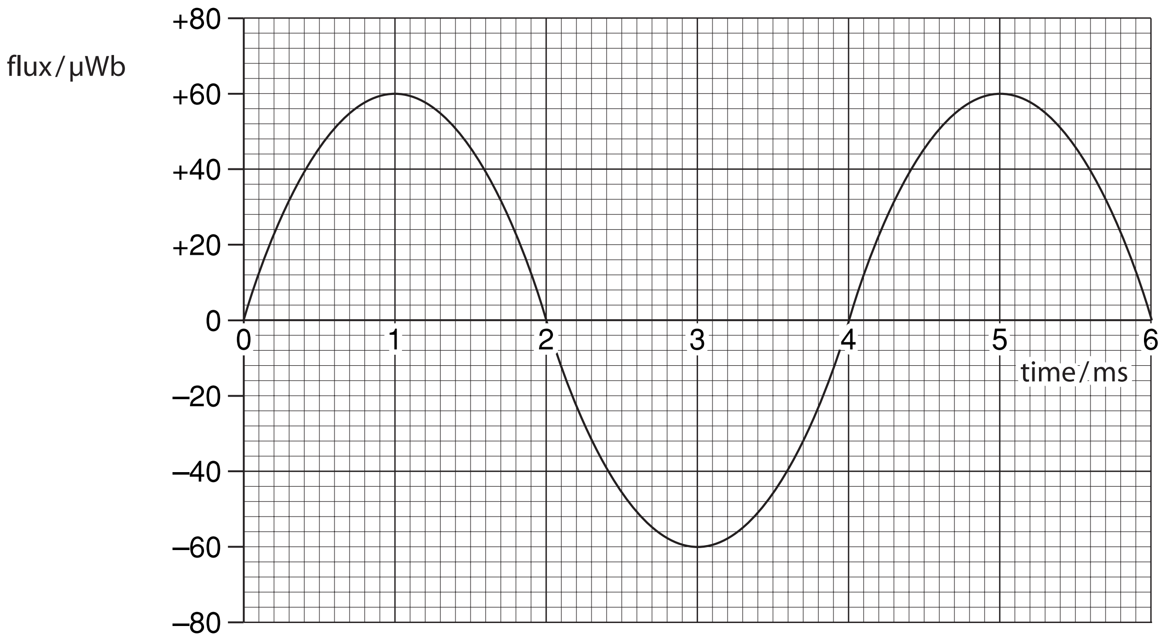


Fig. 3.1

(a) On Fig. 3.1, sketch the variation with time of the emf across the secondary coil.

There is no need for any calculations. [1]

(b) The secondary coil has 75 turns of wire. By measuring a suitable gradient on the graph of Fig. 3.1, show that the maximum emf across the coil is about 10 V.

[2]

4 Here are some statements about particles in a nucleus.

A A stable nucleus always contains more neutrons than protons.
B Emission of a gamma photon always results in a loss of mass for a nucleus.
C A nucleus can always reduce the number of neutrons by emitting a gamma photon.

Which **one** statement is correct?

answer .... [1]

5 Fig. 5.1 represents a gold nucleus.

Fig. 5.1

On Fig. 5.1, sketch **eight** lines to represent the shape and direction of the electric field surrounding the nucleus. [2]

6 The electric potential V_{elec} at a point distance r from a positive charge Q is given by the expression

$$V_{elec} = \frac{kQ}{r}.$$

Explain the meaning of the term *electric potential*.

[2]

7 The force F on a wire of length l carrying a current I at right angles to a magnetic field of flux density B is given by the equation

$$F = IlB.$$

Show that the units of flux density can be $\mathrm{N\,s\,C^{-1}\,m^{-1}}$.

[2]

8 In a scattering experiment, a beam of particles is scattered by nuclei in a thin target.

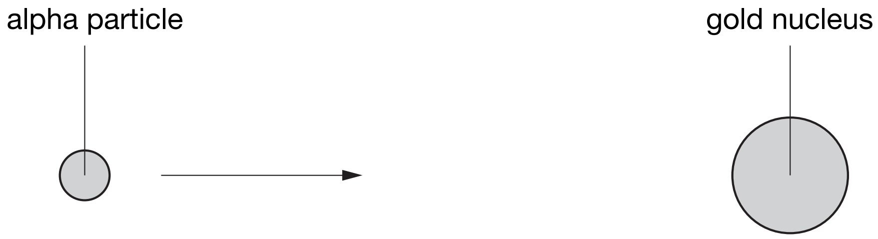
All of the particles in the beam have the same mass, charge and energy.

Of the three quantities mass, charge and energy, which one, by itself, if increased would result in **more** particles being scattered out of the beam by more than 90°?

answer .... [1]

9 An alpha particle has a head-on collision with a gold nucleus.

The collision reverses the direction of the alpha particle's velocity.



On the axes of Fig. 9.1, sketch how the kinetic energy of the alpha particle varies with time t, from well before the collision ($t = 0$) to well after it is over.

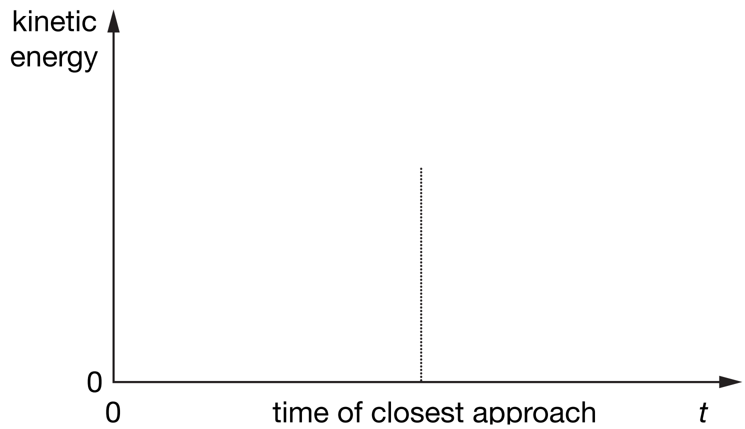


Fig. 9.1

[3]

[Section A Total: 20]

Section B

10 This question is about a type of electric motor.

Computers are often cooled by fans turned by brushless motors.

Details of a simple brushless motor are shown in Fig. 10.1.

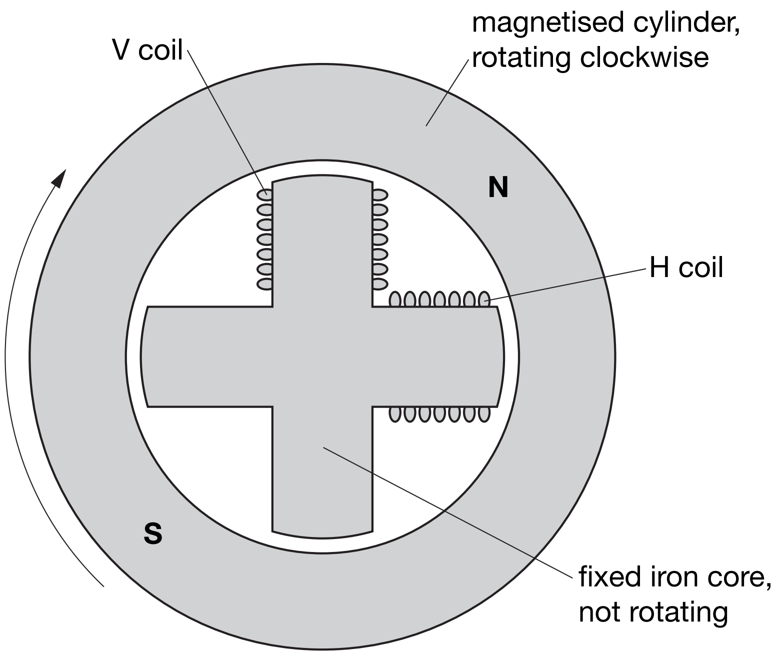


Fig. 10.1

To make the cylinder rotate around the fixed core, pulses of current are alternately applied to the H and V coils wound around the iron core.

(a) Initially, a pulse of current is provided in the H coil. This sets the magnetised cylinder rotating clockwise, starting from the position shown in Fig. 10.1.

(i) Mark on Fig. 10.1 the N and S poles on the **fixed iron core** required to make the magnetised cylinder rotate clockwise. [1]

(ii) Explain how the presence of these poles makes the cylinder rotate clockwise.

[1]

For Examiner's Use

(b) To keep the cylinder rotating, a series of pulses of current are provided in both H and V coils.

The graph of Fig. 10.2 shows how the current in the H coil changes with time.

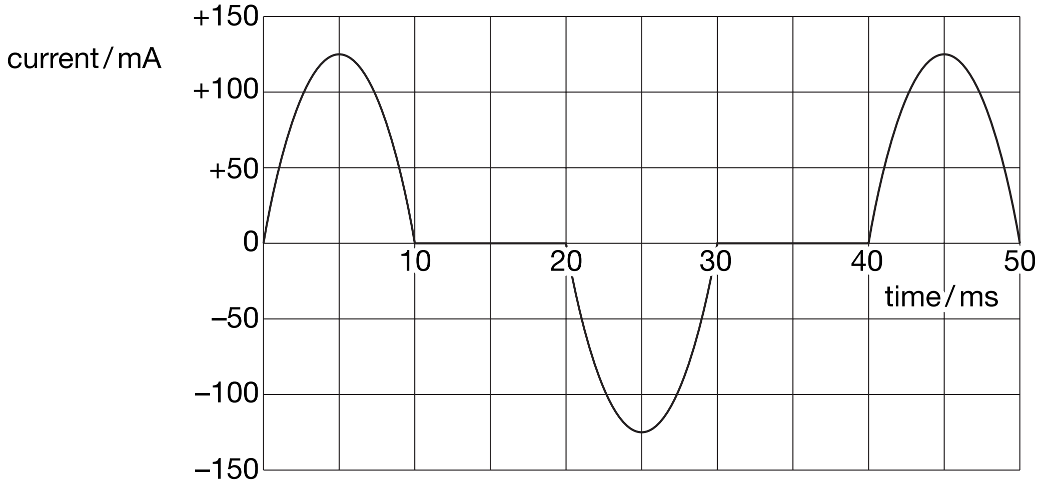


Fig. 10.2

On Fig. 10.2, sketch the pulses of current in the V coil which will keep the magnetised cylinder rotating. [2]

(c) Use data from Fig. 10.2 to explain why the maximum speed of the cylinder will be 25 rotations per second.

[2]

(d) **(i)** Suggest and explain **one** modification to the motor which will make the cylinder rotate faster.

[2]

(ii) Suggest and explain **one** modification to the motor which will result in a larger turning force on the cylinder.

[2]

[Total: 10]

11 This question is about triggering the rapid release of gamma photons from a nucleus.

Fig. 11.1 shows some of the energy levels for a nucleus of hafnium-178.

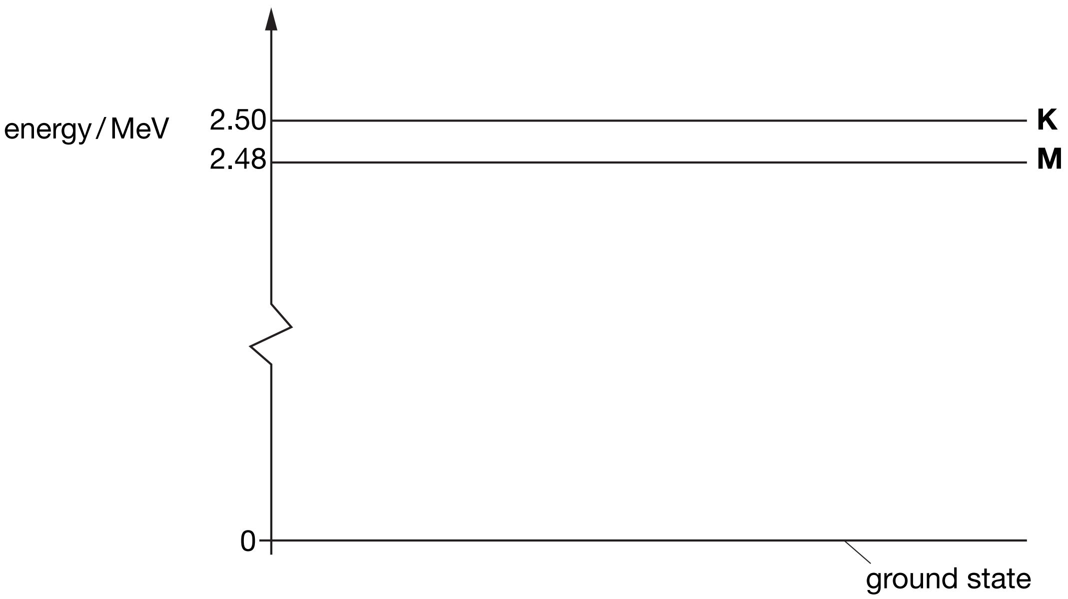


Fig. 11.1

(a) Hafnium-178 is created by bombarding a target of tantalum-181 with high energy protons from an accelerator. This process is represented by the equation

$$^{181}_{73}\text{Ta} + ^{1}_{1}\text{p} \longrightarrow ^{178}_{72}\text{Hf} + \text{X}$$

Calculate the mass and charge numbers of particle X, and hence identify it.

[2]

(b) Some of the hafnium-178 nuclei created are in the excited state, labelled **M** in Fig. 11.1. Nuclei in state **M** decay very slowly, with a decay constant of $7.1 \times 10^{-10}\,\text{s}^{-1}$.

In a recent experiment, a sample of 5.0 ng of hafnium-178 was created in state **M**.

(i) Calculate the mass of a single nucleus of hafnium-178.

$1\,\text{u} = 1.7 \times 10^{-27}\,\text{kg}$

mass = ... kg [1]

(ii) Show that the sample contained about 2×10^{16} nuclei of hafnium-178.

[1]

(iii) Calculate the activity of the sample.

Include the unit of your answer.

activity = ... unit .... [3]

(c) The sample of hafnium-178 in state **M** was exposed to a one second pulse of X-ray photons of wavelength 6.2×10^{-11} m.

(i) Show that the energy of each X-ray photon is 0.020 MeV.

$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$
$h = 6.6 \times 10^{-34}\,\mathrm{J\,s}$
$e = 1.6 \times 10^{-19}\,\mathrm{C}$

[3]

(ii) The X-ray photons are absorbed by the sample.

The energy level **K** is 0.020 MeV above the level **M**.

Explain how this fact could account for the absorption of the X-ray photons.

[2]

(iii) Absorption of the X-ray photons by the sample results in a large increase in activity. Nuclei in the energy level **K** have a large decay constant.

Explain how this could account for the increase in activity.

[2]

[Total: 14]

For Examiner's Use

12 This question is about accelerating particles to high energies.

Particles are accelerated in a ring-shaped evacuated tube, as shown in Fig. 12.1.

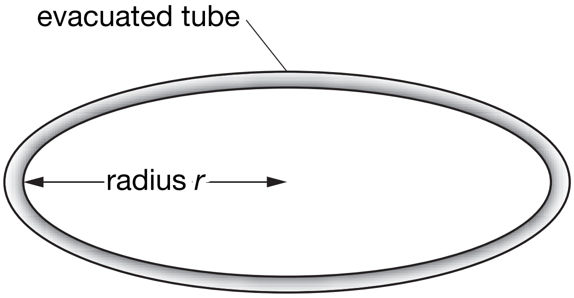


Fig. 12.1

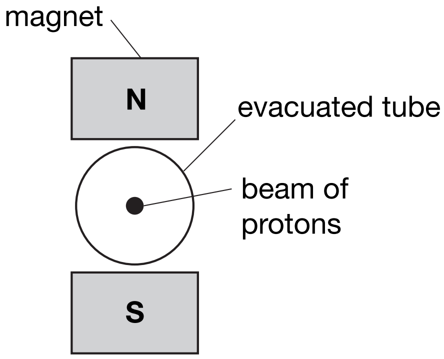


Fig. 12.2

(a) A particle accelerator of this type at CERN accelerates protons to a total energy of 270 GeV.

Use the relationship $E_{rest} = mc^2$ to show that the energy 270 GeV is about 300 times the rest energy of the protons.

$m_p = 1.7 \times 10^{-27}$ kg
$e = 1.6 \times 10^{-19}$ C
$c = 3.0 \times 10^{8}$ m s^{-1}

[3]

(b) Fig. 12.2 shows the magnets above and below the evacuated tube. These force protons moving along the tube to follow a circular path.

(i) Low energy protons of mass m and charge q move at speed v through the magnetic field of flux density B. By using the expressions for the centripetal force and magnetic force on the protons, show that the radius r of the circular path is given by the expression

$$r = \frac{mv}{Bq}.$$

[2]

For Examiner's Use

(ii) Protons with a large total energy *E* move at almost the speed of light *c*.

In these conditions, the radius *r* of the circular path is given by the expression

$$r = \frac{E}{cBq}\ .$$

Calculate the magnetic flux density required to keep 270 GeV protons in a circular path of radius 1.8×10^3 m.

$c = 3.0 \times 10^8\,\text{m s}^{-1}$
$e = 1.6 \times 10^{-19}\,\text{C}$

flux density = ... T [2]

(c) In an experiment, protons and antiprotons travel in opposite directions through the evacuated tube.

(i) Suggest why protons and antiprotons travel in opposite directions in the evacuated tube.

[1]

Sometimes, when a proton and an antiproton collide, a particle called the Z is created. The Z particle is unstable and decays quickly into a positron and an electron.

(ii) Complete the equation for the decay of the Z particle, showing nucleon and charge numbers.

$${}^{0}_{0}\text{Z} \longrightarrow$$

[2]

(iii) The experiment shows that the Z particle has a rest energy of 93 GeV.

Suggest how this is determined by the experiment.

[2]

[Total: 12]

[Turn over

For Examiner's Use

13 This question is about calculating the risk to workers exposed to radioactive materials.

Disposable surgical instruments are sterilised by gamma photons from a sample of cobalt-60. The instruments in their airtight plastic bags are packed into boxes and placed on the conveyor belt , as shown in Fig. 13.1.

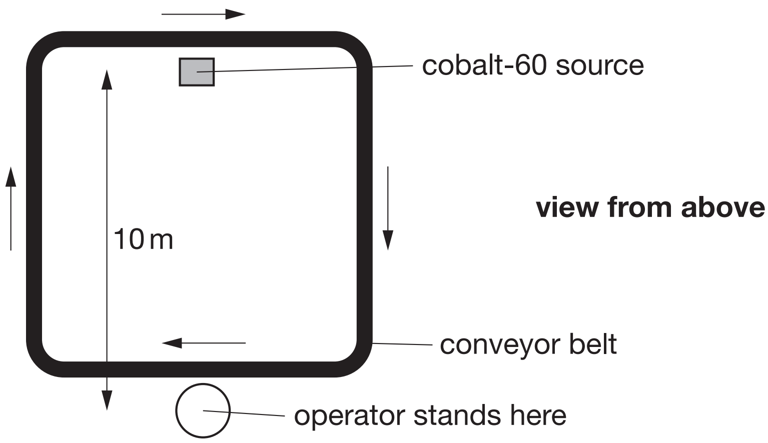


Fig. 13.1

(a) Operators are required to stand on a spot that is 10 m from the cobalt-60 source. Boxes that they load onto the conveyor belt pass much closer to the cobalt-60, and are exposed to a high intensity of gamma photons. The intensity I of gamma photons at a distance d from a source which emits photons at a rate A is given by the expression

$$I = \frac{A}{4\pi d^2} .$$

(i) The source emits gamma photons at a rate of 2.4×10^{16} Bq.

Show that the intensity of gamma photons for the operators would be about $2 \times 10^{13}\,\mathrm{Bq\,m^{-2}}$ in the absence of shielding.

[1]

(ii) Explain why the intensity of gamma photons decreases with increasing distance from the source.

[2]

(iii) A nucleus of cobalt-60 releases a beta particle when it decays, quickly followed by a pair of gamma photons.

Explain why the beta particles contribute very little to the absorbed dose of the operator.

[1]

(b) In order to reduce the intensity of gamma photons for the operators to a safe level, a 1.2 m thick wall of concrete is placed between them and the source, as shown in Fig. 13.2.

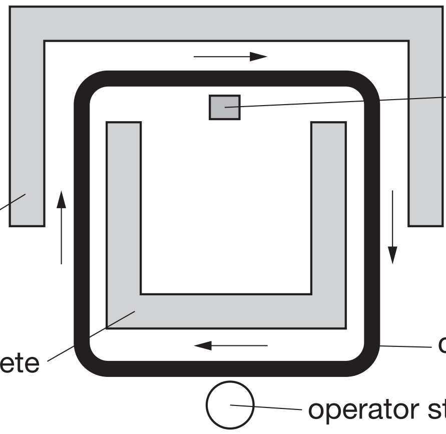


Fig. 13.2

(i) The intensity of the photons is halved for each 4.0×10^{-2} m thickness of concrete that they pass through.

Show that the 1.2 m thickness of concrete reduces the intensity of gamma photons for the operator to about 2×10^{4} Bq m^{-2}.

[2]

(ii) Each operator presents an average area of 0.80 m^{2} for absorption of the gamma photons.

If all of the photons are absorbed by an operator, show that the operator absorbs about 1×10^{-4} J of energy in each eight hour working day.

energy of photons = 1.8×10^{-13} J

[2]

(iii) The average mass of an operator is 75 kg, and the gamma photons have a quality factor of 1.

Show that the absorbed dose of the operator is below the recommended safe limit of 4.0×10^{-6} Sv per day.

[2]

[Total: 10]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER

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