THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCING PHYSICS) 2864/01

Field and Particle Pictures

Candidates answer on the question paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

Wednesday 21 January 2009
Morning

Duration: 1 hour 15 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.
- 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.
- The total number of marks for this paper is **70**.
- 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 Relationships Booklet. Any additional data required are given in the appropriate question.
- This document consists of **16** pages. Any blank pages are indicated.

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

 OCR is an exempt Charity

Turn over

Answer **all** the questions.

Section A

1 Here is a list of units.

J C^{-1} **V m^{-1}** **Wb** **Wb m^{-2}**

(a) Which is a correct unit for magnetic field strength?

.... **[1]**

(b) Which is a correct unit for electric potential?

.... **[1]**

2 Fig. 2.1 represents a nucleus of helium-4 colliding head on with a nucleus of polonium-210.

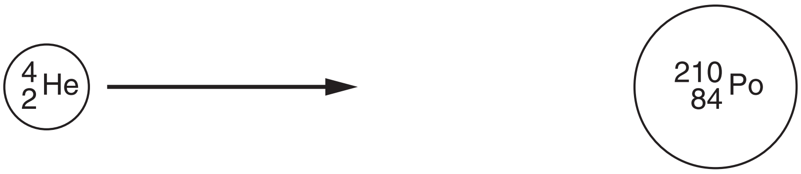

Fig. 2.1

Calculate the potential energy of the helium-4 nucleus when the distance between the centres of the nucleii is 7.3×10^{-15} m.

$k = 9.0 \times 10^{9}$ N m^2 C^{-2}

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

potential energy = ... J **[3]**

3 Fig. 3.1 shows three electric field lines.

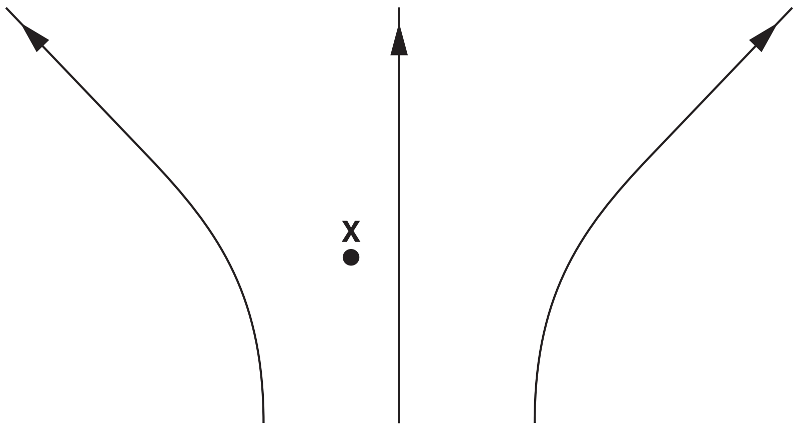

Fig. 3.1

(a) On Fig. 3.1, sketch the equipotential line through the point **X**. **[1]**

(b) Point **X** is at a potential of +200V.
On Fig. 3.1, sketch possible equipotential lines for +100V and +300V.
Label each line with its potential. **[2]**

4 The nuclear equation below shows the decay of the isotope carbon-11.

$$^{11}_{6}\text{C} \rightarrow {}^{11}_{5}\text{B} + {}^{0}_{1}\text{e} + {}^{0}_{0}\nu$$

Carbon-11 emits positrons and has a half-life of 20 minutes.

(a) Calculate the decay constant of carbon-11.

decay constant = ... s^{-1} **[1]**

(b) Here are some attempts to define the decay constant of carbon-11.

A The initial rate at which one mole of the isotope decays.

B The probability of a single nucleus decaying in any second.

C The average activity of one mole of the isotope as it decays.

Which statement (**A**, **B**, or **C**) is correct for the decay constant?

.... **[1]**

5 Antiprotons are created at CERN by firing particles of energy 26 GeV at a rod of iridium. Protons are created at the same time.

(a) Why are protons and antiprotons always created in pairs?

[1]

(b) Calculate the maximum number of proton-antiproton pairs that each 26 GeV particle can produce.

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

number of proton-antiproton pairs = ... **[3]**

6 The rotor of an electric motor is made from thin sheets of iron glued together.
The sentences below explain what happens if the rotor is made from solid iron.
They are in the wrong order.

A Eddy currents appear in the rotor.
B An emf is induced in the rotor.
C The rotor becomes hot.
D The rotor spins round.
E The flux in the rotor changes.
F Current in the rotor coil interacts with flux from the magnet.

Complete the table to show the correct order.

F					

[2]

7 Fig. 7.1 shows a simple generator.

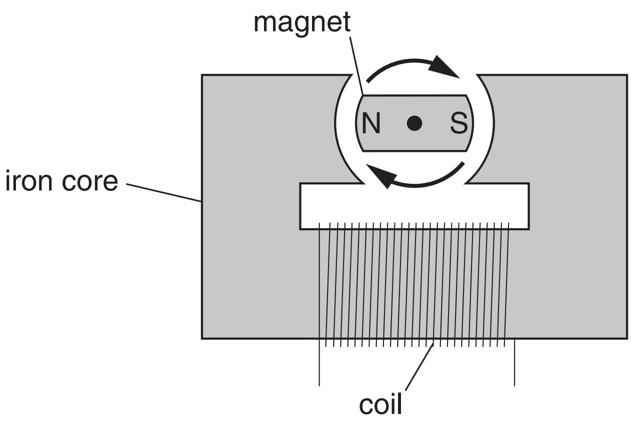

Fig. 7.1

Complete the sentences. Choose the **best** words from this list.

density **intensity** **linkage** **poles** **turns**

As the magnet spins, the flux .... in the iron core changes.

Changes in the flux .... of the coil generate an emf across it. **[2]**

8 Fig. 8.1 shows the standing wave for an electron in an atom.

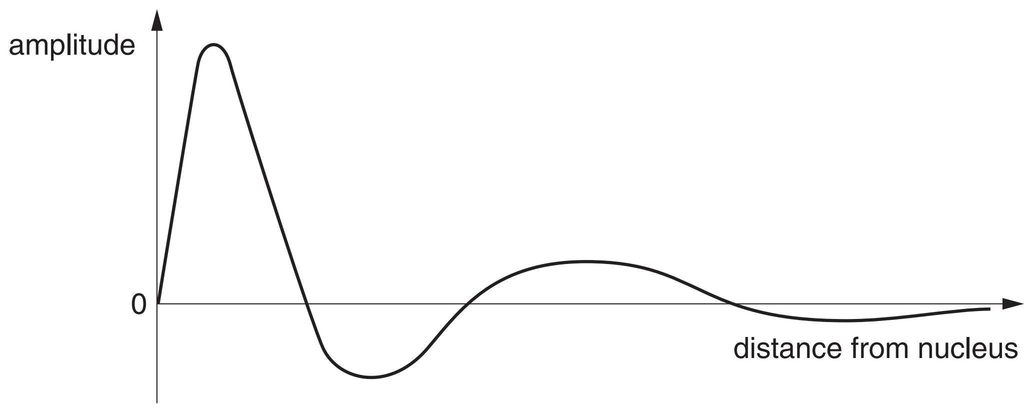

Fig. 8.1

(a) Mark with an **X** the place where the electron is most likely to be found. **[1]**

(b) What feature of the graph shows that the momentum of the electron decreases with increasing distance from the nucleus?

[1]

[Section A Total: 20]

Section B

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

9 This question is about forces on currents in magnetic fields.

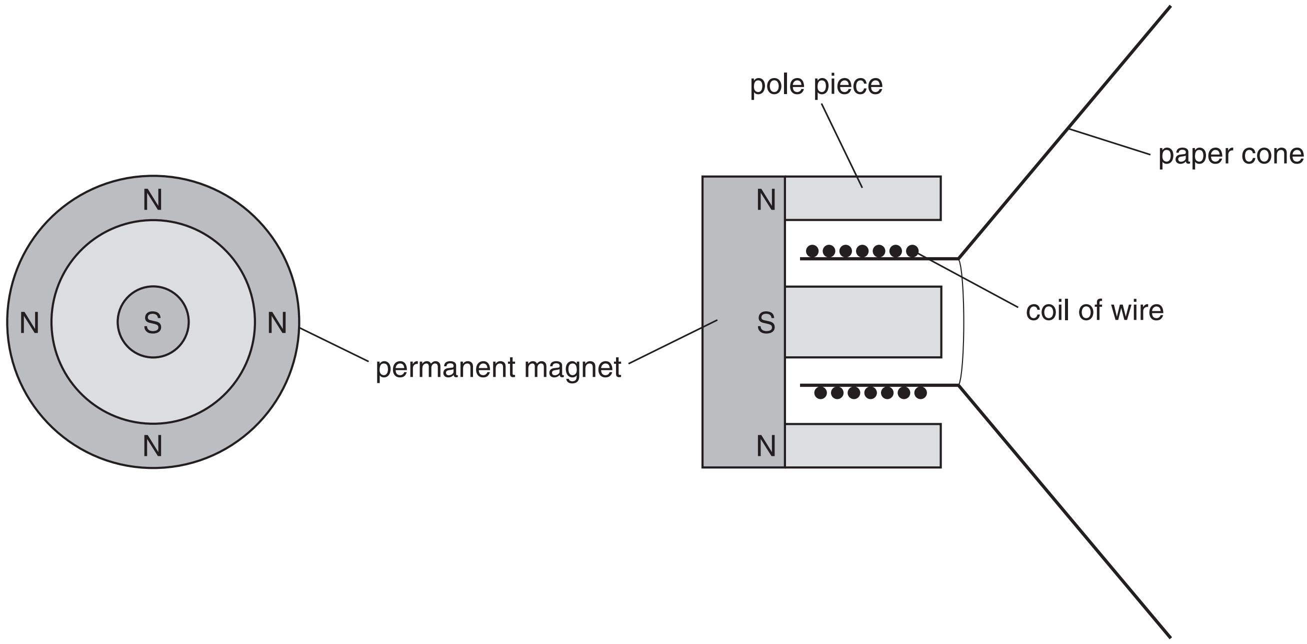

Fig. 9.1

Fig. 9.1 shows the construction of a loudspeaker. A coil of wire is suspended between pole pieces which guide flux from a permanent magnet in the shape of a disc. Alternating current in the coil results in vibration of the paper cone, generating sound.

(a) The permanent magnet has a south pole at its centre and a north pole distributed around its rim. The pole pieces guide the flux so that it is perpendicular to the current in the coil of wire.

(i) Sketch **two** complete loops of flux in the right-hand diagram of Fig. 9.1. **[2]**

(ii) Suggest a material for the pole pieces. Justify your choice of material.

[2]

(b) The force on the coil of wire can be increased by increasing the current in it.
Suggest **three other** modifications to the loudspeaker of Fig. 9.1 which increase the force on the coil of wire.

[3]

(c) The loudspeaker of Fig. 9.1 can also act as a microphone. Sound incident on the paper cone vibrates the coil of wire, generating an emf. The graph of Fig. 9.2 shows how the flux linkage changes with time for a particular sound.

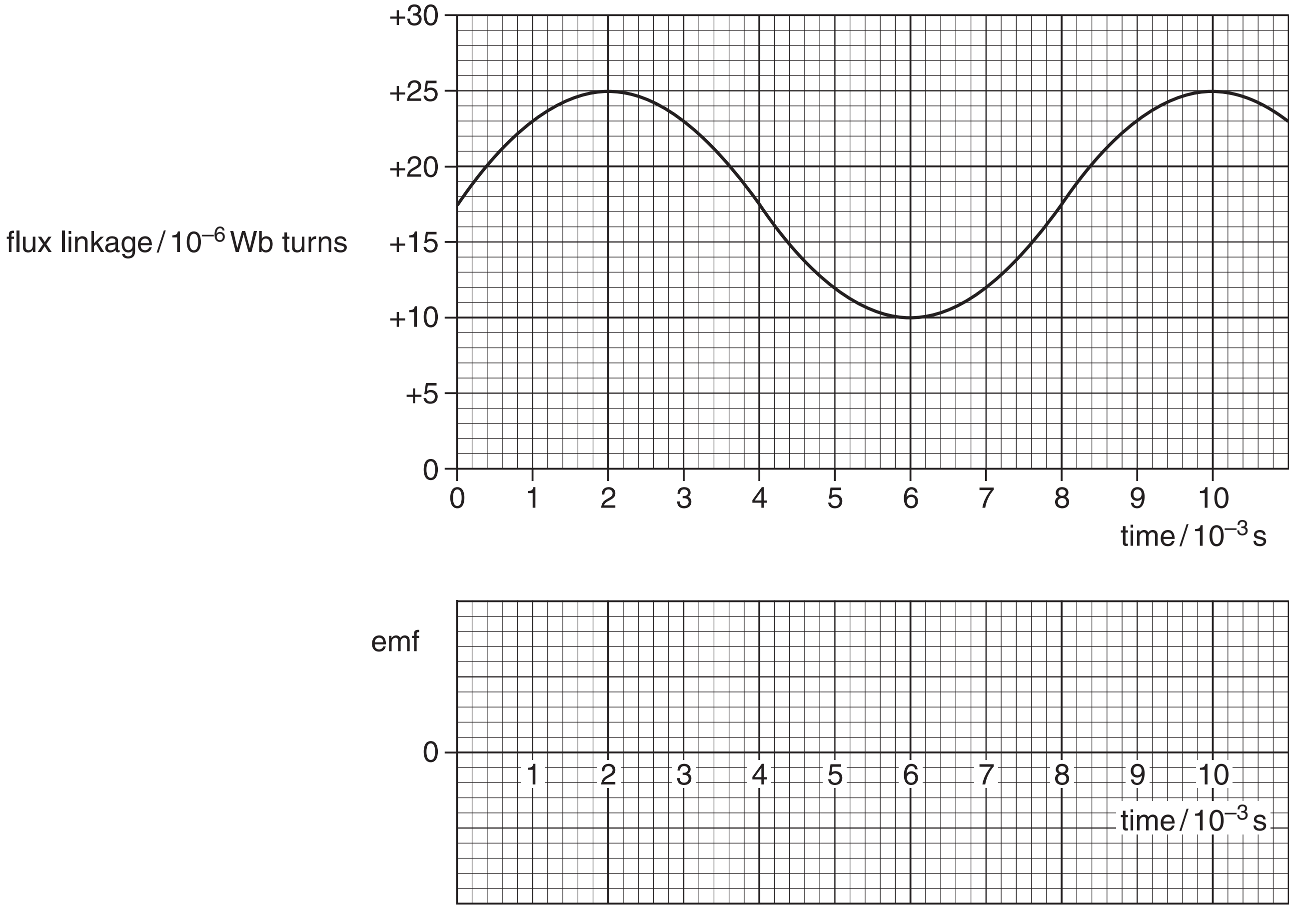

Fig. 9.2

(i) Use the graph of Fig. 9.2 to calculate the amplitude of the emf across the coil.

emf = ... unit .... **[3]**

(ii) On Fig. 9.2, show how the emf across the coil of wire changes with time. **[2]**

[Total: 12]

10 This question is about the risks of ionising radiation.

Polonium-210 is a radioisotope which must be handled carefully.
It has the following properties:

- it is an alpha emitter with a half life of 138 days
- it is absorbed by the liver when swallowed
- it decays to a stable isotope of lead
- it rarely emits gamma photons

(a) **(i)** Use the information above to suggest reasons why the presence of polonium-210 in the body is not only hazardous but also difficult to detect.

[4]

(ii) Complete the nuclear equation for the decay of polonium-210.

$$^{210}_{84}\text{Po} \rightarrow \, ^{....}_{....}\text{He} + \, ^{....}_{....}\text{Pb}$$

[2]

(b) Only a small amount of polonium-210 is required to provide a lethal dose equivalent of 10 Sv in a week.

(i) Show that the absorbed dose rate for that week is about $8 \times 10^{-7}\,\text{J kg}^{-1}\,\text{s}^{-1}$.

1 week = $6.0 \times 10^{5}\,\text{s}$

quality factor for alpha particles = 20

[2]

(ii) Show that the activity of the polonium-210 absorbed by the liver needs to be about $2 \times 10^{6}\,\text{Bq}$.

average mass of liver = 2.3 kg

energy of alpha particles = $8.5 \times 10^{-13}\,\text{J}$

[2]

(iii) Calculate the mass of polonium-210 that the liver must absorb.

$\lambda = 5.8 \times 10^{-8}\,\text{s}^{-1}$ for polonium-210

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

mass = ... kg **[2]**

(c) Fortunately, polonium-210 is very difficult to obtain, even in such tiny quantities.
It is manufactured by exposing the isotope $^{209}_{83}\text{Bi}$ to neutrons from a nuclear reactor to create bismuth-210. This quickly decays to polonium-210, through beta decay.
Write down a pair of nuclear equations to represent the two stages of making polonium-210 from bismuth-209.

[2]

[Total: 14]

11 This question is about particle accelerators.

The Large Hadron Collider (LHC) is the most recent particle accelerator to operate. It accelerates beams of protons to a maximum energy of 7 TeV before colliding them head-on. The high energy protons are guided around in a circle of radius 4.3 km by superconducting magnets which have a maximum flux density of 8.3 T.

(a) A beam of protons move with a speed v in a magnetic field of flux density B in a circle of radius R. Each proton has a mass m and charge e.

(i) By equating the centripetal force on each proton with the magnetic force, show that $B = \frac{p}{eR}$, where $p = mv$ is the momentum of the proton.

[2]

(ii) Protons in the beam move at almost the speed of light c.
At this speed their energy E is given by $E = pc$.
Show that a maximum magnetic field strength of 8.3 T is more than enough to keep protons of energy 7.0×10^{12} eV moving in a circle of radius 4.3 km.

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

[3]

(iii) The LHC can accelerate particles other than protons to energies above 7 TeV.

Use your answers to **(i)** and **(ii)** to explain why nucleii of lead ($^{206}_{82}Pb$) can be accelerated up to 574 TeV.

[3]

(b) Protons are injected into the LHC accelerator with an energy of 450 GeV. They stay in the accelerator, following the same circular path, until they reach an energy of 7.0 TeV.

(i) Explain why the field strength of the superconducting electromagnets has to change from 0.5 T to 8.3 T as the protons acquire energy.

[2]

(ii) The current of the proton beam in the LHC accelerator ring is 0.56 A.
Calculate the number of protons in the accelerator ring.

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

$c = 3.0 \times 10^{8}\,m\,s^{-1}$

number of protons = ... **[2]**

[Total: 12]

12 This question is about inelastic scattering of electrons from atoms.

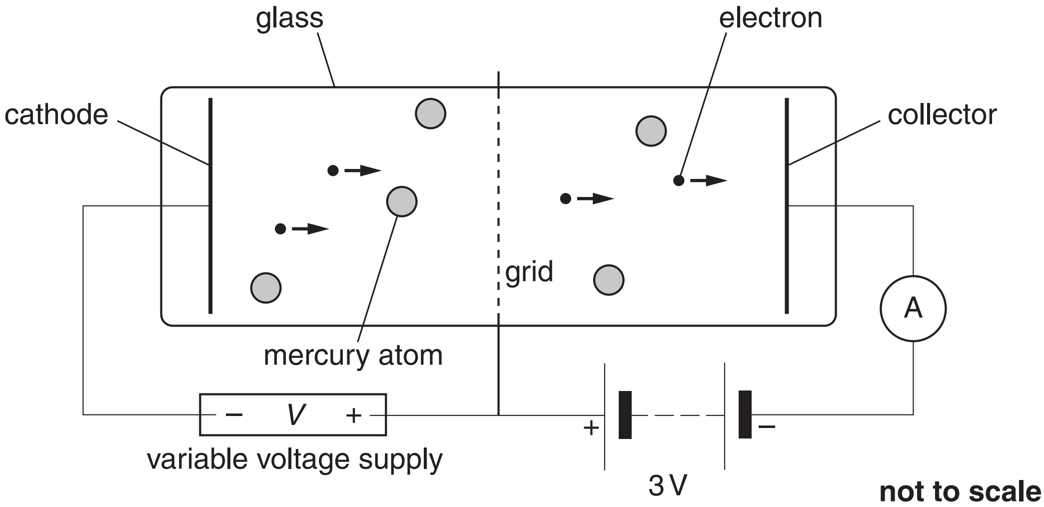

Fig. 12.1

The sealed glass tube of Fig. 12.1 contains a low pressure gas of mercury atoms. Electrons released from the cathode are accelerated towards the grid by the variable potential difference *V*. There are many collisions (elastic or inelastic) between these electrons and mercury atoms. Some electrons have enough energy at the grid to reach the collector and provide a current in the ammeter.

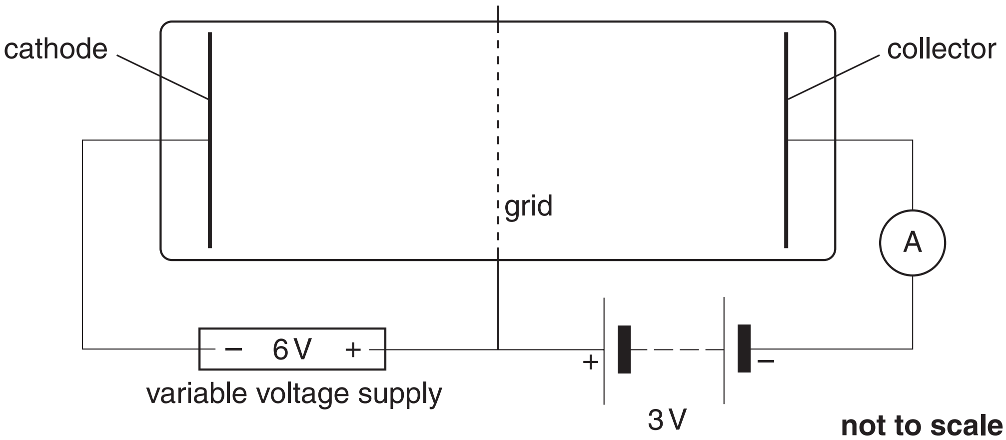

Fig. 12.2

(a) Fig. 12.2 shows the tube when the variable voltage *V* is set to 6 V.

(i) Draw three arrowed lines on Fig. 12.2 to represent the uniform electric field between the **grid** and the **collector** provided by the 3 V battery. **[2]**

(ii) Draw arrowed lines to represent the uniform field between the **cathode** and the **grid** when *V* is 6 V. The grid is midway between the cathode and the collector. **[2]**

(b) The apparatus can be used as follows to provide evidence that the first energy level of a mercury atom is 5 eV above its ground state.
The voltage *V* between grid and cathode is steadily increased from 0 V to 8 V. The ammeter current, showing how many electrons have enough energy to reach the collector:

- remains zero until $V = 3\,\text{V}$
- rises steadily as *V* goes from 3 V to 5 V
- drops rapidly when *V* reaches 5 V
- increases again as *V* goes from 5 V to 8 V.

Explain these observations by considering the change of kinetic energy of the electrons as they pass from the cathode through the grid to the collector.

.

[4]

[Total: 8]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

PLEASE DO NOT WRITE ON THIS PAGE