SYDNEY GRAMMAR SCHOOL

2006
FORM VI
TRIAL HSC EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using blue or black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper
- Write your candidate number at the top of each page in Part B
- Hand in the paper in ONE bundle at the end of the exam.

Check List
Each candidate must have
- Question paper
- Multiple choice answer sheet
- Five-page booklet

Total marks (100)

Section I Pages 2 - 24

(75 marks)

This section has two parts, Part A and Part B

Part A – 15 marks
- Attempt questions 1 - 15
- Allow about 30 minutes for this part

Part B – 60 marks
- Attempt Questions 16 - 28
- Allow about 1 hour and 45 minutes for this part

Section II Pages 25 – 28

(25 marks)
- Use a separate writing booklet
- Attempt Question 34 only.
- Allow about 45 minutes for this section

Masters

AAH – Dr A. Haines
AGY – Mr A. Yabsley
AWW – Mr A. Woolnough
SRW – Mr S. Williams
MRW – Dr M. Ward

Part A

Total marks (15 marks)
Attempt Questions 1-15
Allow about 30 minutes for this Part

Use the multiple-choice Answer Sheet.

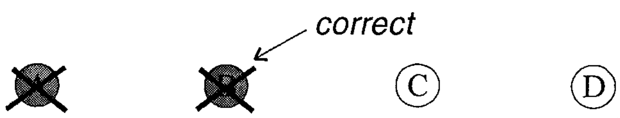
Select the alternative A, B, C or D that best answers the question. Fill the response circle completely.

Sample $2 + 4 =$

(A) 2 (B) 6 (C) 8 (D) 9

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows.



1 An unknown planet, X, has an acceleration due to gravity of 14.0 ms^{-2} at its surface. What is the weight of a 75.0 kg astronaut on the surface of planet X?

(A) 5.17 N
(B) 75.0 N
(C) 388 N
(D) 1050 N

Questions 2, 3 and 4 refer to the following information:

The following quantities describe the properties of the Hubble space telescope and its orbit around the Earth:-

- *Total mass of the telescope = 1.1×10^4 kg*
- *Radius of telescope orbit = 7.0×10^6 m.*

2 What is the orbital speed of the telescope?

(A) 8.2×10^1 ms^{-1}
(B) 7.6×10^3 ms^{-1}
(C) 7.9×10^5 ms^{-1}
(D) 5.7×10^7 ms^{-1}

3 What is the gravitational potential energy of the telescope?

(A) -6.3×10^{11} J
(B) -6.5×10^{10} J
(C) -5.7×10^7 J
(D) -9.0×10^4 J

4 What is the gravitational force between the Earth and the telescope?

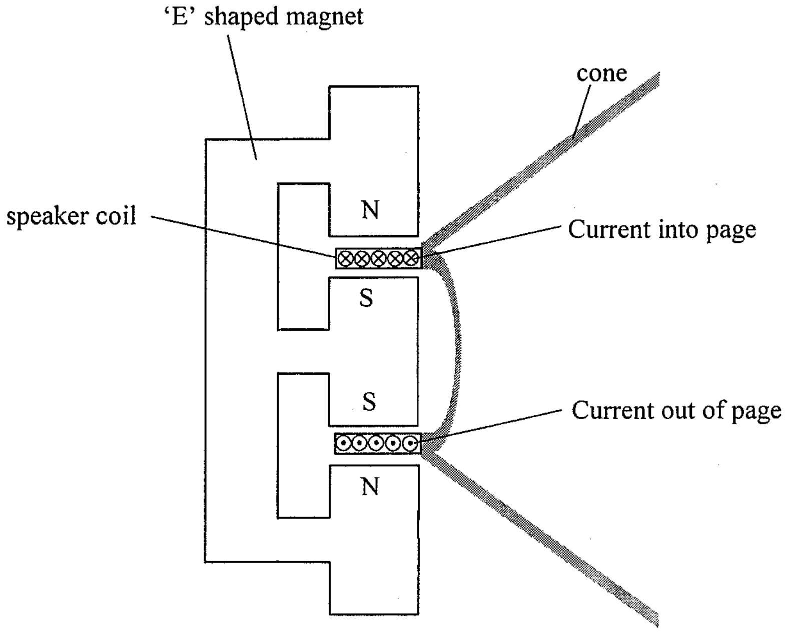
(A) 8.2×10^1 N
(B) 3.0×10^2 N
(C) 9.0×10^4 N
(D) 1.1×10^5 N

5 The star Algol is 3.67×10^{16} m away from Earth, as measured on Earth. A spacecraft travelling between the Earth and Algol measures the distance between Earth and Algol to be 2.15×10^{16} m.

What is the speed of the spacecraft, relative to Earth?

(A) 0.810c
(B) 0.657c
(C) 0.414c
(D) 0.235c

6 The following diagram shows a cross-section of a loudspeaker.



At the instant shown, when the current in the coil is flowing into the page at the top of the coil, which of the following statements describes the motion of the coil (and the attached cone)?

(A) It is oscillating.
(B) It is rotating.
(C) It is accelerating to the right of the page.
(D) It is accelerating to the left of the page.

7 The unit of magnetic flux is the weber, where 1.0 Wb is equivalent to which of the following units?

(A) 1 Am^2
(B) 1 Am^{-2}
(C) 1 Tm^2
(D) 1 Tm^{-2}

8 An electric motor driven from a constant voltage supply is used to move a load. If the magnitude of the load is decreased, which one of the following sets of changes occurs?

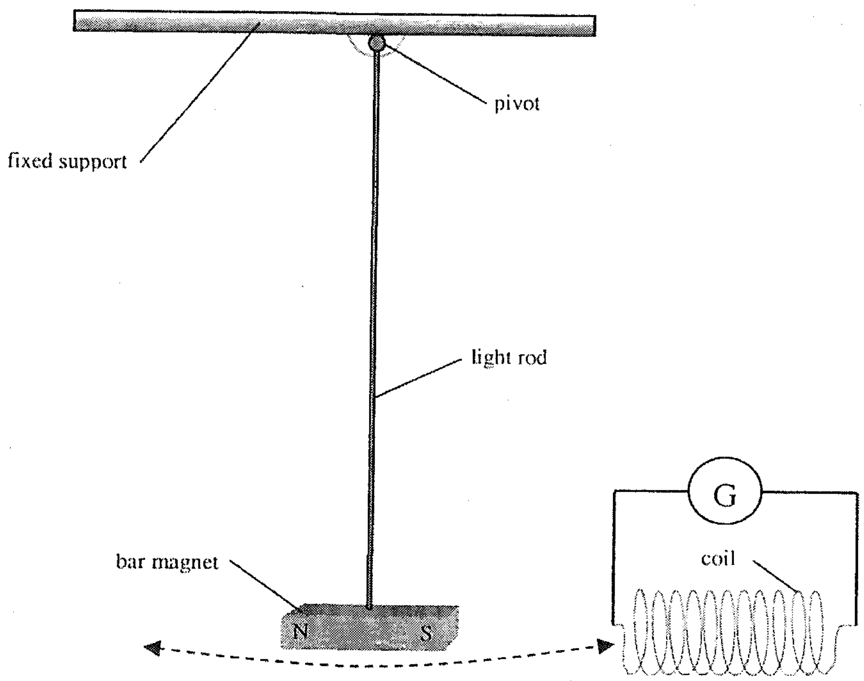
	Speed of rotation	**Induced emf in coil (back emf)**	**Current in the coil**
(A)	increases	increases	decreases
(B)	decreases	decreases	increases
(C)	increases	increases	increases
(D)	decreases	increases	decreases

9 There are 200 turns in the primary coil of an ideal transformer and its secondary coil has 50 turns. If the current in the secondary coil is 40.0 A, what is the current in the primary coil?

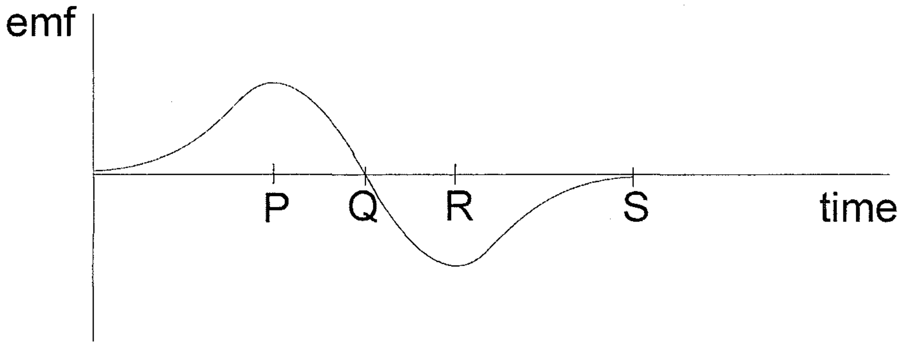
(A) 160 A
(B) 80.0 A
(C) 40.0 A
(D) 10.0 A

Part A continued on the next page

10 The diagram below represents a magnet mounted on a light rod which is oscillating as a simple pendulum. At the end of the swing, the magnet approaches a coil connected to a sensitive galvanometer.



As it swings, the magnet induces an emf (voltage) in the coil. A graph of induced emf plotted against time for the coil is shown below. Times P, Q, R and S are marked on the graph for one complete period of oscillation.



At which of the times P, Q, R, and S is the magnet closest to the coil?

(A) Time P
(B) Time Q
(C) Time R
(D) Time S

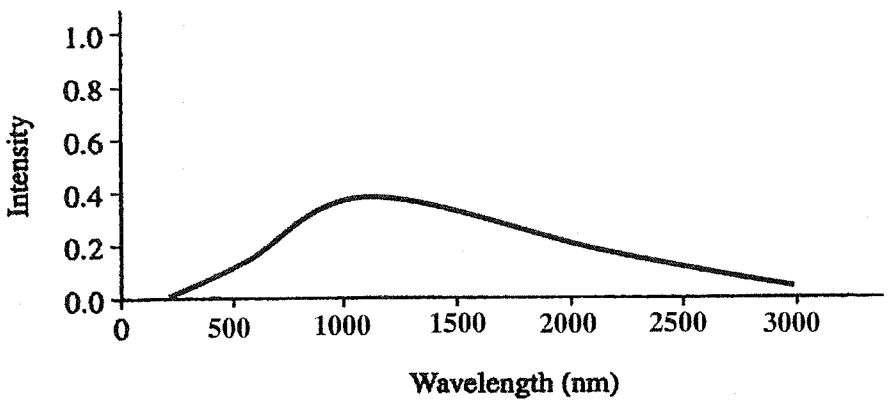
11 Red light from a laser was tested in a laboratory and found to have a wavelength of 635 nm. What is the energy of an individual photon of this light?

(A) 1.04×10^{-36} J
(B) 1.04×10^{-27} J
(C) 3.13×10^{-28} J
(D) 3.13×10^{-19} J

12 In the context of experiments conducted in the nineteenth century, which of the following properties of cathode rays supports **both** the theory that cathode rays are composed of waves **and** the theory that they are particles?

(A) Cathode rays can be deflected by electric fields.
(B) Cathode rays can be deflected by magnetic fields.
(C) A metal object in the path of the cathode rays will cast a sharp shadow.
(D) Cathode rays have a definite charge to mass ratio.

13 The following graph shows intensity of light, at different wavelengths, emitted by a white-hot metal filament in a light bulb at a temperature of 2500 K.



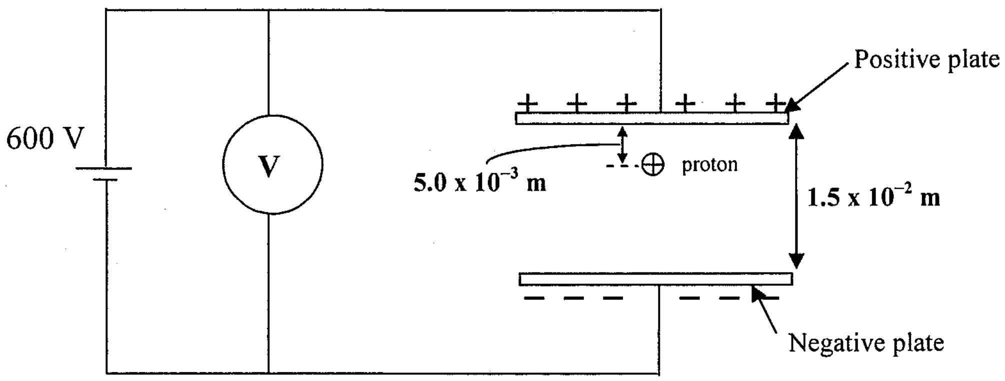
What was Planck's hypothesis to explain this intensity distribution for a black body radiator?

(A) Light emitted and absorbed by black body radiators is in the form of a wave.
(B) Light emitted and absorbed by black body radiators is quantised.
(C) Light emitted and absorbed by black body radiators is a function of the temperature.
(D) Only light above a threshold frequency can be emitted or absorbed by black body radiators.

Questions 14 and 15 refer to the following information:

The diagram below shows a proton between two parallel, charged metal plates. The potential difference between the plates is 600 V and they are 1.5×10^{-2} m apart.

The proton is at a position 5.0×10^{-3} m from the positive (top) plate. The electric charge on a proton is $+1.6 \times 10^{-19}$ C.



14 What is the force on the proton due to the electric field between the plates?

(A) 6.4×10^{-15} N
(B) 6.4×10^{-13} N
(C) 4.0×10^{2} N
(D) 4.0×10^{4} N

15 What is the potential difference between the position of the proton and the negative plate?

(A) 600 V
(B) 400 V
(C) 200 V
(D) 100 V

Class

Candidate Number

Part B

Total marks - 60
Attempt Questions 16 - 28
Allow about 1 hour and 45 minutes for this Part

Answer the questions in the spaces provided
Show all relevant working in questions involving calculations

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Marks

Question 16 (2 marks)

The modern definition of the metre is "the distance travelled by light in a vacuum during 1/299,792,458 of a second." **2**

Explain why the modern metre is defined in this way.

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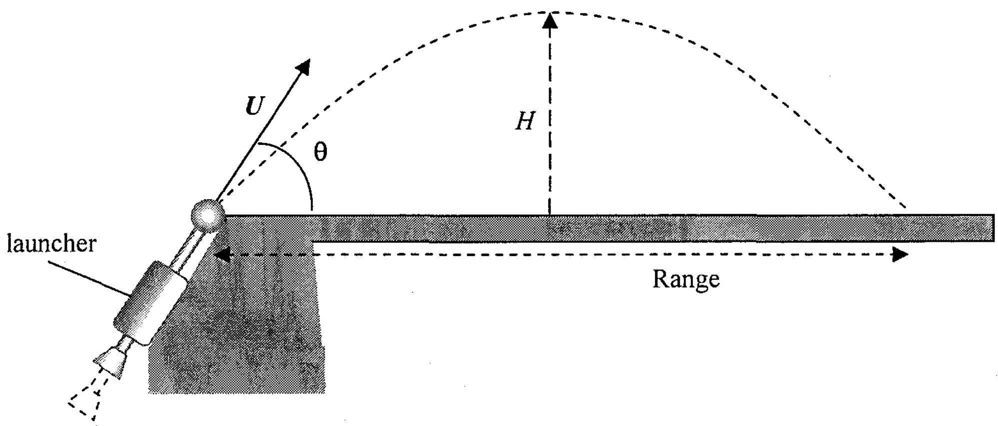
Class

Candidate Number

Marks

Question 17 (6 marks)

A boy performs an experiment with the simple projectile launcher shown below, which launches steel balls a short distance.



By pulling the spring in the launcher to a fixed distance, the boy gives the ball an initial velocity.

In one test run of the launcher, the boy makes a number of observations about the trajectory of the ball. These are shown in the table below as Test Run A.

Result Table Test Run A

Angle of Launch, θ	30^{o}
Maximum Height, H	0.26 m
Range of Ball	1.80 m

This question continues on the next page.

Class

Candidate Number

Question 17 (cont) **Marks**

(a) For Test Run A, calculate the magnitude of the initial vertical velocity of the ball. **2**

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(b) For Test Run A, calculate the total time the ball is in the air. **2**

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(c) For Test Run A, calculate the magnitude of the initial horizontal velocity of the ball. **2**

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Class

Candidate Number

Marks

Question 18 (6 marks)

The following information was included in a NASA press release of June 13th, 2005:

> **Astronomers Announce the Most Earth-Like Planet Yet Found Outside the Solar System**
>
> Taking a major step forward in the search for Earth-like planets beyond our own solar system, a team of astronomers has announced the discovery of the smallest extra-solar planet yet detected. "We keep pushing the limits of what we can detect, and we're getting closer and closer to finding Earths," said team member Steven Vogt, a professor of astronomy and astrophysics at the University of California, Santa Cruz.
>
> The newly discovered "super-Earth" orbits the star Gliese 876, located just 15 light years away in the direction of the constellation Aquarius. The team measured the mass of the planet to be 5.9 Earth masses, and its radius to be 2.2 times that of the Earth. It orbits Gliese 876 with a period of 1.94 days at a distance of 3.15×10^9 m.

Use the information contained in the passage above to answer the following questions:

(a) Calculate the acceleration due to gravity at the surface of the planet. **2**

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(b) Compare the escape velocity of the planet to that of the Earth. **2**

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This question continues on the next page

Class

Candidate Number

Question 18 (cont) **Marks**

(c) Calculate the mass of the star, Gliese 876. **2**

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Class

Candidate Number

Marks

Question 19 (6 marks)

The Michelson-Morley experiment attempted to measure the velocity of the Earth through the aether. Evaluate the significance of this experiment to the aether model of light. **6**

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Class

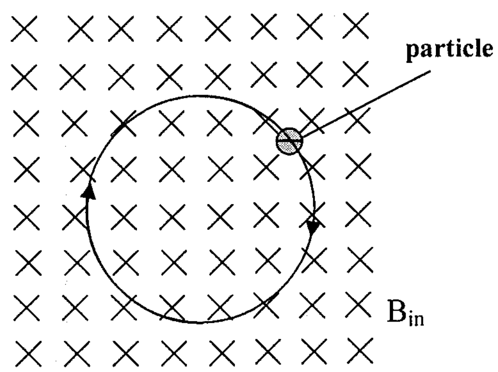
Candidate Number

Section I – Part B (continued)

Marks

Question 20 (4 marks)

The diagram below illustrates the path of a negatively charged particle moving in a magnetic field. The magnetic field is directed into the page.



(a) Explain why the path of the particle is circular. **2**

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(b) Describe the change to the radius of the path if a negatively charged particle of the same mass and speed but twice the charge is travelling in the same magnetic field. **2**

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Class

Candidate Number

Marks

Question 21 (4 marks)

Compare and contrast the structure and function of a simple AC electric **generator** with that of a DC electric **motor**. **4**

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Question 22 (3 marks)

An electricity transmission line consists of two wires separated by 4.0 metres and the towers supporting the wires are 200 metres apart. Each wire is carrying a current of 1.78×10^2 A. The currents are flowing in opposite directions.

Determine the magnitude and direction of the force per metre exerted by each current on the other. **3**

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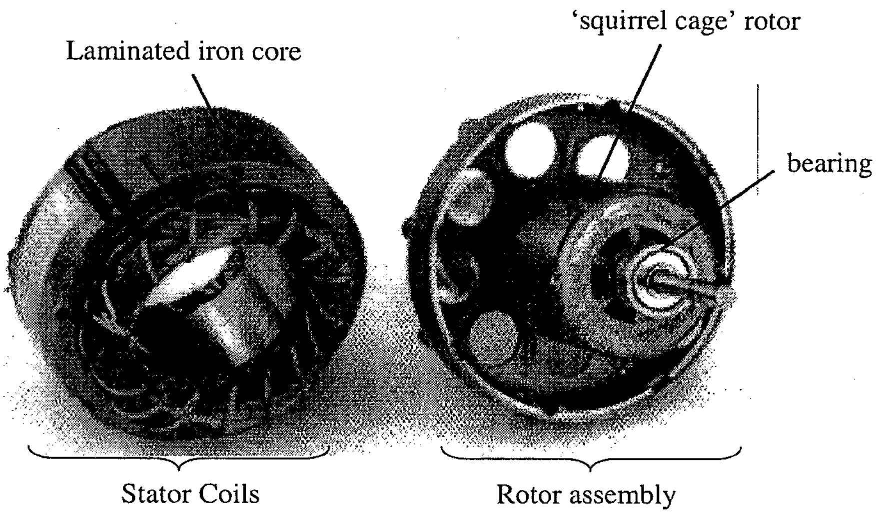
Class

Candidate Number

Marks

Question 23 (4 marks)

The photograph below shows the parts of an AC electric motor.



(a) Outline the function of the stator coils in this motor. **1**

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(b) Describe the principle of operation of the type of motor illlustrated above. **3**

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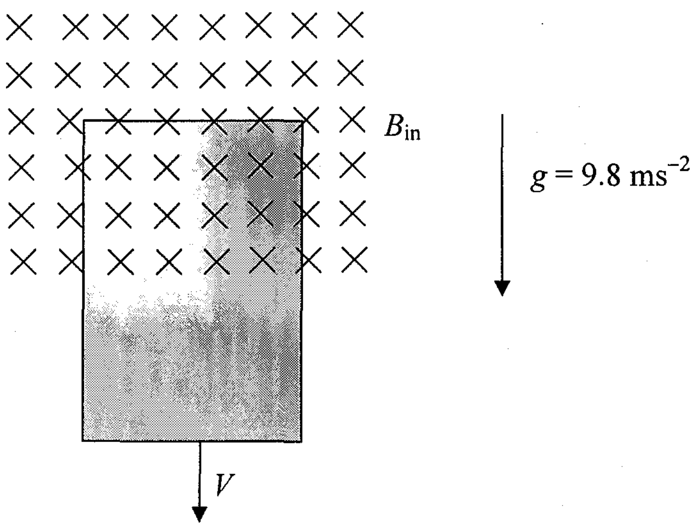
Class

Candidate Number

Marks

Question 24 (5 marks)

The following diagram shows an aluminium sheet dropping, under the influence of gravity, between the poles of a strong permanent magnet. At the position shown, the sheet has an instantaneous velocity, *V*, and is dropping out of the field. Only the top half of the sheet remains between the poles of the magnet.



(a) On the diagram above, draw in the eddy current that is generated in the sheet, showing both the position and the direction of the current. **2**

(b) Explain, in terms of the physical principles involved, the effect of the eddy current on the subsequent motion of the sheet. **3**

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Class

Candidate Number

Section I – Part B (continued)

Question 25 (3 marks)

Marks

Heinrich Hertz performed an experiment to measure the speed of radio waves using the principle of interference of waves produced by a reflection from a metal plate. Discuss the significance of the result of this experiment. **3**

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Class

Candidate Number

Marks

Question 26 (4 marks)

In the early nineteenth century, it was experimentally shown that light had wave properties such as interference and diffraction. However, this classical wave model of light could not be used to explain the observations made in experiments on the photoelectric effect. Use Einstein's reconceptualisation of the model of light to explain ONE observation made during photoelectric experiments. **4**

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Class

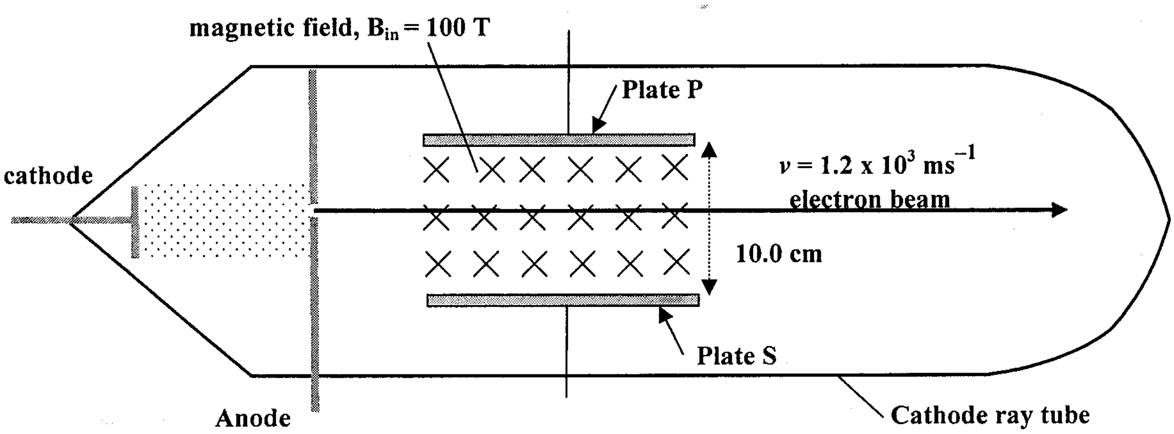
Candidate Number

Marks

Question 27 (6 marks)

The diagram below shows a thin beam of electrons in a cathode ray tube. The electrons are moving at a velocity, $v = 1.2 \times 10^3$ ms^{-1} into a region of magnetic field between two electrically charged deflector plates (P and S). Due to the combined effect of the electric and magnetic fields between plates P and S, the electrons pass undeflected between the plates.

The magnetic field has a magnitude of 100 T.



(a) Determine the magnitude and direction of the force on a single electron due to the magnetic field only. **2**

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This question continues on the next page

Class

Candidate Number

Marks

Question 27 (cont)

(b) Determine the magnitude and direction of the force on each electron due to the electric field. Show working or explain your answer. **2**

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(c) Derive an equation for the velocity of an electron between the deflector plates when the magnetic and electric forces are in balance. **2**

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Class

Candidate Number

Marks

Question 28 (7 marks)

Explain how energy savings are currently made during the generation and transmission of electricity through the power grid and assess the possible use of superconductors in these applications. **7**

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Section II

25 marks
Attempt Question 34 only from Questions 31 - 35
Allow about 45 minutes for this section.

Answer the question in a writing booklet. Extra writing booklets are available.
Show all relevant working in questions involving calculations.

Marks

Question 34 - From Quanta to Quarks (25 marks)

(a) Identify a radio-isotope commonly used in industry and outline how it is used. **2**

(b) Two of Bohr's postulates, relating to the behaviour of electrons in the hydrogen atom, have been stated as follows:

- *Electrons can revolve around the nucleus in certain stable orbits without radiating energy or falling toward the nucleus despite having opposite charges to the nucleus.*
- *An electron in a stable orbit has an angular momentum that is an integer multiple of* $\frac{h}{2\pi}$

From these postulates Bohr determined that the total energy, E_n, of an electron in a stable orbit is:

$$E_n = -\left\{\frac{2\pi^2 k^2 e^4 m_e}{h^2}\right\}\frac{1}{n^2} \qquad \text{OR} \qquad E_n = \frac{E_1}{n^2}$$

Where:

- E_1 = the magnitude of the first energy state.
- n = 1, 2, 3, 4, ...(an integer indicating the principle quantum state).
- k = Coulomb's constant.
- e = the charge on the electron.
- m_e = the mass of the electron.
- h = Planck's constant.

Question 34 continues on the next page

Question 34 continued **Marks**

(i) State one other postulate of the Bohr model and use it to account for the change in energy that occurs when an electron makes a transition from one stable orbit to another. **2**

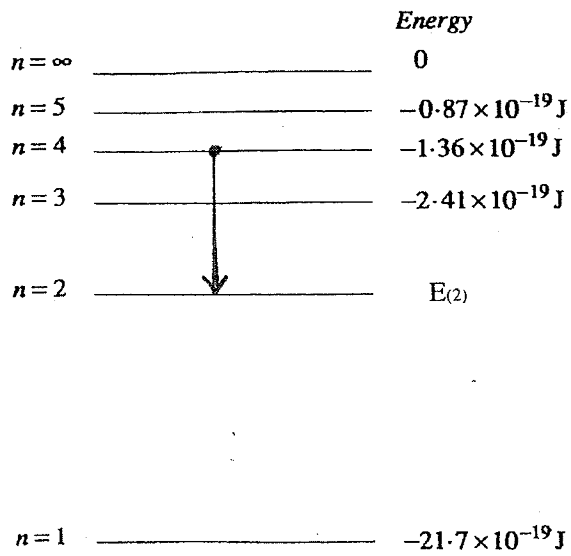
(ii) Beginning with the energy equation stated on the previous page, describe how Bohr's postulates led to a mathematical model that accounted for the existence of the Balmer series of the hydrogen spectrum and the empirical equation:- **7**

$$\frac{1}{\lambda} = R_H \left\{ \frac{1}{2^2} - \frac{1}{n^2} \right\}$$

Where:

- R_H = Rydberg's constant
- $n = 3, 4, 5, 6$

(c) The diagram below shows some of the energy levels for the electron in the hydrogen atom:-



The arrow shows a transition when an electron moves from the energy level n = 4 to energy level n = 2.

Question 34 continues on the next page

Question 34 continued **Marks**

(i) An electron is found to emit light during the transition from energy level n = 4 to energy level n = 2. This light has a wavelength of 486 nm. Calculate the frequency of the light emitted. **1**

(ii) Calculate the energy, $E_{(2)}$, in joules, of energy level n = 2. **2**

(d) (i) Calculate the de Broglie wavelength of an electron travelling at a velocity of 8.56×10^3 ms^{-1}. **2**

(ii) Describe the confirmation of de Broglie's proposal by Davisson and Germer. **3**

(e) Assess the contributions made by Heisenberg and Pauli to the development of atomic theory. **6**

END OF PAPER

Physics

Data Sheet

Charge on the electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Radius of Earth, R_E	6.4×10^6 m
Speed of light, c	3.00×10^8 m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2.0×10^{-7} N A^{-2}
Universal gravitational constant, G	6.7×10^{-11} N m^2 kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck's constant, h	6.626×10^{-34} J s
Rydberg's constant, R (hydrogen)	1.097×10^7 m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^3 kg m^{-3}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}

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FORMULAE SHEET

$$v = f\lambda$$

$$I \propto \frac{1}{d^2}$$

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$

$$E = \frac{F}{q}$$

$$R = \frac{V}{I}$$

$$P = VI$$

$$Energy = VIt$$

$$v_{av} = \frac{\Delta r}{\Delta t}$$

$$a_{av} = \frac{\Delta v}{\Delta t} = \frac{v-u}{t}$$

$$\sum F = ma$$

$$F = \frac{mv^2}{r}$$

$$E_k = \frac{1}{2}mv^2$$

$$W = Fs$$

$$p = mv$$

$$Impulse = Ft$$

$$E_p = -\frac{Gm_1m_2}{r}$$

$$F = mg$$

$$v_x^2 = u_x^2$$

$$v = u + at$$

$$v_y^2 = u_y^2 + 2a_y\Delta y$$

$$\Delta x = u_x t$$

$$\Delta y = u_y t + \frac{1}{2}a_y t^2$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$F = \frac{Gm_1m_2}{d^2}$$

$$E = mc^2$$

$$l_v = l_0\sqrt{1-\frac{v^2}{c^2}}$$

$$t_v = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$m_v = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

FORMULAE SHEET

$$\frac{F}{l} = k\frac{I_1 I_2}{d}$$

$$F = BIl\sin\theta$$

$$\tau = Fd$$

$$\tau = nBIA\cos\theta$$

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

$$d = \frac{1}{P}$$

$$M = m - 5\log\left(\frac{d}{10}\right)$$

$$\frac{I_A}{I_B} = 100^{\frac{(m_B - m_A)}{5}}$$

$$m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$$

$$F = qvB\sin\theta$$

$$E = \frac{V}{d}$$

$$E = hf$$

$$c = f\lambda$$

$$Z = \rho v$$

$$\frac{I_r}{I_0} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

$$\lambda = \frac{h}{mv}$$

$$A_0 = \frac{V_{out}}{V_{in}}$$

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79	
	Au	Symbol of element
Atomic Weight	197.0	
	Gold	Name of element

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Ununbium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [146.9] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinides

89 Ac [227.0] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237.0] Neptunium	94 Pu [239.1] Plutonium	95 Am [241.1] Americium	96 Cm [244.1] Curium	97 Bk [249.1] Berkelium	98 Cf [252.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium

Where the atomic weight is not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.
The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.

SYDNEY GRAMMAR SCHOOL

CRIB

2006
FORM VI
TRIAL HSC EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using blue or black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper
- Write your candidate number at the top of each page in Part B
- Hand in the paper in ONE bundle at the end of the exam.

Check List
Each candidate must have
- Question paper
- Multiple choice answer sheet
- Five-page booklet

Total marks (100)

Section I Pages 2 - 24

(75 marks)

This section has two parts, Part A and Part B

Part A – 15 marks
- Attempt questions 1 - 15
- Allow about 30 minutes for this part

Part B – 60 marks
- Attempt Questions 16 - 28
- Allow about 1 hour and 45 minutes for this part

Section II Pages 25 – 28

(25 marks)
- Use a separate writing booklet
- Attempt Question 34 only.
- Allow about 45 minutes for this section

Masters

AAH – Dr A. Haines
AGY – Mr A. Yabsley
AWW – Mr A. Woolnough
SRW – Mr S. Williams
MRW – Dr M. Ward

SGS Answers 2006

Part A

Total marks (15 marks)
Attempt Questions 1-15
Allow about 30 minutes for this Part

1. D
2. B
3. A
4. C
5. A
6. D
7. C
8. A
9. D
10. B
11. D
12. C
13. B
14. A
15. B

Class

Candidate Number

Part B
Total marks - 60
Attempt Questions 16 - 28
Allow about 1 hour and 45 minutes for this Part

Answer the questions in the spaces provided
Show all relevant working in questions involving calculations

---

Marks

Question 16 (2 marks)

The modern definition of the metre is "the distance travelled by light in a vacuum during 1/299,792,458 of a second." **2**

Explain why the modern metre is defined in this way.

The speed of light is constant for all observers... 1

so this definition ensures that the metre is a universally consistent length. 1

NB general comments about 'accuracy' → max 1 mk

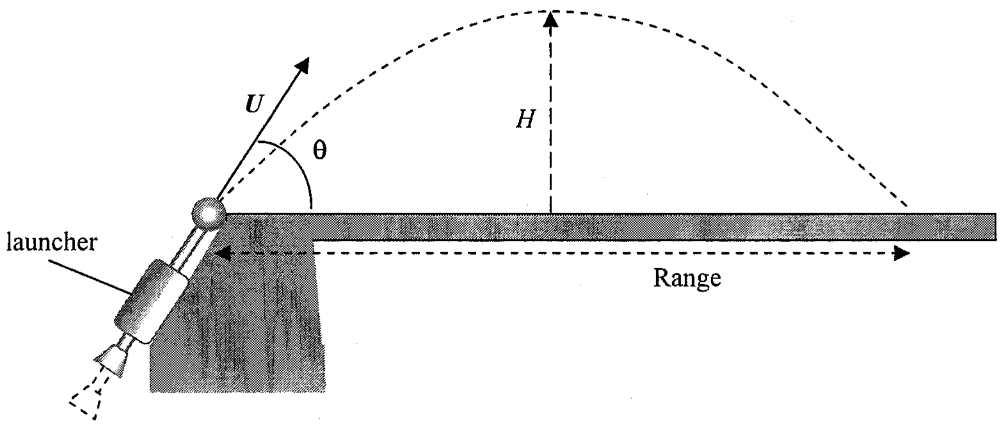
Class

Candidate Number

Marks

Question 17 (6 marks)

A boy performs an experiment with the simple projectile launcher shown below, which launches steel balls a short distance.



By pulling the spring in the launcher to a fixed distance, the boy gives the ball an initial velocity.
In one test run of the launcher, the boy makes a number of observations about the trajectory of the ball. These are shown in the table below as Test Run A.

Result Table Test Run A

Angle of Launch, θ	30^{o}
Maximum Height, H	0.26 m
Range of Ball	1.80 m

This question continues on the next page.

Class

Candidate Number

Question 17 (cont) **Marks**

(a) For Test Run A, calculate the magnitude of the initial vertical velocity of the ball. **2**

$u_v = ?\quad a_v = -g\quad r_v = 0.26m\quad v_v = 0$

use $v^2 = u^2 + 2ar$

$0^2 = u_v^2 - 19.6x0.26$ *(1 mark)*

$u_v^2 = 5.096\ \therefore\ u_v = 2.3ms^{-1}$ *(1 mark)*

(b) For Test Run A, calculate the total time the ball is in the air. **2**

$u_v = 2.257ms^{-1}\quad v_v = -2.257ms^{-1}\quad a_v = -g$

use $t = \frac{v-u}{a}$

$t = \frac{-2x2.257}{-9.8}$ *(1 mark)*

$t = 0.46s$ *(1 mark)*

(c) For Test Run A, calculate the magnitude of the initial horizontal velocity of the ball. **2**

$Range = U_H\ x\ t$

$\therefore U_H = Range/t = 1.80/0.46$ *(1 mark)*

$=U_H = 3.9ms^{-1}$ *(1 mark)*

Class

Candidate Number

Marks

Question 18 (6 marks)

The following information was included in a NASA press release of June 13th, 2005:

> **Astronomers Announce the Most Earth-Like Planet Yet Found Outside the Solar System**
>
> Taking a major step forward in the search for Earth-like planets beyond our own solar system, a team of astronomers has announced the discovery of the smallest extra-solar planet yet detected. "We keep pushing the limits of what we can detect, and we're getting closer and closer to finding Earths," said team member Steven Vogt, a professor of astronomy and astrophysics at the University of California, Santa Cruz.
>
> The newly discovered "super-Earth" orbits the star Gliese 876, located just 15 light years away in the direction of the constellation Aquarius. The team measured the mass of the planet to be 5.9 Earth masses, and its radius to be 2.2 times that of the Earth. It orbits Gliese 876 with a period of 1.94 days at a distance of 3.15 x 10^9 m.

Use the information contained in the passage above to answer the following questions:

(a) Calculate the acceleration due to gravity at the surface of the planet. **2**

$$A = G.M/r^2 = \frac{(6.67\text{x}10^{-11}) \text{ x } 5.9 \text{ x } (6.0\text{x}10^{24})}{(2.2 \text{ x } 6.4\text{x}10^6)^2}$$ (1 mark)

$= 11.9ms^{-2}$ *(1 mark)*

(b) Compare the escape velocity of the planet to that of the Earth. **2**

$$V_E = \sqrt{\frac{2GM_E}{r_E}} \qquad V_P = \sqrt{\frac{2G.5.9.M_E}{r_E}}$$ *(1 mark)*

$$\therefore\ V_P = \sqrt{\frac{5.9}{2.2}}\,V_E \quad \therefore\ V_P = 1.64V_E$$ *(1 mark)*

This question continues on the next page

Class

Candidate Number

Question 18 (cont) **Marks**

(c) Calculate the mass of the star, Gliese 876. **2**

$$\frac{r^3}{T^2} = \frac{G.M}{4\pi^2}$$

$$\therefore M = \frac{4\pi 2r3}{GT^2}$$

$M = 4 \text{ x } \pi^2 \text{ x } (3.15\text{x}10^9)^3$ *(1 mark)*

$M = 6.6\text{x}10^{29}\text{kg}$ *(1 mark)*

Class

Candidate Number

Marks

Question 19 (6 marks)

The Michelson-Morley experiment attempted to measure the velocity of the Earth through the aether. Evaluate the significance of this experiment to the aether model of light. **6**

5-6 marks were awarded for answers that addressed all of the following points:

- **An outline of the aether model of light.** **L**
- **The aim (or likely outcome) of the MM expt in terms of the aether model.** **A**
- **A brief description of the MM expt.** **D**
- **The outcome of the MM expt.** **O**
- **The subsequent interpretation of the Null result.** **I**
- **An explicit evaluation of the significance of the experiment.** **E**
- **Expressed in appropriate and precise physical terminology.** **T**

Class

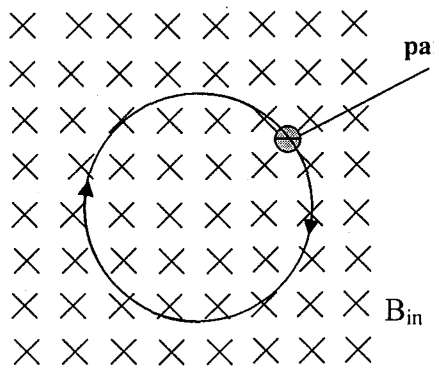
Candidate Number

Section I – Part B (continued)

Marks

Question 20 (4 marks)

The diagram below illustrates the path of a negatively charged particle moving in a magnetic field. The magnetic field is directed into the page.



(a) Explain why the path of the particle is circular. **2**

velocity is perpendicular to force (or acceleration) (1 mark)

force is directed towards the centre and provides a centripetal force (1 mark)

(b) Describe the change to the radius of the path if a negatively charged particle of the same mass and speed but twice the charge is travelling in the same magnetic field. **2**

$r = mv/qB \therefore r \propto 1/q$

$\therefore$ *if q doubled, then r decreased to r/2*

Class

Candidate Number

Marks

Question 21 (4 marks)

Compare and contrast the structure and function of a simple AC electric **generator** with that of a DC electric **motor**. **4**

FD = function difference

AC generator : mechanical energy → electrical energy
DC motor : electrical energy → mechanical energy
} *must have both for 1 mark*

SS = same structure

Both have $\vec{B}$ field, rotating armature (coil) (1 mark)

SD = different structure

split ring commutator versus slip ring commutator (1 mark)

1 mark for each comparison – must have similarities and differences (at least one of each)

Question 22 (3 marks)

An electricity transmission line consists of two wires separated by 4.0 metres and the towers supporting the wires are 200 metres apart. Each wire is carrying a current of 1.78×10^2 A. The currents are flowing in opposite directions.

Determine the magnitude and direction of the force per metre exerted by each current on the other. **3**

$F/l = KI_1I_2/d$

$= \dfrac{2\times10^{-7} \times 1.78\times10^{2} \times 1.78\times10^{2}}{4}$ *1 mark for correct substitution into correct formula*

$= 1.58\times10^{-3}\,Nm^{-1}$ *repulsion (1mark for answer and 1 mark for repulsion)*

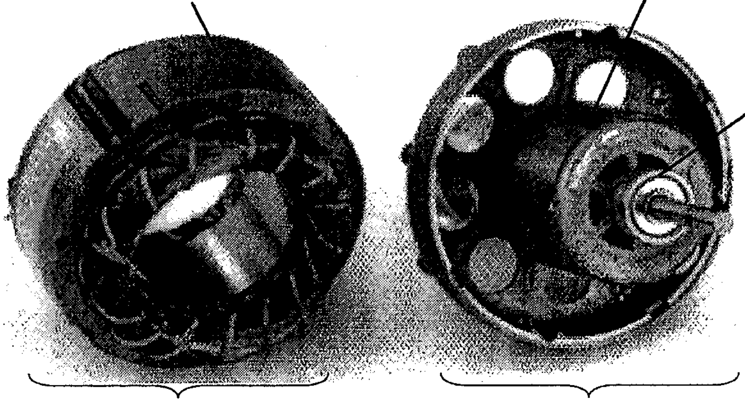
Class

Candidate Number

Marks

Question 23 (4 marks)

The photograph below shows the parts of an AC electric motor.



(a) Outline the function of the stator coils in this motor. **1**

Produces a (rotating) magnetic field

(b) Describe the principle of operation of the type of motor illlustrated above. **3**

$\Delta\varnothing$ = changing/rotating magnetic field of stator induces eddy currents within the rotor (i.e. need to mention ΔB or $\Delta\varnothing$ in stator induces I in the rotor. (1 mark)

F = current (I) in rotor experiences a force due to the motor effect. (1 mark)

D = direction of rotor's rotation same as the magnetic field rotation of the stator (1 mark)

Class

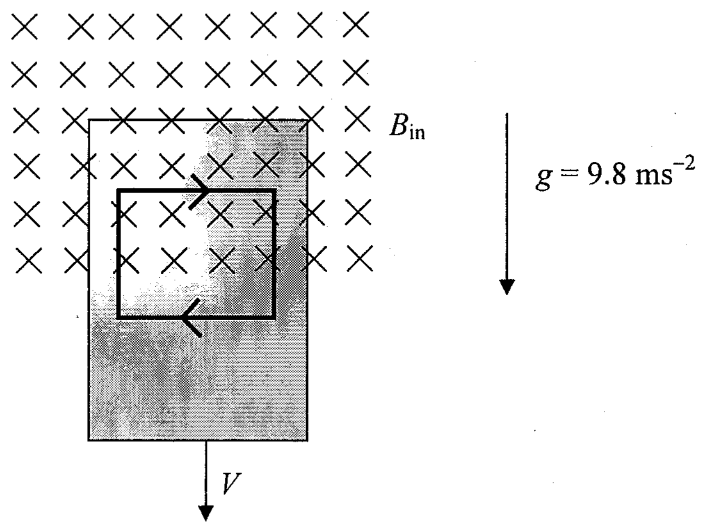
Candidate Number

Marks

Question 24 (5 marks)

The following diagram shows an aluminium sheet dropping, under the influence of gravity, between the poles of a strong permanent magnet. At the position shown, the sheet has an instantaneous velocity, *V,* and is dropping out of the field. Only the top half of the sheet remains between the poles of the magnet.

loop must be in filed and outside field



(a) On the diagram above, draw in the eddy current that is generated in the sheet, showing both the position and the direction of the current. **2**

Eddy current loop on metal in field and outside field (1 mark)
Direction of induced current correct (1 mark)

(b) Explain, in terms of the physical principles involved, the effect of the eddy current on the subsequent motion of the sheet. **3**

F = eddy current causes an upward force on the aluminium shed (1 mark)

L = statement of Lenz's Law i.e. direction of the eddy current produces a magnetic field that interacts with the external field so as to oppose the charge (1 mark)

M = description of motion i.e. upward force reduces the acceleration (<9.8ms^{-2}) or slows the velocity of the sheet (1 mark)

Class

Candidate Number

Section I – Part B (continued)

Question 25 (3 marks)

Marks

Heinrich Hertz performed an experiment to measure the speed of radio waves using the principle of interference of waves produced by a reflection from a metal plate. Discuss the significance of the result of this experiment. **3**

radio waves travel at c (1 mark)

light travels at c, radio waves are e/m (1 mark)

$\therefore$ *light is e/m (1 mark)*

Class

Candidate Number

Marks

Question 26 (4 marks)

In the early nineteenth century, it was experimentally shown that light had wave properties such as interference and diffraction. However, this classical wave model of light could not be used to explain the observations made in experiments on the photoelectric effect. Use Einstein's reconceptualisation of the model of light to explain ONE observation made during photoelectric experiments. 4

Observations:

- *Threshold frequency*
- $\mathcal{E}_K$ *of photoelectrons independent of intensity*
- *photo current* α *intensity*
- *slope of graph is "h"*

2 marks for well described observation

1 mark for poor description of correct observation or general photoelectric idea only

Einstein:

Light is photons of energy $\mathcal{E} = hf$

"all or nothing rule" i.e. photon enrgy must be > work function

$\mathcal{E} = hf - hf_o$

Photons collide with electrons on metal surface and displace them if sufficient energy.

1 mark for Einstein's photons

1 mark for how it explained observations. i.e. all or nothing

Class

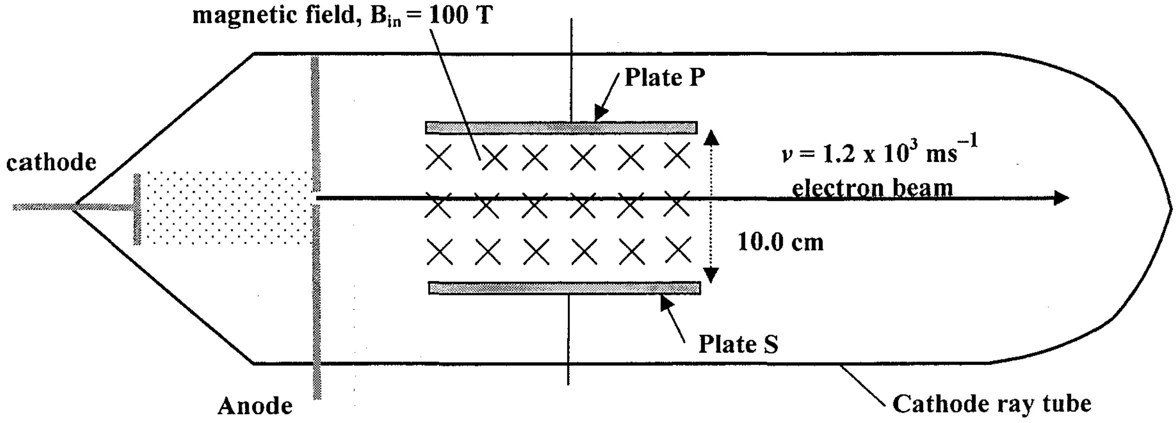
Candidate Number

Marks

Question 27 (6 marks)

The diagram below shows a thin beam of electrons in a cathode ray tube. The electrons are moving at a velocity, $v = 1.2 \times 10^3\ ms^{-1}$ into a region of magnetic field between two electrically charged deflector plates (P and S). Due to the combined effect of the electric and magnetic fields between plates P and S, the electrons pass undeflected between the plates.

The magnetic field has a magnitude of 100 T.



(a) Determine the magnitude and direction of the force on a single electron due to the magnetic field only. **2**

$v = 1.2x10^3 ms^{-1}$, $B = 100T$, $q = 1.6x10^{-19}C$

$F = Bqv$

$F = 100 \times 1.6x10^{-19} \times 1.2x10^3$

$= 1.92x10\text{-}14N$ (1 mark) down (1 mark)

This question continues on the next page

Class

Candidate Number

Marks

Question 27 (cont)

(b) Determine the magnitude and direction of the force on each electron due to the electric field. Show working or explain your answer. **2**

$\vec{F}_B + \vec{F}_E = 0$

$\therefore \vec{F}_B = -\vec{F}_E$

i.e. 1.92×10^{-14} *N Up (1 mark)*

(c) Derive an equation for the velocity of an electron between the deflector plates when the magnetic and electric forces are in balance. **2**

$\left|\vec{F}_E\right| = \left|\vec{F}_B\right|$

$\therefore \vec{E}q = \vec{B}qv$

$\therefore v = \vec{E} / \vec{B}$

Class

Candidate Number

Marks

Question 28 (7 marks)

Explain how energy savings are currently made during the generation and transmission of electricity through the power grid and assess the possible use of superconductors in these applications. **7**

3 for current savings

e.g. high voltage ∴ low current

reduce ohmic heating

AC is more efficient

laminations of cores in transformers

4 for superconductors

1 each for two advantages/features

1 each for two disadvantages

Note: max of 5 if no negatives of superconductors mentioned

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Section II

25 marks
Attempt Question 34 only from Questions 31 - 35
Allow about 45 minutes for this section.

Answer the question in a writing booklet. Extra writing booklets are available.
Show all relevant working in questions involving calculations.

Marks

Question 34 - From Quanta to Quarks (25 marks)

(a) Identify a radio-isotope commonly used in industry and outline how it is used. **2**

Typical answer

Iridium 192

Is used to inspect metal parts and welds for defects. The radiation passes through the object being inspected and an image is recorded on film.

(b) Two of Bohr's postulates, relating to the behaviour of electrons in the hydrogen atom, have been stated as follows:

- *Electrons can revolve around the nucleus in certain stable orbits without radiating energy or falling toward the nucleus despite having opposite charges to the nucleus.*
- *An electron in a stable orbit has an angular momentum that is an integer multiple of* $\frac{h}{2\pi}$

From these postulates Bohr determined that the total energy, E_n, of an electron in a stable orbit is:

$$E_n = -\left\{\frac{2\pi^2 k^2 e^4 m_e}{h^2}\right\}\frac{1}{n^2} \qquad \text{OR} \qquad E_n = \frac{E_1}{n^2}$$

Where:

- E_1 = the magnitude of the first energy state.
- n = 1, 2, 3, 4, ...(an integer indicating the principle quantum state).
- k = Coulomb's constant.
- e = the charge on the electron.
- m_e = the mass of the electron.
- h = Planck's constant.

Question 34 continues on the next page

Question 34 continued **Marks**

(i) State one other postulate of the Bohr model and use it to account for the change in energy that occurs when an electron makes a transition from one stable orbit to another. **2**

Typical answer

An atom (or electron) only emits or absorbes energy when it makes a transition from one state to another

OR

When an electron makes a transition between one state an another, the event is accompanied by the emission or absorption of a quantum of radiation (a photon).
AND
***The energy change** is equal to the difference in energy between the two states **and this energy becomes a photon** with energy:*

$$hf = E_{final} - E_{initial}$$

(ii) Beginning with the energy equation stated on the previous page, describe how Bohr's postulates led to a mathematical model that accounted for the existence of the Balmer series of the hydrogen spectrum and the empirical equation:- **7**

$$\frac{1}{\lambda} = R_H\left\{\frac{1}{2^2} - \frac{1}{n^2}\right\}$$

Where:

- R_H = Rydberg's constant
- $n = 3, 4, 5, 6$

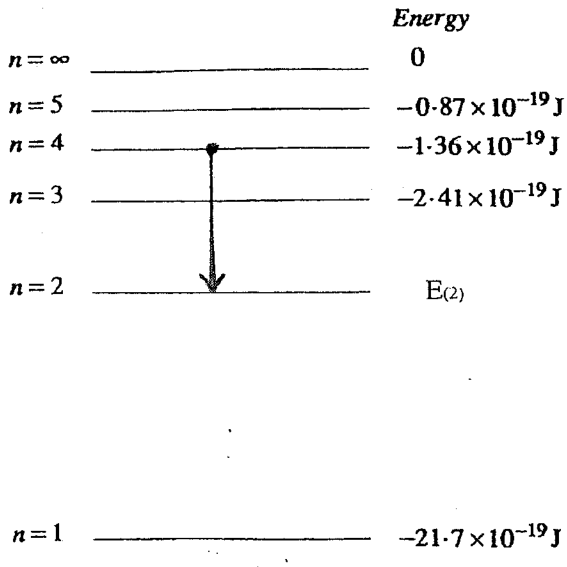
SAMPLE ANSWER

Note: more mathematical steps may be shown.

- *Bohr postulated that when an electron in the hydrogen makes a transition from a higher energy state to a lower state that radiation is emitted in the form of a photon with an energy equal to the difference between the energies of the initial and final states.*
- *Using the energy state equation given:* $E_n = \frac{E_1}{n^2}$
  the equation for the change of energy when an electron makes a transition is:
  $$\Delta E = E_1\left\{\frac{1}{n_f^2} - \frac{1}{n_i^2}\right\}$$
- *the energy change above is equal to the energy of the photon emitted during the transition, therefore:*
  $$hf = E_1\left\{\frac{1}{n_f^2} - \frac{1}{n_i^2}\right\}$$
- *Expressing the energy change in terms of wavelength*

  Since $\Delta E = hf = \frac{hc}{\lambda}$ then $\frac{1}{\lambda} = \frac{E_1}{hc}\left\{\frac{1}{n_f^2} - \frac{1}{n_i^2}\right\}$
- *Bohr equation is a mathematical model that allows for the prediction of the wavelengths in the hydrogen spectrum. Bohr's equation has the same form as the empirical equation of Balmer for the hydrogen spectrum and the value of the Rydberg constant, determined empirically, can be evaluated from the theoretical constant of the Bohr equation. The values of the constant is the same in both equations. Thus the Bohr model of energy change during electron transitions accounts for the empirical equation of Balmer.*
- *Substituting* $n_f = 2$ *and the various values of* $n_i = 3, 4, 5,$ *in the Bohr equation allows for the calculation of the wavelength of lines in the Balmer series. The predicted wavelengths calculated in this way are equal to the wavelengths measured in experiments. Thus the Bohr model of energy change during electron transitions accounts for emission lines in the Balmer series.*

(c) The diagram below shows some of the energy levels for the electron in the hydrogen atom:-



The arrow shows a transition when an electron moves from the energy level n = 4 to energy level n = 2.

(i) An electron is found to emit light during the transition from energy level n = 4 to energy level n = 2. This light has a wavelength of 486 nm. Calculate the frequency of the light emitted. **1**

$$f = \frac{c}{\lambda} \qquad f = \frac{3 \text{ x } 10^{8}}{4.86 \text{ x } 10^{-7}}$$

1

$$f = 6.17 \text{ x } 10^{14} \text{ Hz}$$

(ii) Calculate the energy, E(2), in joules, of energy level n = 2. **2**

$$\Delta E = hf \qquad \Delta E = 4.1 \text{ x } 10^{-19} \text{ J}$$

$$E_2 = \frac{E_1}{2^2} \qquad E_2 = \frac{-21.7 \text{ x } 10^{-19}}{4}$$

$$E_2 = -5.425 \text{ x } 10^{-19} \text{ J}$$

(d) (i) Calculate the de Broglie wavelength of an electron travelling at a velocity of 8.56 x 10^3 ms^{-1}. **2**

$$\lambda = \frac{h}{mv} \qquad f = \frac{6.626 \text{ x } 10^{-34}}{(9.109 \text{ x } 10^{-31})(8.56 \text{ x } 10^{3})}$$

$$\lambda = 8.5 \text{ x } 10^{-8} \text{ m}$$

(ii) Describe the confirmation of de Broglie's proposal by Davisson and Germer. **3 marks**

- *Describes an experiement involving an electron beam directed at a crystal of nickel.* 1
- *Describes the result of the experiment as an observed diffraction of electrons.* 1
- *Makes the link that diffraction is a property that is specific to waves.* 1

(e) Assess the contributions made by Heisenberg and Pauli to the development of atomic theory.

	Marking Criteria	
	Outlines two contributions made by ***Heisenberg*** *to atomic theory* *Examples are in the following list:* • *Developed matrix mechanics to apply quantum theory to the atomic model and replacing the ad hoc model of Bohr.* • *Developed the uncertainty principle that stated* $\Delta x.\Delta p = \frac{h}{2\pi}$ • *Proposed an atomic nucleus consisting of protons and neutrons*	
	Outlines two contribution made by ***Pauli*** *to atomic theory* *Examples are in the following list:* • *Proposed the exclusion principle that no two electrons in the same atoms can have the same quantum state (ie the same set of 4 quantum numbers).* • *Proposed the fourth quantum number for electron spin.* • *Derived the Balmer equation using quantum mechanics.* • *Predicted the existence to the neutrino to explain the conservation of energy and momentum in beta decay.*	
	Assesses the contributions made by ***Heisenberg*** *to atomic theory* *Examples are in the following list:* • *Quantum theory and the uncertainty principle produced a model of the atom in which the electrons exist in electron orbitals that were more in the nature of probability clouds than simple circular orbits of Bohr.* • *The uncertainty principle was consistent with the idea that electrons have a wave nature when in a quantised energy state*	
	Assesses the contributions made by ***Pauli*** *to atomic theory* *Examples are in the following list:* • *The exclusion principle explained the numbers of electrons in each quantum level of the atoms in the periodic table and explained chemical properties such as valency an group similarity of elements.* • *The four quantum numbers explained aspects of the hydrogen spectrum such as hyperfine spectral lines and Zeeman splitting due to strong magnetic fields* • *The existance of the neutrino explained the decay of a neutron into a proton and increased our knowledge of the substructure of the atom.*	