SYDNEY GRAMMAR SCHOOL

2014
FORM VI
TRIAL HSC EXAMINATION

Physics

Thursday 7th August 8.40 a.m.

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
- 2 x Five-page booklets

Total marks (100)

Section I Pages 3 - 28

(75 marks)

This section has two parts, Part A and Part B

Part A – 20 marks

- Attempt Questions 1 - 20
- Allow about 35 minutes for this part

Part B – 55 marks

- Attempt All Questions
- Allow about 1 hour and 40 minutes for this part

Section II Pages 29 – 31

(25 marks)
- Use separate writing booklets
- Attempt Question 38 only.
- Allow about 45 minutes for this section

Masters

AAH – Dr A. Haines
SRW – Mr S. Williams
MRW – Dr M. Ward
PCK – Dr P. Knight

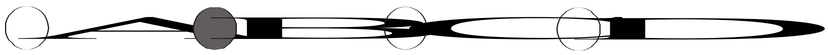
Part A
Total marks (20 marks)
Attempt Questions 1-20
Allow about 35 minutes for this Part

Use the multiple-choice Answer Sheet.

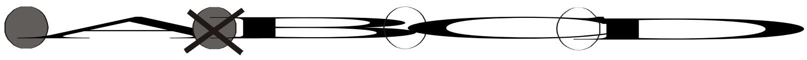
Select the alternative A, B, C or D that best answers the question. Fill the response circle completely.

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 If the mass of the Earth was doubled and its radius was also doubled then the new value for the acceleration due to gravity on Earth would be:

(A) 0.5 g

(B) g

(C) 2g

(D) 4g

2 If r_1 and T_1 represent the distance and period of Planet 1 from a star of mass M and r_2 and T_2 represent the distance and period of Planet 2 from the same star, then the quantity $\left(\frac{r_1^3}{T_1^2}\right) \times \left(\frac{T_2^2}{r_2^3}\right)$ would equal:

(A) M

(B) $GM/(4\pi^2)$

(C) 1

(D) $4\pi^2/(GM)$

3 A projectile fired at a speed of u and an angle of θ to the horizontal, reaches a maximum height of H. When the same projectile is fired again at the same angle with a new higher initial speed it reaches a new maximum height of 2H. It true to say that:

(A) the new initial speed was $2u$

(B) the new initial speed was $\sqrt{2}\,u$

(C) the new initial speed was $4\,u$

(D) the new initial speed was $u\,/2$

4 A train travelling at 0.8c passes an observer on the platform who measures the length of the train as 100m. What would a passenger on the train measure the length of the train to be?

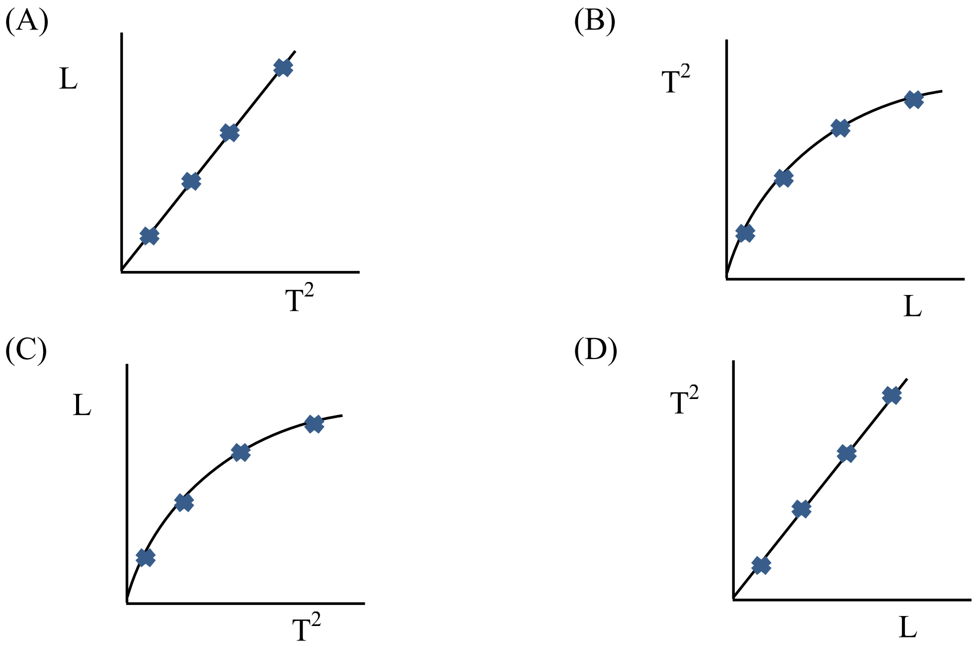
(A) 60m

(B) 100m

(C) 125m

(D) 167m

5 An experiment was performed to investigate how the Period T of a pendulum varies with its length L. Theoretically the square of the period of a pendulum is given by the formula $T^2=4\pi^2\frac{L}{g}$. If the experimental results were graphed with the independent variable on the horizontal axis, which graph best represents the relationship between the variables?



6 A satellite of mass *m* in orbit around the Earth has a velocity of *v*. The gravitational potential energy of the satellite is:

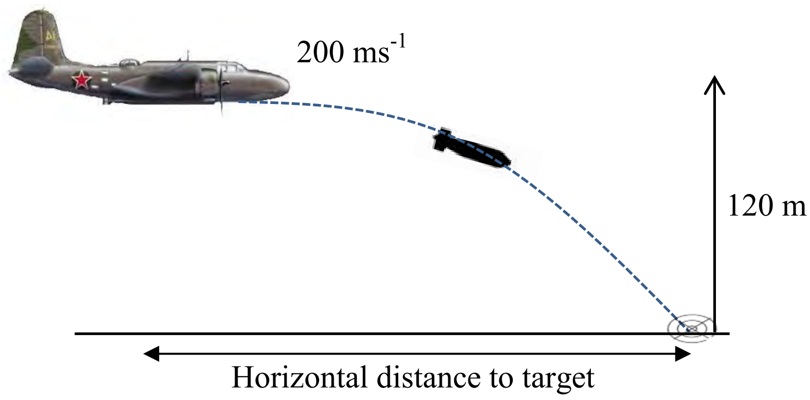
(A) $-mv^2$

(B) $-\frac{Gm}{rv}$

(C) $-\frac{Gmv}{r}$

(D) $-\frac{1}{2}mv^2$

7 A bomber is flying horizontally at $200ms^{-1}$ at an altitude of 120m. At what horizontal distance from the target does the bomber need to drop a bomb so that it hits the target?



(A) 700m

(B) 767m

(C) 990m

(D) 4898m

8 An electric motor with a constant voltage supply is used to raise a weight. If the weight is decreased the speed of rotation of the motor increases. Which of the following quantities will decrease in value?

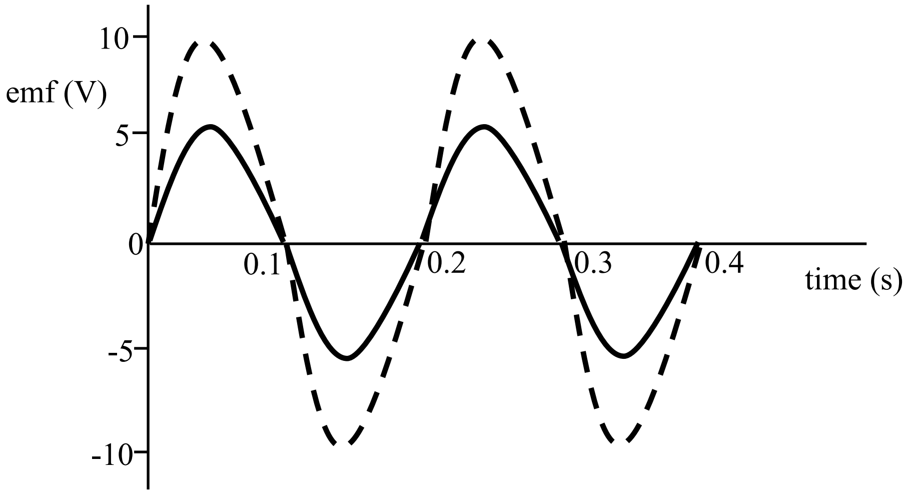
(A) Resistance of the coil

(B) Back emf induced in the coil

(C) Current in coil

(D) The rate of change of flux in the coil

9 In the graph shown, the solid curve shows how the emf produced by a simple generator varies with time. The dashed curve is the output from the same generator after a modification has been made to the generator.



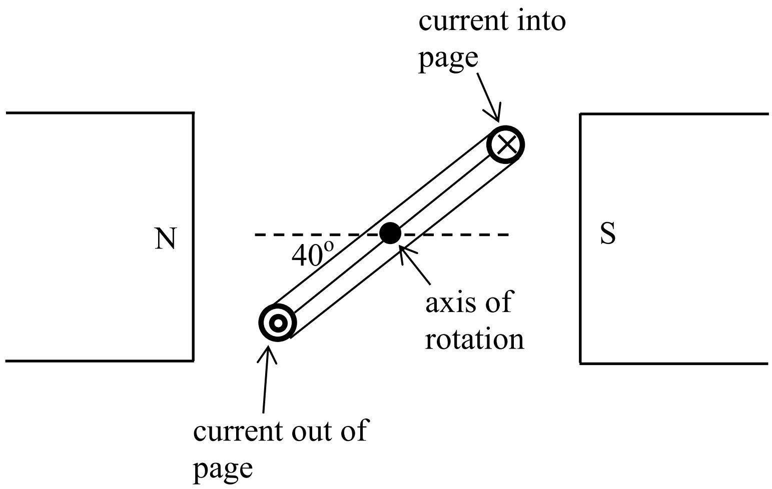
Which modification was made to produce the result shown?

(A) The speed of rotation of the coil was doubled.
(B) The number of turns in the coil was doubled.
(C) A split-ring commutator was added.
(D) The area of the coil was halved.

10 Two parallel wires have identical currents running through them. If the wires are 0.15m apart and attract each other with a force of 2.5×10^{-6} N per metre, what is the current in each wire?

(A) 0.53A
(B) 1.37 A
(C) 1.88 A
(D) 9.13 A

11 The diagram below shows a side-on view of a square coil in a simplified DC motor. The coil has sides of length 0.250 m and consists of 100 turns. The magnitude of the uniform magnetic field strength between the poles is 0.800 T.



At the instant shown, if the magnitude of the torque is 0.775 Nm, what is the current in the coil?

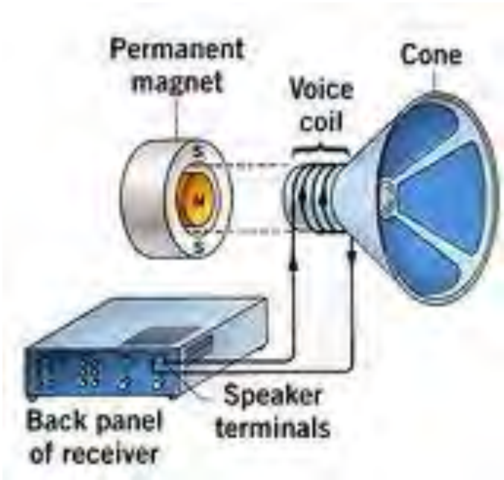
(A) 0.0603A

(B) 0.101 A

(C) 0.202 A

(D) 0.241 A

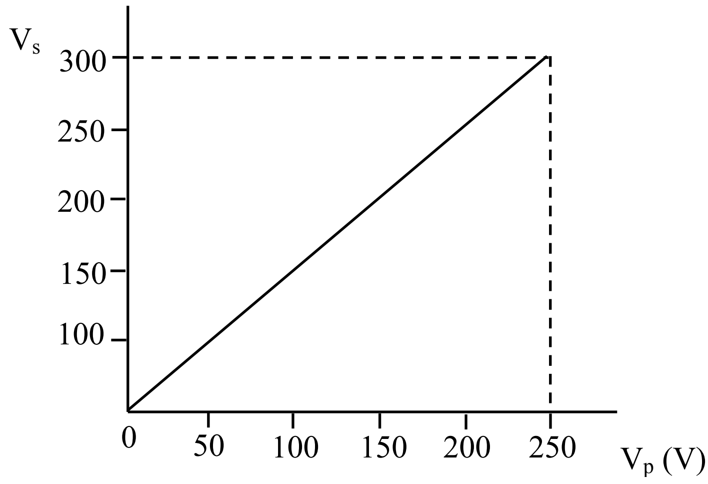
12 A diagram of a loudspeaker is shown below.



Which row in the following table shows the set of conditions that would result in the loudspeaker producing a loud high pitched sound?

	AC voltage frequency	AC voltage
(A)	Low	Low
(B)	Low	High
(C)	High	Low
(D)	High	High

13 The primary coil of an ideal transformer is connected to a voltage supply (V_p). This input voltage is varied and the corresponding voltage output in the secondary coil (V_s) is recorded. The following graph shows the results.



The number of turns in the secondary coil is 120.
What is the number of turns in the primary coil?

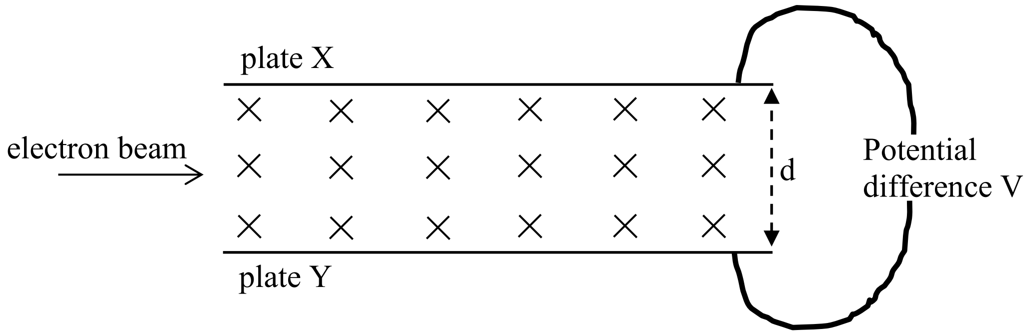
(A) 10

(B) 100

(C) 144

(D) 14400

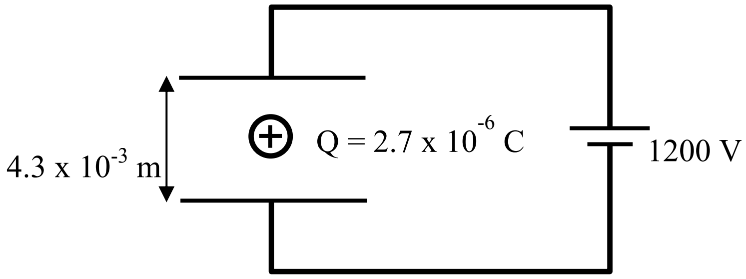
14 Two parallel horizontal plates are separated by a distance of d metres and have a potential difference of V volts maintained between them. Also present is a uniform magnetic field of B Teslas. A horizontal beam of electrons is directed between the plates so that it is moving at right angles to the magnetic field as shown below.



The electron beam passes between the plates undeflected.
Which choice below best denotes the experimental setup for this to occur?

	The speed of the electrons	Polarity of plate X with respect to plate Y
(A)	v = E/B	positive
(B)	v = B/E	positive
(C)	v = E/B	negative
(D)	v = B/E	negative

15 The diagram below shows a charged particle positioned between two charged, parallel, metal plates.



Using the information given in the diagram, determine the magnitude of the electrostatic force acting on the particle.

(A) 1.4×10^{-5} N

(B) 7.5×10^{-1} N

(C) 2.8×10^{5} N

(D) 1.9×10^{6} N

16 In the field of Quantum Physics, Max Planck is known for:

(A) mass defect and the binding energy of a nucleus.

(B) the concept of wave-particle duality.

(C) the explanation of the black-body spectrum.

(D) the first quantum mechanical model of the Hydrogen atom.

17 A certain type of infra-red laser emits radiation with a wavelength of 930 nm. What frequency does this correspond to?

(A) 2.8×10^{11} Hz

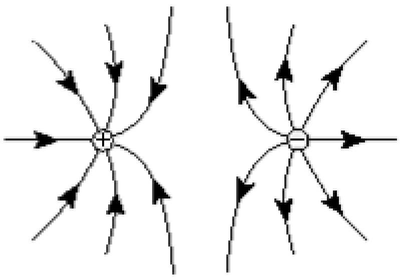
(B) 3.2×10^{14} Hz

(C) 5.8×10^{21} Hz

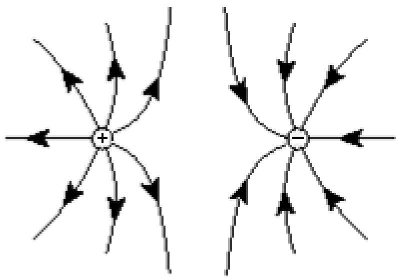
(D) 1.4×10^{27} Hz

18 Which of the diagrams below best represents the electric field around two opposite charges?

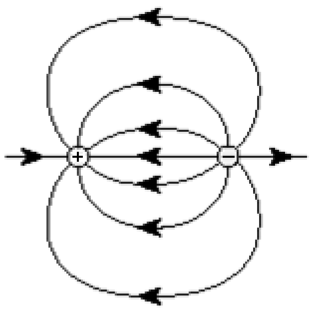
(A)



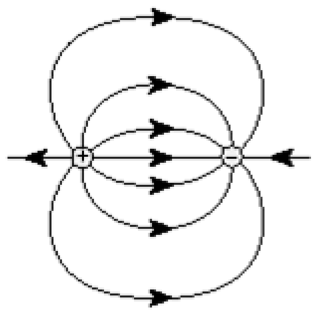
(B)



(C)



(D)



19 Consider the diagram below, which shows a striation pattern in a cathode ray tube.

What is the cause of striation patterns like this?

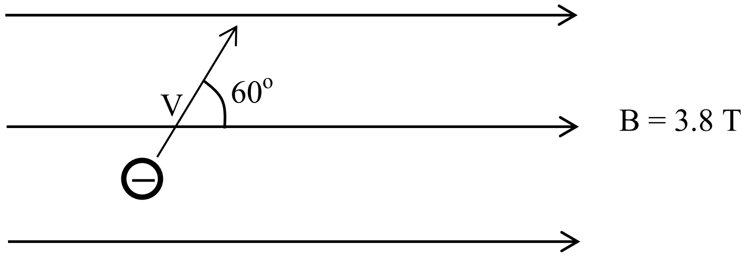
(A) High voltages across low pressure gases.

(B) The interference of radio waves.

(C) Black-body radiation.

(D) The photoelectric effect.

20 The diagram below shows an electron moving in a uniform magnetic field.



If the magnitude of the force acting on the electron is 1.4×10^{-14} N, calculate its speed.

(A) 1.2×10^4 ms^{-1}

(B) 2.3×10^4 ms^{-1}

(C) 2.7×10^4 ms^{-1}

(D) 4.6×10^4 ms^{-1}

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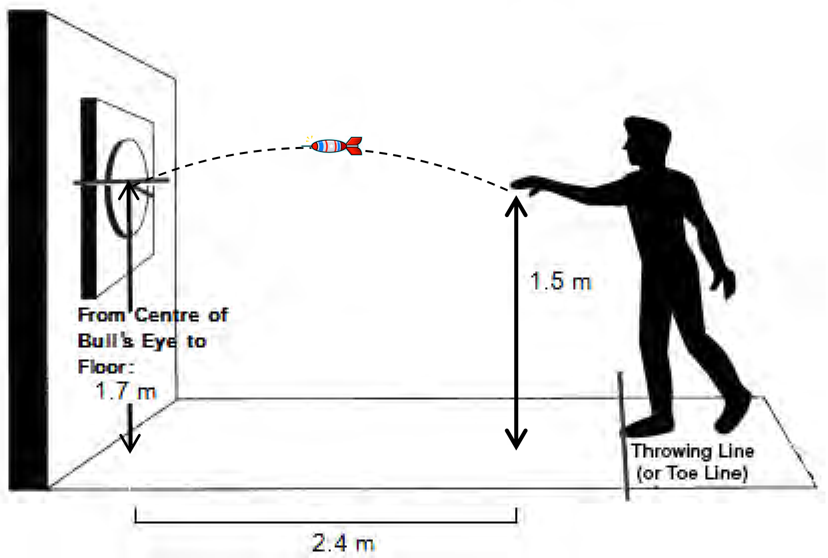
Part B
Total marks - 55
Attempt Questions 21 - 34
Allow about 1 hour and 40 minutes for this Part

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

Question 21 (4 marks) **Marks**

A dart player releases a dart 2.4 m away from the dartboard where the bullseye is 1.7 m from the ground. The player successfully hits the bullseye by throwing from a height of 1.5 m at an angle of 30° above the horizontal.

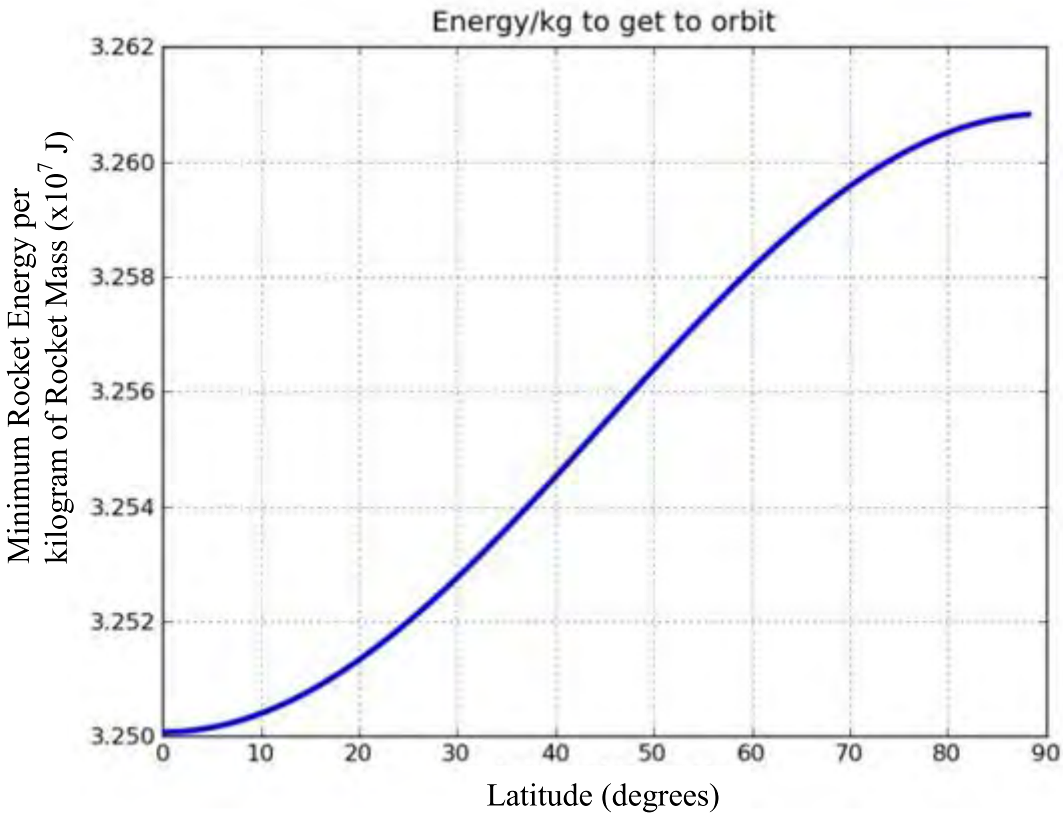


Determine the intial velocity of the dart **4**

Candidate Number:___________________________

Question 22 (2 marks) **Marks**

The graph below shows the minimum rocket energy needed per kilogram of mass to reach an orbital altitude of 250 km as a function of launch latitude on the Earth's surface.



With reference to this graph, discuss the effect of the Earth's motion on the launch of a rocket.

____ **2**

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Question 23 (4 marks) **Marks**

A projectile of mass 1150 kg is fired vertically from the surface of an asteroid of mass 1.1×10^{20} kg and radius 2.6×10^{6} m with a speed of 50 ms^{-1}.

a) Determine the initial kinetic energy of the projectile. **1**

b) Determine the initial gravitational potential energy of the projectile. **1**

c) Determine the maximum distance the projectile reaches from the centre of the asteroid. **2**

Candidate Number:____________________________

Question 24 (5 marks) **Marks**

A satellite of mass 1200 kg is in orbit around the Earth at a distance of 22000 km from the centre of the Earth.

a) Calculate the magnitude of the centripetal acceleration of the satellite at this distance. **1**

b) Determine the period of the satellite. **2**

c) Explain why the orbital velocity is independent of the mass of the satellite. **2**

Candidate Number:____________________________

Question 25 (3 marks) **Marks**

A laser mounted on the floor of a train carriage travelling at high speed fires a light pulse towards a mirror on the ceiling of the train directly above the laser.

An observer in the carriage can time how long this light pulse takes to travel from the laser, reflect from the mirror on the ceiling and then travel back to a detector at the laser source.

With the aid of a diagram and with reference to an external observer, explain how this situation demonstrates the phenomenon of time dilation.

3

Candidate Number:____________________________

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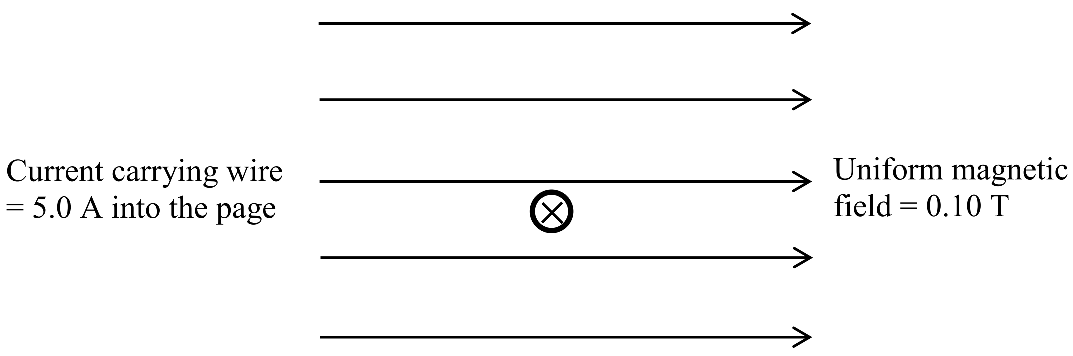
Question 26 (3 marks) **Marks**

A straight wire with a current of 5.0 A is placed in a uniform magnetic field of 0.10 T as shown in the diagram below.



Calculate the magnitude and direction of the magnetic force on a 5.0 cm length of the straight wire.

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Question 27 (2 marks)

Name one design strategy that is used to reduce heating in transformers and explain why this strategy is effective.

____ **2**

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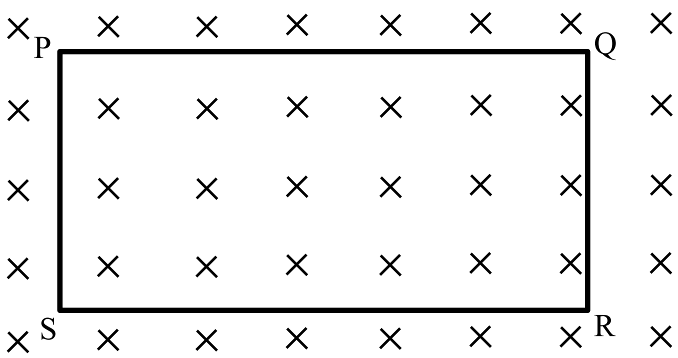
Candidate Number:____________________________

Question 28 (4 marks) **Marks**

A rectangular single turn loop of wire PQRS, with a resistance of 0.6 Ω, is placed at right angles to a uniform magnetic field of 0.15 T directed into the page. The width of the loop PS is 10 cm and the length PQ is 20 cm as shown in the following diagram.



B = 0.15 T into the page

The magnetic field is decreased uniformly to zero in 0.03s.

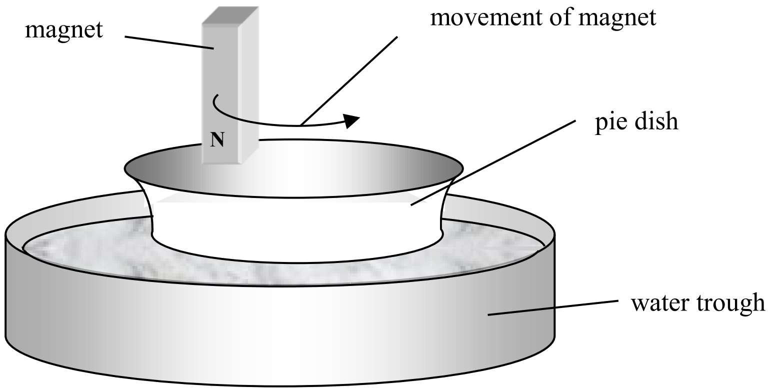
a) Calculate the magnitude of the current induced in the loop. **3**

b) On the diagram above, clearly indicate with an arrow the direction of the current induced in the loop. **1**

Candidate Number:____________________________

Question 29 (5 marks) **Marks**

A permanent magnet is moved very quickly in an anti-clockwise direction above an aluminium pie dish that is floating on water as shown in the following diagram.



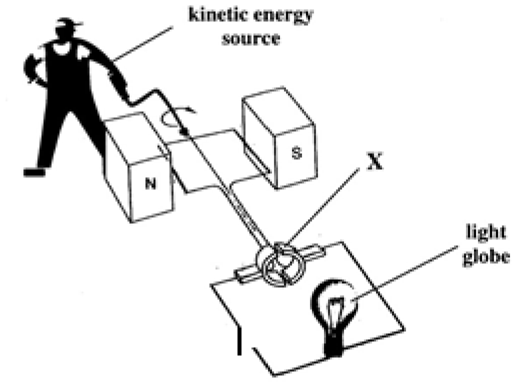
a) Explain using physical laws what happens to the pie dish when the magnet is moving above the pie dish. **4**

b) This experiment is used to demonstrate the principal of an AC induction motor. Identify the part of an AC induction motor represented by the pie dish. **1**

Candidate Number:__________________________

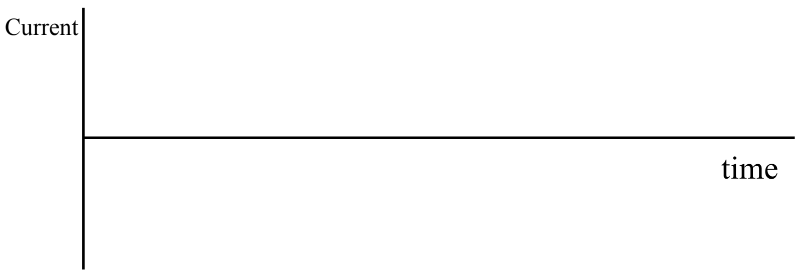
Question 30 (5 marks) **Marks**

The diagram below shows a simple generator used in a Physics practical lesson.



a) A student notices that when the switch is closed and the light globe glows, the handle becomes harder to turn than when the switch is open and the light globe is not glowing. Explain the students observations. **3**

b) This generator has a split ring/commutator to connect the rotating coil to the light globe. On the following axes, draw a graph of how the current in the light globe would change over time when the handle is rotated at a steady rate for two complete turns. Assume the coil of the generator is at the position shown in the diagram above at t = 0 s.



2

Candidate Number:___________________________

Question 31 (4 marks) **Marks**

With the aid of a diagram describe how Heinrich Hertz demonstrated that radio waves were part of the electromagnetic spectrum.

4

Candidate Number:____________________________

Question 32 (4 marks)

A cathode ray oscilloscope is a modified version of the cathode ray tube. Justify this statement, with reference to the function of a cathode ray oscilloscope and the features of a cathode ray tube.

4

Candidate Number:____________________________

Question 33 (6 marks) **Marks**

Assess the role of experiments that were conducted to determine the nature of cathode rays in the late nineteenth century. **6**

Candidate Number:______________________________

Question 34 (4 marks) **Marks**

Sodium metal has a threshold frequency of 5.50×10^{14} Hz. When low intensity blue light of frequency 7.60×10^{14} Hz is shone onto the sodium, electrons are emitted from it. However, when high intensity red light of frequency 4.30×10^{14} Hz is shone onto the metal, no electrons are emitted.

a) Calculate the *work function* of sodium. **1**

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b) Calculate the maximum kinetic energy of the electrons emitted from the sodium by the blue light above. **1**

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c) With reference to Einstein's photon model of light, explain why high intensity red light will not emit electrons from sodium, but low intensity blue light will. **2**

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Candidate Number:____________________________

Section II

25 marks

Attempt Question 38 only from Questions 35 - 39
Allow about 45 minutes for this section.

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

Candidate Number:______________________________

Question 38 - From Quanta to Quarks (25 marks) **Marks**

a) Outline the features of the Rutherford model of the atom. **2**

b) For the Hydrogen atom:

(i) calculate the longest wavelength in the Balmer series of spectral emission lines. **2**

(ii) determine the energy difference between the stationary states that produced this emission line. **1**

(iii) describe how Bohr's model of the hydrogen atom was able to explain the emission spectrum of hydrogen. **5**

c) In the treatment of cancers by radiotherapy a metastable Barium-137 isotope (Ba-137m) is used to produce a gamma ray of energy 662 keV. Determine the change in binding energy per nucleon for this process. **1**

Question 38 continued on next page

Candidate Number:____________________________

Question 38 - From Quanta to Quarks (continued)

START A NEW BOOKLET FOR PARTS d), e) AND f)

d) The isotope Dysprosium-150 decays 64% of the time by β^+ decay, and 36% of the time by α decay.

(i) The equation for the α decay is

$$^{150}_{66}Dy \rightarrow {}^{146}_{64}Gd + {}^{4}_{2}\alpha$$

Calculate the energy released in this α decay using the following data table: **2**

Isotope	Nuclear Mass (atomic mass units)
$^{150}_{66}Dy$	149.925585
$^{146}_{64}Gd$	145.918311
$^{4}_{2}\alpha$	4.001506

(ii) Write the transmutation equation for the β^+ decay. **2**

e) Explain how the Davisson and Germer experiment supported Louis de Broglie's idea of matter waves. **4**

f) Describe how the principles of conservation of momentum and conservation of energy were used in the discovery of the neutrino by Pauli, and the neutron by Chadwick. **6**

End of Paper

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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
Mass of Earth	6.0×10^{24} kg
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	6.67×10^{-11} N m^2 kg^{-2}
Planck's constant, h	6.626×10^{-34} J s
Rydberg's constant, R_H	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}

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
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 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 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc 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 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 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 Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm 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 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 112 and above have been reported but not fully authenticated.

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may have been modified.

SYDNEY GRAMMAR SCHOOL

Class

Candidate Number

Physics

Section I Part A
ANSWER SHEET

2014
HIGHER SCHOOL CERTIFICATE
TRIAL EXAMINATION
Thu 7 August 8.40 am

General Instructions

- Write your class and candidate number in the space provided.
- Attempt all questions 1 – 20
- Use a blue or black pen
- Select the alternative A, B, C, or D that best answers the question.
- Fill in the response circle completely.

1.	●	B	C	D
2.	A	B	●	D
3.	○	●	C	D
4.	A	B	C	●
5.	A	B	C	●
6.	●	B	C	D
7.	A	B	●	D
8.	A	B	●	D
9.	A	●	C	D
10.	A	●	C	D
11.	A	B	●	D
12.	A	B	C	●
13.	A	●	C	D
14.	●	B	C	D
15.	A	●	C	D
16.	A	B	●	D
17.	A	●	C	D
18.	A	B	C	●
19.	●	B	C	D
20.	A	B	●	D

MARK

Candidate Number:____________________

SRW

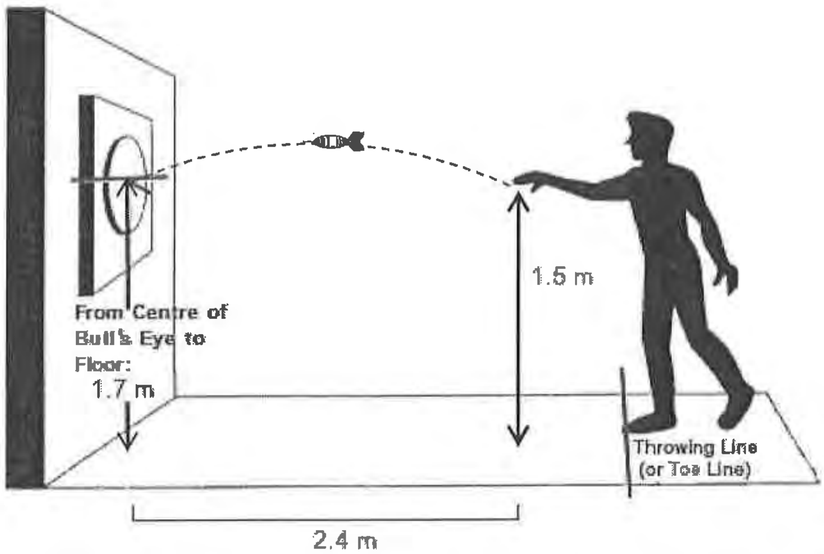
CRIB

Part B
Total marks - 55
Attempt Questions 21 - 34
Allow about 1 hour and 40 minutes for this Part

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

Question 21 (4 marks) **Marks**

A dart player releases a dart 2.4 m away from the dartboard where the bullseye is 1.7 m from the ground. The player successfully hits the bullseye by throwing from a height of 1.5 m at an angle of 30° above the horizontal.



Determine the intial velocity of the dart 4

$\boxed{u_H = u\cos 30 \quad u_V = u\sin 30}$ (1)

$\boxed{2.4 = u\cos 30 t}$ (1) $\boxed{0.2 = u\sin 30 \times \frac{2.4}{u\cos 30} - \frac{4.9 \times 2.4^2}{u^2\cos^2 30}}$ (1)

$\therefore 0.2 = 2.4\tan 30 - \frac{37.632}{u^2}$

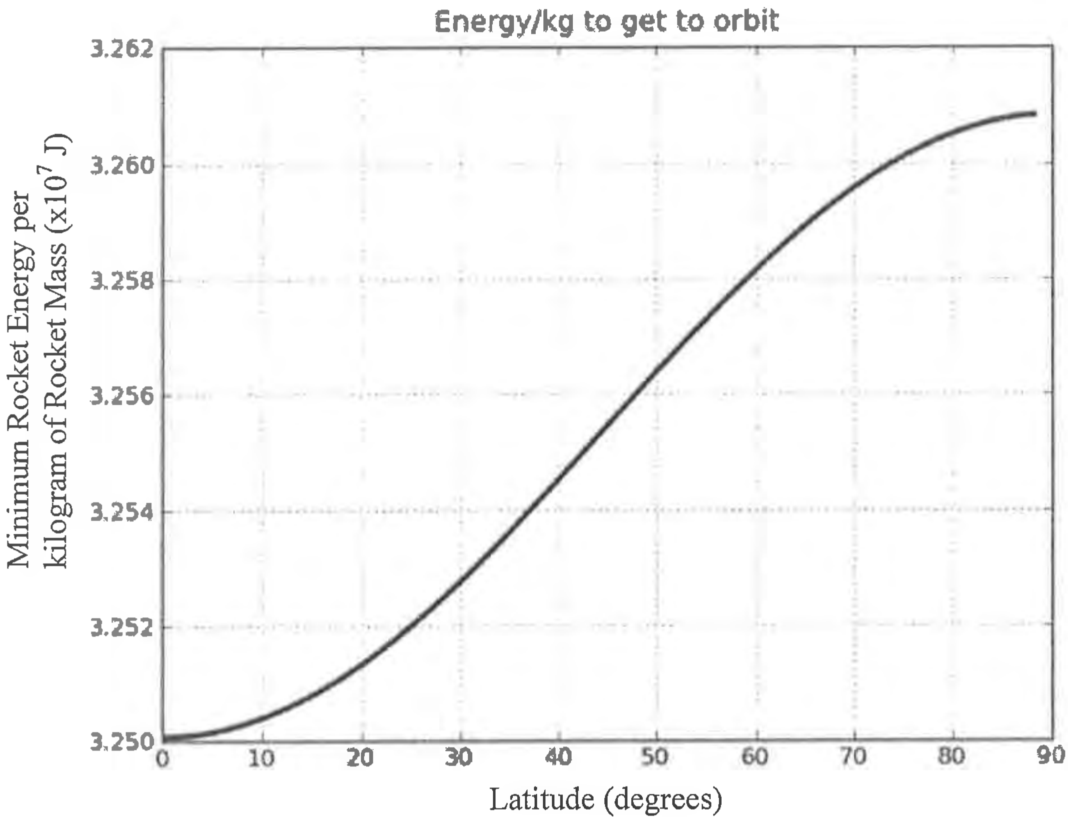
$\therefore u^2 = 31.74$

$\boxed{u = 5.6 \text{ m/s}}$ (1)

Candidate Number:________________________

Question 22 (2 marks) **Marks**

The graph below shows the minimum rocket energy needed per kilogram of mass to reach an orbital altitude of 250 km as a function of launch latitude on the Earth's surface.



With reference to this graph, discuss the effect of the Earth's motion on the launch of a rocket.

(1) comment about velocity is highest at equator **2**

(1) comment about energy required is therefore least at equator

Candidate Number:__________________________

Question 23 (4 marks) **Marks**

A projectile of mass 1150 kg is fired vertically from the surface of an asteroid of mass 1.1×10^{20} kg and radius 2.6×10^{6} m with a speed of 50 ms^{-1}.

a) Determine the initial kinetic energy of the projectile. **1**

1.44×10^{6} J

b) Determine the initial gravitational potential energy of the projectile. **1**

-3.245×10^{6} J

c) Determine the maximum distance the projectile reaches from the centre of the asteroid. **2**

1 $(a) + (b) = -\dfrac{6.67 \times 10^{-11} \times 1150 \times 1.1 \times 10^{20}}{r}$

1 $r = 4.67 \times 10^{6}$ m

Candidate Number:________________________

Question 24 (5 marks) **Marks**

A satellite of mass 1200 kg is in orbit around the Earth at a distance of 22000 km from the centre of the Earth.

a) Calculate the magnitude of the centripetal acceleration of the satellite at this distance. **1**

$g = \frac{GM}{r^2} = 0.83 \text{ m/s}^2$

b) Determine the period of the satellite. **2**

(1) $T = \sqrt{\frac{4\pi^2 r^3}{GM}}$

(1) $T = 3.24 \times 10^4 \text{ s}$ (9 hours)

c) Explain why the orbital velocity is independent of the mass of the satellite. **2**

(1) $\frac{GMm}{r^2} = \frac{mv^2}{r}$ (or in words)

(1) hence $v = \sqrt{\frac{GM}{r}}$ which does not depend on the mass of the satellite

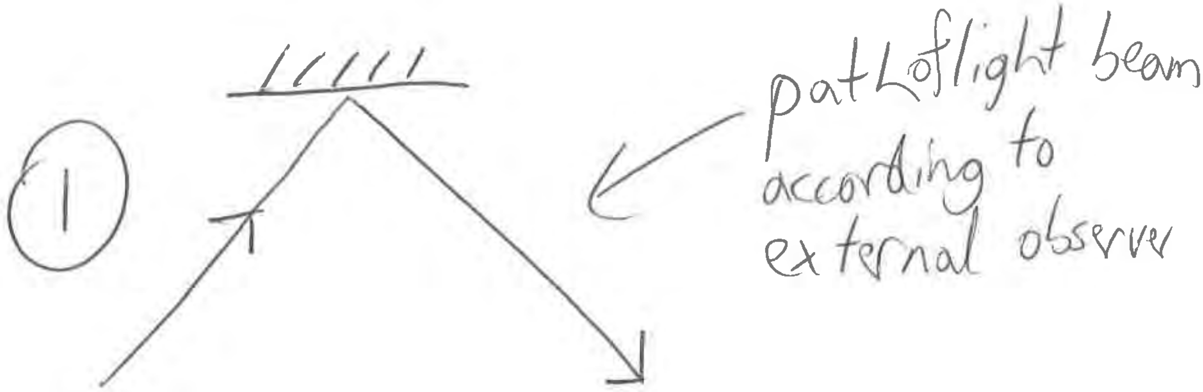
Candidate Number:_______________

Question 25 (3 marks) **Marks**

A laser mounted on the floor of a train carriage travelling at high speed fires a light pulse towards a mirror on the ceiling of the train directly above the laser.

An observer in the carriage can time how long this light pulse takes to travel from the laser, reflect from the mirror on the ceiling and then travel back to a detector at the laser source.

With the aid of a diagram and with reference to an external observer, explain how this situation demonstrates the phenomenon of time dilation.



3

1 Path is longer since in the time taken to reach the mirror the carriage has moved

1 Since c is a constant for all inertial frames the time taken according to the external observer is longer.

Candidate Number:____________________________

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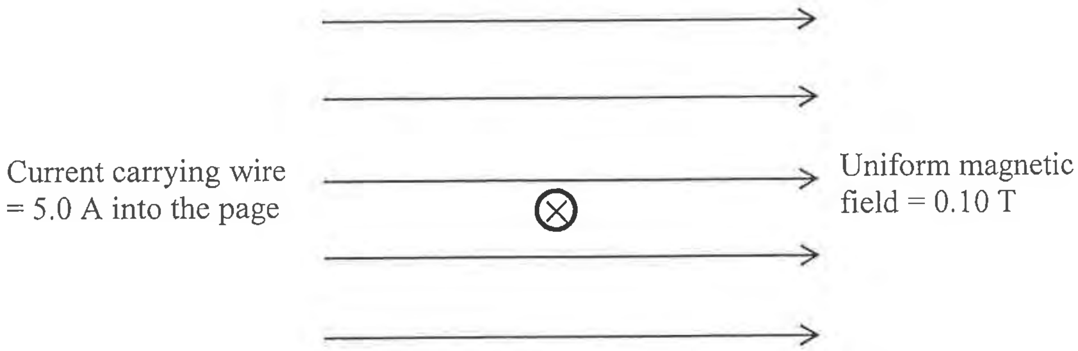
Candidate Number:____________________

Question 26 (3 marks) **Marks**

A straight wire with a current of 5.0 A is placed in a uniform magnetic field of 0.10 T as shown in the diagram below.



Calculate the magnitude and direction of the magnetic force on a 5.0 cm length of the straight wire.

$F = nBIL\sin\theta$ ✓① mk 3

$= 1 \times 0.10 \times 5.0 \times 5/100 \times \sin 90$

$= 0.025\,N$ ✓① correct substitution with answer

Notes: 1. if $F = 2.5\,N$ + correct direction //x 2mks down the page

2. if $F = 2.5 \times 10^{-3}\,N$ + correct direction //x 2mks ✓① mk

3. if correct substitution into correct formula but answer incorrect with correct direction //x 2mks

Direction

Question 27 (2 marks)

Name one design strategy that is used to reduce heating in transformers and explain why this strategy is effective.

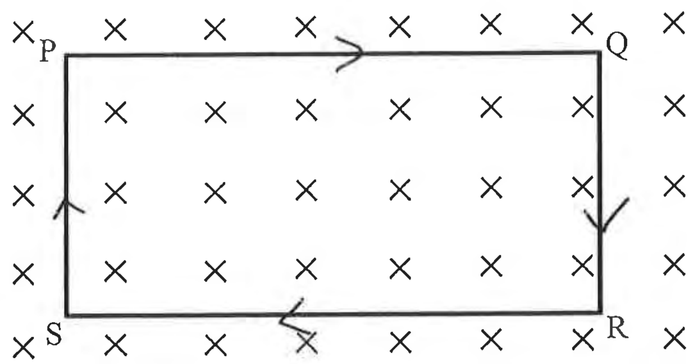
✓① mk Name of strategy e.g. heat sinks, Laminations 2

✓① mk + correct explanation based on minimises eddy currents ∴ minimises heat production ∴ improves efficiency

Candidate Number:________________________

Question 28 (4 marks) **Marks**

A rectangular single turn loop of wire PQRS, with a resistance of 0.6 Ω, is placed at right angles to a uniform magnetic field of 0.15 T directed into the page. The width of the loop PS is 10 cm and the length PQ is 20 cm as shown in the following diagram.



B = 0.15 T into the page

The magnetic field is decreased uniformly to zero in 0.03s.

a) Calculate the magnitude of the current induced in the loop. 3

$$emf = -1 \times (0.1 \times 0.2) \frac{[0.15 - 0]}{0.03}$$

$$= 0.1V$$

$$I = emf/R$$

$$= 0.1/0.6$$

$$= 0.167A$$

✓① mk for $\Delta\phi$

✓① mk for $emf = \frac{-N\Delta\phi}{\Delta t}$

✓① mk for $emf = IR$.

b) On the diagram above, clearly indicate with an arrow the direction of the current induced in the loop. 1

✓① mk.

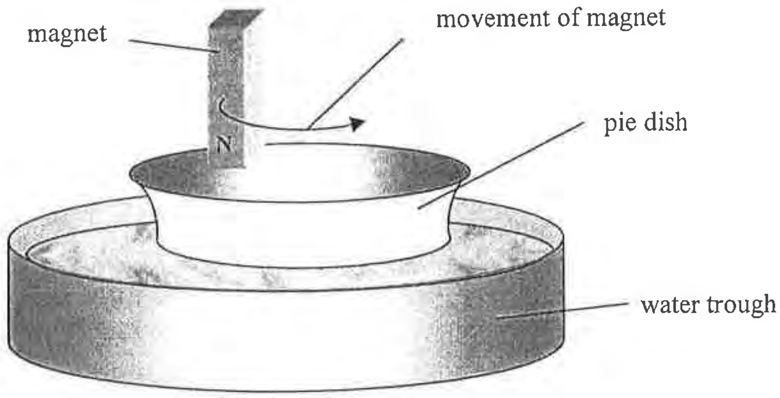
Answer shown on diagram.

Candidate Number:___________________________

Question 29 (5 marks) **Marks**

A permanent magnet is moved very quickly in an anti-clockwise direction above an aluminium pie dish that is floating on water as shown in the following diagram.

To score full marks, answers needed to refer to the physical laws i.e. Faraday's Law and Lenz's Law.



a) Explain using physical laws what happens to the pie dish when the magnet is moving above the pie dish. 4

① mk ✓ M = pie dish rotates in the same direction (i.e anti-clockwise) as the magnet.

① mk ✓ $\Delta\phi$ = moving magnet produces a change in flux which by

① mk ✓ F = Faraday's Law an emf is induced that results in eddy currents

① mk ✓ L = Lenz's Law

$\Delta\phi \rightarrow I \rightarrow B \rightarrow$ opposes $\Delta\phi$

or $\Delta\phi \rightarrow I \rightarrow B \rightarrow$ interacts with the ~~external~~ B field (motor effect) $\rightarrow$ force to oppose motion

b) This experiment is used to demonstrate the principal of an AC induction motor. Identify the part of an AC induction motor represented by the pie dish. 1

✓ ① mk.

rotor. (squirrel cage)

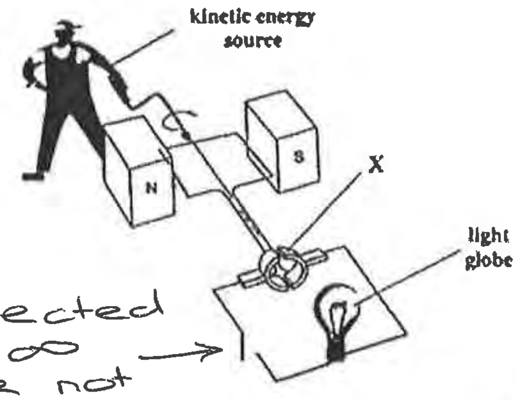
did not allow
× coils
× inner coils
× stator

Candidate Number:________________________

Question 30 (5 marks) **Marks**

The diagram below shows a simple generator used in a Physics practical lesson.

Notes:
1. emf's do not flow
2. extra effort is not due to overcoming "back emf"
3. In Lenz's Law, * force opposes the motion "not the emf or current
4. do not use the word "resistance" when you mean "force".



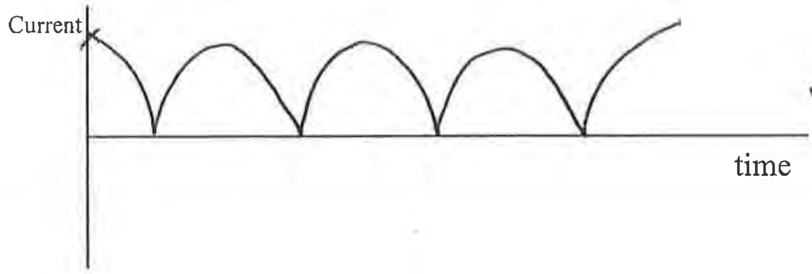
5. non-connected circuit is ∞ resistance not 0 Ω.

a) A student notices that when the switch is closed and the light globe glows, the handle becomes harder to turn than when the switch is open and the light globe is not glowing. Explain the students observations. 3

✓ I = induced current flows when switch closed
= no induced current flows when switch open
✓ L = correct statement of Lenz's Law i.e. direction of induced current produces a magnetic field that interacts with the external field in such a way that provides a
✓ F = force that opposes the motion of the coil
OR/ when switch closed, current flows ∴ more work needed to produce this energy ∴ more force necessary as W = Fr.

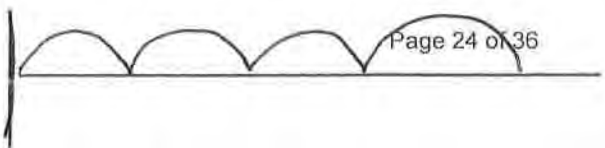
To obtain full marks, answers needed to refer to the physical principles involved and were logical and coherent and expressed in correct terminology.

b) This generator has a split ring/commutator to connect the rotating coil to the light globe. On the following axes, draw a graph of how the current in the light globe would change over time when the handle is rotated at a steady rate for two complete turns. Assume the coil of the generator is at the position shown in the diagram above at t = 0 s. 2

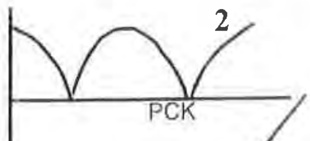


✓✓ * starts at maximum
* 1st quadrant
* two periods

if



✓ ✗



✓ ✗

AAH - CRIB

Question 31 (4 marks) **Marks**

With the aid of a diagram describe how Heinrich Hertz demonstrated that radio waves were part of the electromagnetic spectrum.

For **FOUR MARKS**:

- Provides a good, labelled diagram of the experimental set-up.
- Describes Hertz's production and reception of radio waves.
- Describes Hertz's investigation into the wave nature of the radio waves, *including his measurement of their speed*.
- Relates the speed of radio waves and their wave properties to the electromagnetic spectrum.

THREE MARKS were awarded for reasonable answers that either omitted the measurement of speed, or were lacking in sufficient detail.

TWO MARKS for answers that a described the production and reception of radio waves well, but contained very little else.

ONE MARK for answering some aspect of the question; e.g. how Hertz produced radio waves.

NOTE:

1. Hertz's work on the photoelectric effect is not really relevant here.
2. Hertz did not use a radio to detect radio waves!
3. Too many diagrams were very poor, and added nothing to the answer.

Question 32 (4 marks)

A cathode ray oscilloscope is a modified version of the cathode ray tube. Justify this statement, with reference to the function of a cathode ray oscilloscope and the features of a cathode ray tube.

FOUR MARKS for GOOD answers addressing the following points:

- The CRO as a diagnostic tool, allowing analysis of voltage v time.
- The function of the three main features of the CRT, i.e.:
    - The electron gun to produce an electron beam.
    - A clear description of the role of the metal deflection plates: horizontal deflection to create a time axis, vertical deflection determined by an input voltage.
    - A fluorescent screen, calibrated to allow quantitative measurement.

THREE MARKS were usually awarded for either:

- GOOD descriptions of the parts of the CRT, that did not address the function of the CRO, or
- REASONABLE answers that lacked some detail, usually in the specific role of the deflection plates.

TWO MARKS were usually awarded for demonstrating a REASONABLE understanding of the features of a CRT that were lacking in specifics.

ONE MARKS was usually awarded for demonstrating a BASIC understanding of the features of a CRT.

NOTE:

1. The easiest way to get full marks on this question was to give a labelled diagram of the features of the CRO, with a small amount of explanatory text for every feature. Very few boys did this.
2. Some boys did not know the function of a CRO
3. Many boys confused cathode ray tubes with discharge tubes.

Question 33 (6 marks) **Marks**

Assess the role of experiments that were conducted to determine the nature of cathode rays in the late nineteenth century.

FIVE or **SIX MARKS** for a GOOD ANSWER that addresses ***most*** of the following points:

- DESCRIBES early experiments with cathode ray tubes to investigate the properties of cathode rays, e.g.:
  - Maltese Cross – to demonstrate CR travel in straight lines.
  - Paddle Wheel – to demonstrate CR have momentum.
  - Deflected by Magnetic Fields – CR are particles with negative charge.
  - Not Deflected by Electric Fields – CR are a form of em radiation.

  …and ***clearly shows the link between the experiment, the observation and the nature of cathode rays***.
- OUTLINES the apparent contradictory properties of cathode rays.
- DESCRIBES the measurement of e/m by Thomson and recognises that this experiment - credited as the discovery of the electron - is key to resolving the debate over the nature of cathode rays.
- PROVIDES an overall assessment, recognising the key role played by experiments in determining the nature of cathode rays.

THREE or **FOUR MARKS** for a REASONABLE ANSWER that:

- PROVIDES a reasonably comprehensive description of the experiments used to determine the nature of cathode rays.
- ASSESSES the importance of these experiments.

ONE or **TWO MARKS** for describing one or two experiments concerning the nature of cathode rays.

Question 34 (4 marks) **Marks**

Sodium metal has a threshold frequency of 5.50×10^{14} Hz. When low intensity blue light of frequency 7.60×10^{14} Hz is shone onto the sodium, electrons are emitted from it. However, when high intensity red light of frequency 4.30×10^{14} Hz is shone onto the metal, no electrons are emitted.

a) Calculate the *work function* of sodium. **1**

$\phi = h.f_o = 6.626 \times 10^{-34} \times 5.50 \times 10^{14} = \underline{\mathbf{3.64 \times 10^{-19}\ J}}$

b) Calculate the maximum kinetic energy of the electrons emitted from the sodium by the blue light above.

$KE_{MAX} = h(f - f_o) = 6.626 \times 10^{-34} \times (7.60 \times 10^{14} - 5.50 \times 10^{14})$ **1**

$= \underline{\mathbf{1.39 \times 10^{-19}\ J}}$

c) With reference to Einstein's photon model of light, explain why high intensity red light will not emit electrons from sodium, but low intensity blue light will. **2**

For **TWO MARKS**:

- Makes reference to the photon model of light.
- Identifies the lack of effect of intensity.
- Relates the frequency / energy of red and blue photons to the threshold frequency / workfunction of sodium to explain the observations given.

(The best answers referred to E=hf, but that was not essential for full marks)

ONE MARK for addressing only one or two of these points.

(A large number of boys did not refer to the blue or red light in their answer!)

Question 38 - From Quanta to Quarks (25 marks) **PCK**

a) Outline the features of the Rutherford model of the atom. **2**

Marking guide	Marks
Addresses 2 of the following • <u>Structure</u> – Small nucleus with *orbiting* electrons (mostly empty space) • <u>Mass</u> – The central nucleus is dense and contains most of the mass of the atom • <u>Charge</u> – The nucleus is positively charged with orbiting negative electrons (*many answers fail to identify the electron as negatively charged*)	2
Addresses only 1 feature correctly	1

b) For the Hydrogen atom:

(i) calculate the longest wavelength in the Balmer series of spectral emission lines. **2**

The longest wavelength (is smallest frequency) are is therefore created by the smallest energy change $\Delta E = hf$ (between adjacent stationary states in the balmer series)

Balmer series means $n_f=2$, smallest energy change when $n_i=3$. Using the Rydberg formula

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^{\ 2}} - \frac{1}{n_i^{\ 2}}\right] \quad \therefore \frac{1}{\lambda} = 1.097\times 10^7\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = 1{,}523{,}611 \quad \therefore \lambda = 6.5633546\times 10^{-7}\ m$$

wavelength = **656nm** (or 6.56e-7m) (wrong answer 365nm if using $n_i=\infty$)

Marking guide	Marks
Correctly identifying Balmer $n_f=2$, AND longest wavelength from $n_i=3$ AND solves the Rydberg equation (ie correctly inverting wavelength)	1
ONLY correctly completing TWO of the above	1

Markers Note: *(for those who picked $n_i=6$) The Balmer series is all lines where $n_f=2$ and $n_i>2$, not just the lines in the visible part of the spectrum*

(ii) determine the energy difference between the stationary states that produced this emission line. **1**

The energy difference between stationary states is the same as the energy of the photon emitted

$$E = hf = \frac{hc}{\lambda} = \frac{(6.626\times 10^{-34})(3\times 10^8)}{6.5633546\times 10^{-7}} = 3.0286342\times 10^{-19} J$$

$$\mathbf{3.03\times 10^{-19}} \boldsymbol{J}\ \ (3 sigfig)\ also\ 1.9eV)$$

Marking guide	Marks
Correct answer in Joules or eV	1

(iii) describe how Bohr's model of the hydrogen atom was able to explain the emission spectrum of hydrogen. **5**

<table>
<tr><th>Marking guide</th><th>Marks</th></tr>
<tr><td>High mark answers are able to specifically (not generally) link how Bohr's model and postulates are able to explain how all the wavelengths of light in the hydrogen emission spectrum are produced

Answers included:

Descriptions of Bohr's modal, specifically the 3 postulates

AND

Critical parts connecting postulates to production of spectral emission lines

1. Stationary energy levels lead to discrete spectral lines (1st postulate). Not a spectrum of wavelengths

2. Clearly explaining how the spectral lines are formed (2nd postulate)(explicitly)The transition from a high energy stationary state to a lower energy state emits a photon with the same energy and the wavelength of the photon is determined by Einstein/Plank's E=hf. Better answers clearly distinguished the following:

o Clearly distinguishing that spectral emission lines are produced when transitioning from a higher orbit to a lower orbit

o One transition between 2 orbits corresponds to one spectral line in the emission spectrum

o The initial and final orbits are the numbers in Rydberg equation

o Describing how the different series in the Hydrogen spectrum are formed (including diagrammatically)

3. Bohr was able to use 3rd postulate to derive the Rydberg equation (quoted) which allows calculation of all wavelengths of the hydrogen emission spectrum</td><td>4-5</td></tr>
<tr><td>Simply stating Bohr's postulates without relating them to the production of hydrogen emission spectral line wavelengths
OR

General statements about fixed orbits and how electrons changing orbits emits or absorbs photons of equal energy</td><td>2-3</td></tr>
<tr><td>Basic information about the movement of electrons producing light</td><td>1</td></tr>
</table>

Markers Notes: *Too many answers focussed on just the visible part of the hydrogen spectrum as opposed to the whole spectrum. The hydrogen spectrum is all spectral lines produced by hydrogen regardless of how 'visible' they are. The Lyman (UV) [1906-1914] and Paschen (IR) [1908] series were known by the time of Bohr's model [1913].*

c) In the treatment of cancers by radiotherapy a metastable Barium-137 isotope (Ba-137m) is used to produce a gamma ray of energy 662 keV. Determine the change in binding energy per nucleon for this process. **1**

The change in binding energy in the nucleus is released as the energy released in the gamma ray. Similar to Bohr's model.

Marking guide	Marks
Correct answer 662,000eV per 137 nucleons = 4832eV/nucleon or **4.83keV/nucleon** (3sigfig) (or 7.74×10^{-16} Joules)	1

d) The isotope Dysprosium-150 decays 64% of the time by β^+ decay, and 36% of the time by α decay.

(i) The equation for the α decay is

$$^{150}_{66}Dy \rightarrow {}^{146}_{64}Gd + {}^{4}_{2}\alpha$$

Calculate the energy released in this α decay using the following data table: **2**

Mass defect = 149.925585-(145.918311+4.001506) = **0.005768 amu**

0.005768 x 931.5 =5.372892MeV = **5.4 MeV**

or (0.005768)x(1.661×10^{-27})x(9×10^{16}) = 8.6225832×10^{-13} = **8.6×10^{-13} J**

Marking guide	Marks
Correct mass defect (amu or kg)	1
Correct answer in (Joules or eV)	1

(ii) Write the transmutation equation for the β^+ decay. **2**

Answer

$$^{150}_{66}Dy \rightarrow {}^{150}_{65}Tb + {}^{0}_{+1}\beta + {}^{0}_{0}\upsilon$$

Marking guide	Marks
Conservation of mass number 150	1

Missing one thing
• Tb symbol and atomic number 65
• Beta positive particle (positron) correct symbol
• Neutrino
  ○ (ignored mistake of identifying it incorrectly as an antineutrino)
  ○ (ignored ambiguous drawing of greek nu (ν) with gamma symbol (γ))
	1

e) Explain how the Davisson and Germer experiment supported Louis de Broglie's idea of matter waves. **4**

Marking guide	Marks
Davison Germer Experiment was to experimentally prove Broglie's idea of matter waves De Broglie proposed that matter has an associated wavelength given by the matter's momentum $\lambda = \frac{h}{mv}$. (must be included, with description, not just writing the equation)	1
Description of Davison and Germer experiment Correct description and details of how the experiment was performed with an electron beam (known velocity), Ni crystal and Electron detector. A labelled diagram can be sufficient.	1
Correct details about how the interference pattern was observed or measured Diffraction/interference pattern was produced by • Changing electron speed at a fixed angle (what they did) • fixed electron speed and changing incident angle (also acceptable)	1
Summary/Quality Diffraction and interference are a property of waves and the wavelength measured correspond to the theoretical value proposed by de Broglie's equation	1

Markers note: *Wave-particle duality was a concept that was accepted later – specifically after Heisenbergs uncertainty principle. De Broglie was still thinking that electrons were particles with an associated wavelength or pilot wave.*

f)	Describe how the principles of conservation of momentum and conservation of energy were used in the discovery of the neutrino by Pauli, and the neutron by Chadwick. **6**

Answers were expected to clearly describe how a specific elastic collision where momentum and *kinetic* energy is conserved was used to determine the existence and properties of new particles.

Marking guide	Marks
Notes •	
Discovery of the Neutron • Description of Chadwick's experimental setup • Explanation of elastic scattering of neutron and protons in paraffin (and/or recoil of hydrogen/nitrogen gases) allowing properties of neutron to be determined. • Description of properties of neutron discovered. (ie Determines unknown radiation/particle is neutral and roughly 1.1 times the mass of a proton)	1-3
Discovery of the Neutrino • Description of the Kinetic Energy spectrum of electrons during beta decay (*Answers must specifically address the spectrum of the kinetic energy of the beta particles. Answers that simply state that the momentum/energy after the collision was less or different than before the decay is not enough*) • Existence of neutrino proposed by Pauli as additional particle in elastic scattering (sum of momentum of recoiling daughter nuclei and beta and neutrino is zero) so that momentum and *kinetic* energy is conserved. • Description of neutrino properties needed: near massless, chargeless. *(technically Pauli proposed the necessity of the neutrino, but it was actually directly experimentally identified later)*	1-3

Markers Notes:

- Many are getting the axes incorrect on the beta particle kinetic energy after decay (this could be ignored if the written explanation expressed the correct meaning.