SYDNEY GRAMMAR SCHOOL

2013
FORM VI
TRIAL HSC EXAMINATION

Physics

Monday 5th August 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 2 - 26

(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 27 – 30

(25 marks)
- Use separate writing booklets
- Attempt Question 36 only.
- Allow about 45 minutes for this section

Masters

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

1 Wikipedia uses the following phrase:

"the use of the relative movement and gravity of a planet or other celestial body to alter the path and speed of a spacecraft, typically in order to save propellant, time, and expense."

to describe:

(A) Kepler's 3rd Law.

(B) geostationary orbits.

(C) projectile motion.

(D) the slingshot effect.

2 During the early stages of the launch of a rocket, an astronaut typically experiences:

(A) decreasing g-forces, because the net force acting on him increases.

(B) increasing g-forces, because the velocity of the rocket increases.

(C) decreasing g-forces, because the force of gravity acting on him decreases.

(D) increasing g-forces, because the acceleration of the rocket increases.

3 A satellite of mass 1500 kg is orbiting a planet at an orbital radius of 2.6×10^7 m. It experiences a centripetal force of 4.7×10^3 N. The speed of the satellite is:

(A) 1.3×10^3 ms^{-1}

(B) 9.0×10^3 ms^{-1}

(C) 4.6×10^7 ms^{-1}

(D) 8.1×10^7 ms^{-1}

4 The table below contains data on the dwarf planet Eris.

Physical Property	**Value**
Orbital Radius	1.01×10^{13} m
Planetary Radius	1.16×10^{6} m
Length of Day	26 hours
Length of Year	561 Earth years
Mass	1.67×10^{22} kg

Using this data, calculate the acceleration due to gravity on the surface of Eris.

(A) 1.3×10^{-6} ms^{-2}

(B) 8.3×10^{-4} ms^{-2}

(C) 1.1×10^{-1} ms^{-2}

(D) 8.3×10^{-1} ms^{-2}

Questions 5 and 6 refer to the diagram below, which shows a projectile launched at an angle of 30° above a horizontal surface at a speed of 27.0 ms^{-1}.

5 The horizontal component of the initial velocity of the projectile is:

(A) 0 ms^{-1}

(B) 13.5 ms^{-1}

(C) 23.4 ms^{-1}

(D) 27.0 ms^{-1}

6 The horizontal range of the projectile is:

(A) 32.2 m

(B) 37.2 m

(C) 64.4 m

(D) 74.4 m

7 An electron in a particle accelerator is found to have a mass of 1.42×10^{-30} kg. The speed of the electron is:

(A) 2.30×10^{8} ms^{-1}

(B) 1.92×10^{8} ms^{-1}

(C) 1.77×10^{8} ms^{-1}

(D) 1.23×10^{8} ms^{-1}

8 A transformer designed to convert Australian domestic voltage (240 V AC) to a voltage compatible in the USA (120 V AC) has 200 turns in its primary coil. What is the number of turns in its secondary coil?

(A) 100

(B) 120

(C) 200

(D) 400

9 A square coil of side length 0.5 m sitting in a perpendicular field, experiences a magnetic flux of 100 Wb. If both the magnetic field strength and the side length are doubled, the new magnetic flux will be:

(A) 100Wb

(B) 200Wb

(C) 400Wb

(D) 800Wb

10 Edison and Westinghouse were involved in competition to supply electricity to homes in the USA. Which of the following is a true statement?

(A) Westinghouse advocated the adoption of DC as the method of distribution.

(B) AC is more useful than DC as it is easier to convert the high voltages used in transmission to the lower voltages used in the home.

(C) DC is more dangerous than AC as DC was used in the first electric chair.

(D) DC is more efficient than AC because DC can easily be stepped up to higher voltages.

11 Which of the following is a true statement about the operation of a transformer?

(A) Step down transformers require a laminated core as the input energy is lower than the output energy.

(B) A back emf is induced in the secondary coil which reduces the efficiency of the transformer.

(C) A laminated iron core improves the efficiency of a transformer by disrupting the eddy currents.

(D) Eddy currents in the core produce energy which is transferred to the secondary coil to improve the efficiency of a transformer.

12 A DC motor:

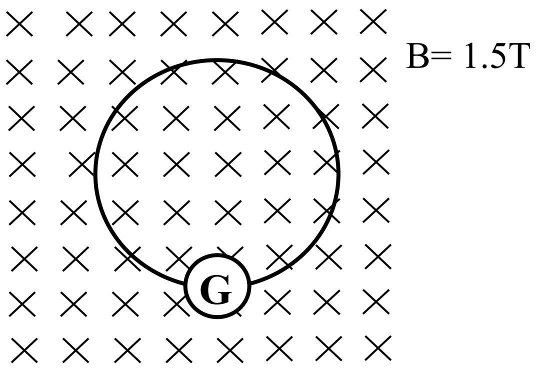
(A) Uses a split ring commutator to deliver the current to the coil.

(B) Uses slip rings to deliver the current to the coil.

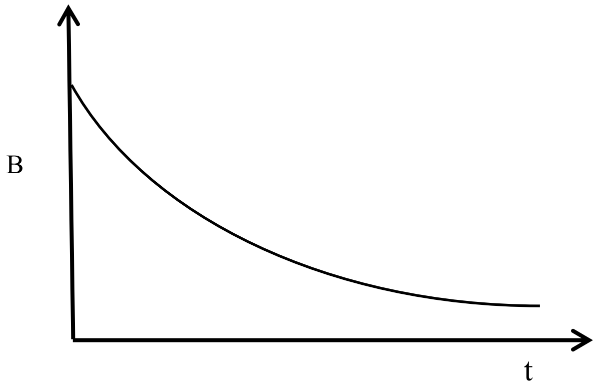
(C) Has no direct electrical connection to the coil.

(D) Uses a squirrel cage to convert AC into DC in the coil.

13 The following diagram shows a single loop of wire in a magnetic field. The initial strength of the magnetic field is 1.5T and it is directed into the page. A galvanometer is connected to the loop to measure any current that flows in it.

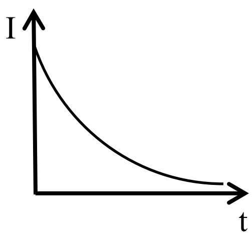


The magnetic field changes over time as shown in the following graph.

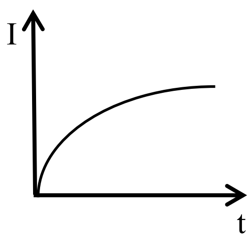


Which of the following graphs correctly shows how the magnitude of the current in the loop varies with time as the magnetic field changes?

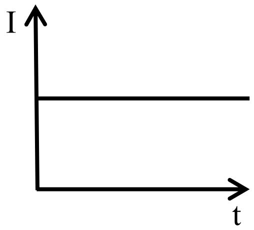
(A)



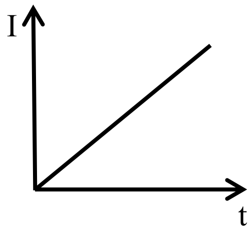
(B)



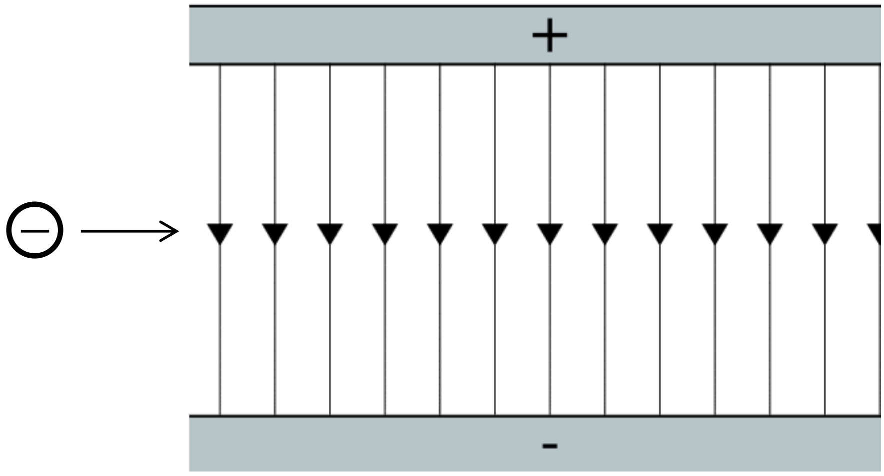
(C)



(D)



Questions 14 and 15 refer to the diagram below, which shows an electron travelling to the right between a pair of charged parallel metal plates.



14 If the voltage between the plates is 100V and their separation is 0.10 m then the magnitude of the force on an electron fired between the plates is:

(A) $1.6\text{x } 10^{-16}$ N.

(B) $1.6\text{x } 10^{-17}$ N.

(C) $1.6 \text{ x } 10^{-18}$N.

(D) $1.6 \text{ x } 10^{-19}$ N.

15 If it was desired for the electrons to be undeflected using a magnetic field in addition to the electric field above, then the direction of the magnetic field would need to be:

(A) Left to right.

(B) Right to left.

(C) Into the page.

(D) Out of the page.

16 The scientist responsible for the first production and detection of radio waves was:

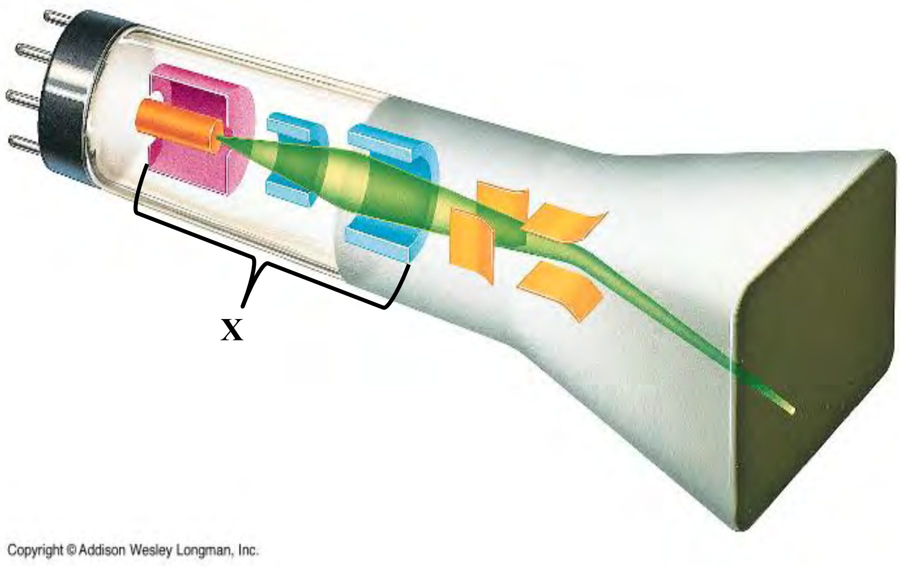
(A) Planck

(B) Hertz

(C) Einstein

(D) Faraday

17 In the diagram of a cathode ray tube below, what is the function of the components labelled X?



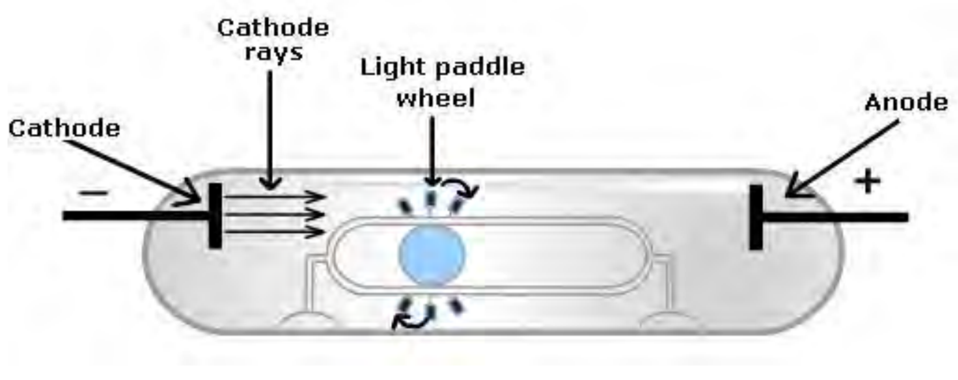
(A) To fluoresce when hit by an electron beam.

(B) To deflect electrons horizontally.

(C) To deflect electrons vertically.

(D) To produce high speed electrons.

18 At the end of the Nineteenth Century, Physicists used this piece of equipment to demonstrate that cathode rays:



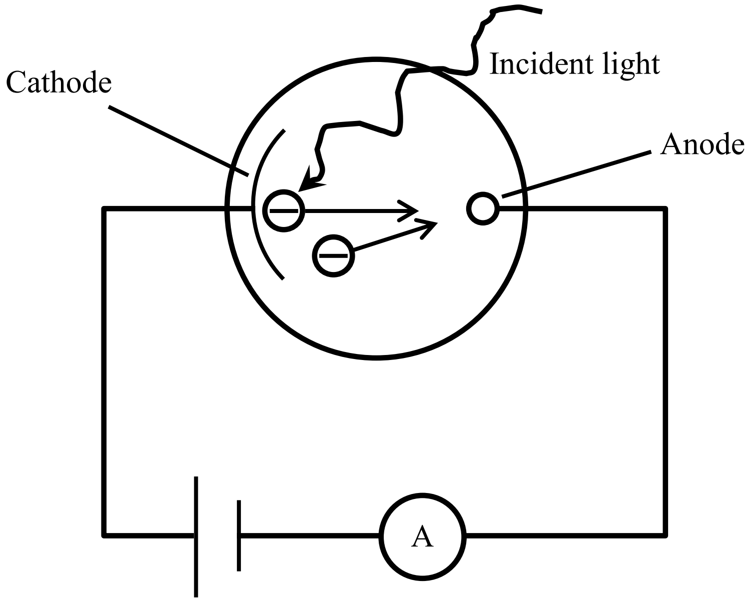
(A) travel in straight lines.

(B) can be deflected by electric fields.

(C) possess momentum.

(D) are independent of the cathode.

19 The device below is most probably used to:



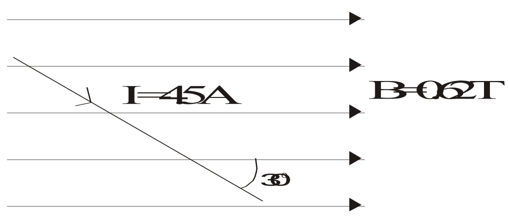
(A) demonstrate the photoelectric effect.

(B) measure the speed of radio waves.

(C) demonstrate black body radiation.

(D) demonstrate thermionic emission.

20 The diagram below shows a current carrying wire inclined at 30^o to a magnetic field. The force that the wire experiences as a result of its interaction with the field is 1.2 N. The length of the wire in the field is:



(A) 0.43 m

(B) 0.86 m

(C) 1.1 m

(D) 1.7 m

Candidate Number:___________________________

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 (3 marks)

"The surface of the Earth is not an inertial frame of reference"

Assess the validity of this statement. **3**

Candidate Number:___________________________

Question 22 (5 marks) **Marks**

In October 2012, European scientists reported the discovery of a planet orbiting the star Alpha Centauri B. The planet was reported to have an orbital radius of 6.0×10^{9} m and an orbital period of 2.8×10^{5} s. The scientists estimated the mass of the planet to be 6.6×10^{24} kg.

a) Calculate the mass of the star Alpha Centauri B.

3

b) Calculate the gravitational force between the star and the planet.

2

Candidate Number:__________________________

Question 23 (7 marks) **Marks**

Discuss the effect of Einstein's Special Theory of Relativity on our understanding of the concepts of space and time. 7

Candidate Number:_____________________________

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Question 24 (3 marks)

Explain what is meant by the term 'the escape velocity at the surface of the Earth' and calculate its value.

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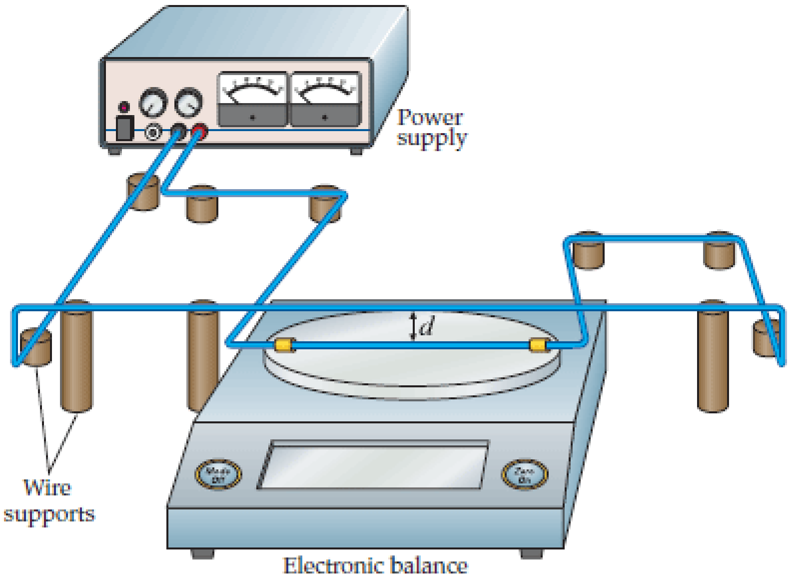
Question 25 (8 marks) **Marks**

A physics practical was conducted to examine the force between two current carrying wires. The following equipment was set up using an electronic balance determine the force between the wires.



The electronic balance was zeroed before the current was switched on so that the reading was directly measuring the force between the wires. The effective length over which the wires interact was measured to be 0.0975 m.

I (A)	Balance reading (g)	I^2 (A^2)	Force between wires (N)
20	0.55	4.0×10^2	5.4×10^{-3}
30	1.22	9.0×10^2	1.2×10^{-2}
40	2.18	1.6×10^3	2.1×10^{-2}
45	2.75	2.0×10^3	2.7×10^{-2}
50	3.40	2.5×10^3	3.3×10^{-2}

Question 25 continued on next page.

Candidate Number:___________________________

Question 25 continued. **Marks**

a) Use this data to draw a graph of the force between the wires (on the y-axis) against the current squared (on the x axis) on the grid provided below. **4**

Question 25 continued on next page.

Candidate Number:____________________________

Question 25 continued.

b) Determine the gradient of the graph. **2**

c) Using your value for the gradient and any other relevant information, determine the separation, *d*, of the wires. **2**

Candidate Number:____________________________

Question 26 (3 marks)

Describe the application of the motor effect in a loudspeaker. **3**

Candidate Number:____________________________

Question 27 (3 marks) **Marks**

Explain how an AC induction motor operates

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Candidate Number:____________________________

Question 28 (4 marks)

Discuss how energy losses in the transmission of electricity from the power station to the home are minimised.

4

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Question 29 (3 marks) **Marks**

In the 19th Century experiments by Crookes using primitive cathode ray tubes failed to show the deflection of cathode rays by electric fields. Discuss how this and other observations resulted in a debate on the nature of cathode rays.

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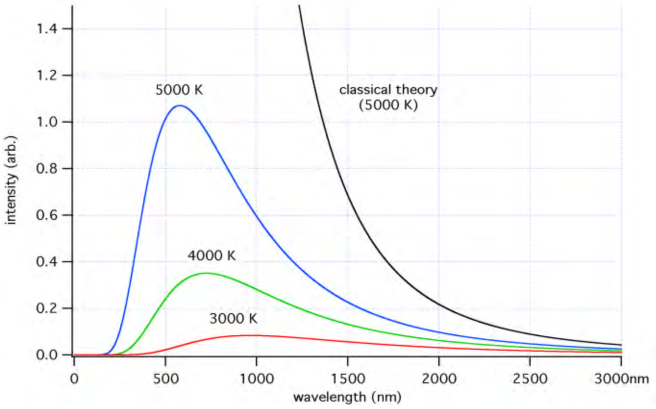
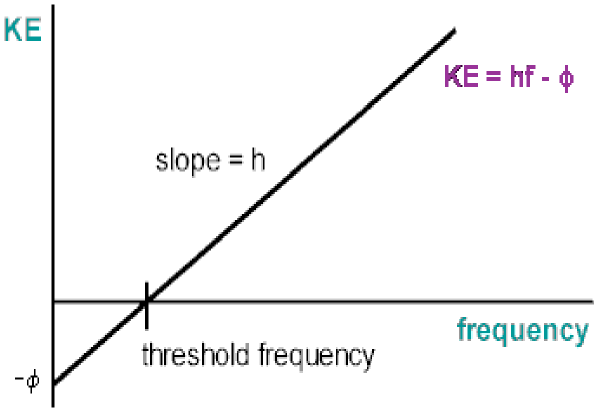
Question 30 (6 marks) **Marks**

Consider the following graphs which depict the results of experiments performed from the late 19th to early 20th century.





With reference to these graphs, discuss the importance of experiments in the development of quantum physics from classical physics.

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Question 31 (6 marks) **Marks**

Two identical photons of wavelength 4.22×10^{-7} m are created when a certain amount of matter, M, is converted to energy.

a) Calculate the energy of one of these photons. **2**

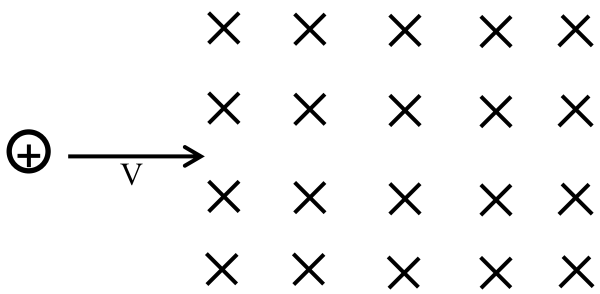
b) Calculate the mass, M. **2**

c) If one of these photons collides with a piece of sodium of work function 3.65×10^{-19} J, calculate maximum kinetic energy of the electron emitted. **2**

Candidate Number:___________________________

Question 32 (4 marks) **Marks**

An experiment was performed in which a proton was fired into a magnetic field as shown below.



a) Complete the diagram above to show the path of the proton in the magnetic field. **2**

b) Describe and explain the effect of increasing the initial velocity of the proton on its path in the magnetic field. **2**

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Candidate Number:___________________________

Section II

25 marks

Attempt Question 36 only from Questions 33 - 37
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.

Pages

Candidate Number:___________________________

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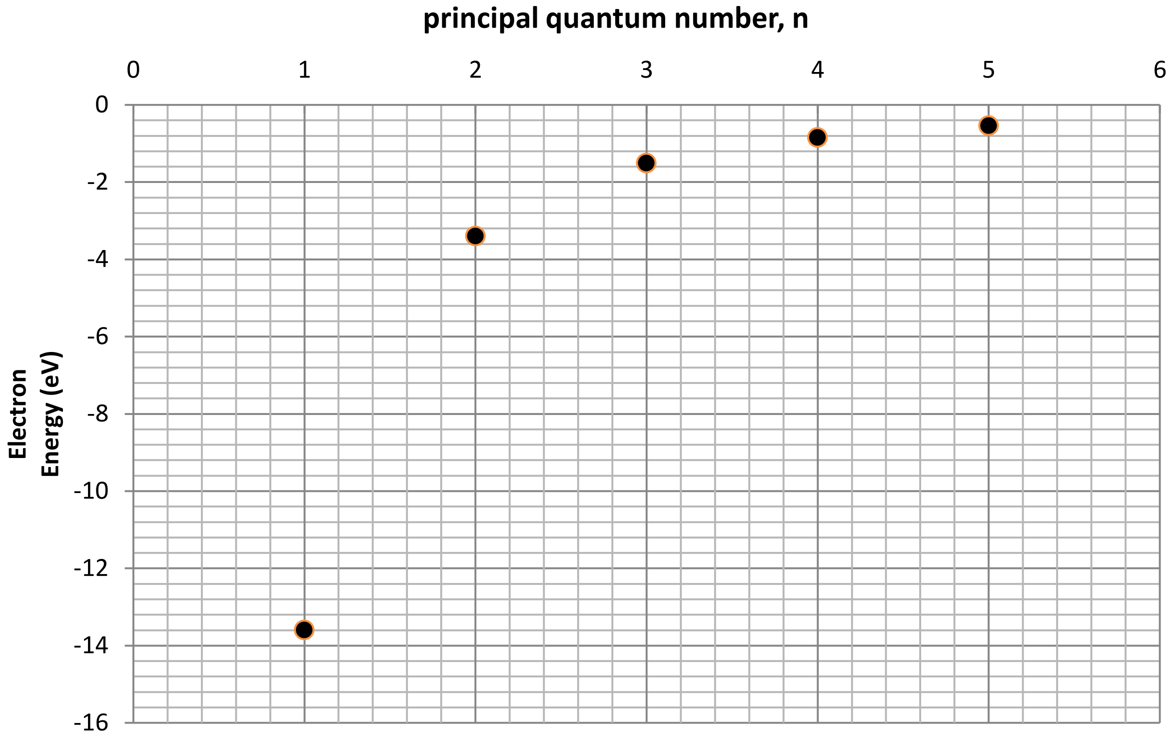
Candidate Number:______________________________

Question 36 - From Quanta to Quarks (25 marks) **Marks**



a) The graph above shows the electron energy levels of the Hydrogen atom.

(i) Use the graph to determine the energy of the 3rd electron energy level **1**

(ii) Using the graph, or otherwise, determine the frequency of the photon released when an electron transitions between the 5th and the 3rd energy levels. **3**

b)

(i) In the Bohr model of the Hydrogen atom, the radius of the first electron energy level is 4.90×10^{-11} m. Electrons in this orbit have a speed of 2.36×10^{6} ms^{-1}.
Explain why Louis de Broglie would have found this to be evidence in support of his proposal of 'matter-waves'. **4**

(ii) Describe the process of nuclear fission and explain how it can lead to an uncontrolled chain reaction. **4**

Question 36 continued on next page

Candidate Number:___________________________

Question 36 - From Quanta to Quarks (continued)

START A NEW BOOKLET FOR PARTS c) AND d)

c)

Scientists estimate there may well be hundreds of millions of tonnes of Helium-3 in the rocks of the Moon, after being one of the isotopes ejected from the Sun's surface for billions of years. It is extremely rare on Earth, since our atmosphere and magnetic field prevent these solar particles reaching the surface.
Theoretically it could be used as a fuel for a fusion reactor as shown in this formula:

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2\,^{1}_{1}H$$

The masses of these species are given in the table:

Name	*Symbol*	*Mass (in amu)*
hydrogen-1	$^{1}_{1}H$	1.007825
helium-3	$^{3}_{2}He$	3.016029
helium-4	$^{4}_{2}He$	4.002603

Determine the amount of energy released (in MeV) when two nuclei of helium-3 fuse together. **3**

d)

(i) Describe an experiment you have performed to observe the spectrum of Hydrogen. **3**

(ii) Explain how the spectrum of Hydrogen was significant in the development, acceptance and ultimate failure of the Bohr model of the atom. **7**

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
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

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

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

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

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

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

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

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

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

$$Z = \rho v$$

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

SYDNEY GRAMMAR SCHOOL

Class

Candidate Number

Physics

Section I Part A
ANSWER SHEET

2013
HIGHER SCHOOL CERTIFICATE
TRIAL EXAMINATION
Mon 5 August 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.	A	B	C	●
2.	A	B	C	●
3.	A	●	C	D
4.	A	B	C	●
5.	A	B	●	D
6.	A	B	●	D
7.	●	B	C	D
8.	●	B	C	D
9.	A	B	C	●
10.	A	●	C	D
11.	A	B	●	D
12.	●	B	C	D
13.	●	B	C	D
14.	●	B	C	D
15.	A	B	●	D
16.	A	●	C	D
17.	A	B	C	●
18.	A	B	●	D
19.	●	B	C	D
20.	A	●	C	D

MARK

AAH - CRIB

Question 21 (3 marks)

"The surface of the Earth is not an inertial frame of reference"

Assess the validity of this statement.

For 3 Marks:

- Identifies an inertial frame as one that is not accelerating.
- Recognises that the Earth's rotational or orbital motion includes acceleration.
- Therefore correctly assesses that the statement is valid.

NB:

1. Boys who did not recognise that the Earth is accelerating = **Maximum of 2**.
2. Many boys gave answers of the form: *"On the one hand it is, on the other hand it isn't"*! Unless they made it very clear what they meant by this (and most of them didn't), these boys tended to score very poorly.
3. Far too many boys did not define what an inertial frame was.

Question 22 (5 marks) **Marks**

In October 2012, European scientists reported the discovery of a planet orbiting the star Alpha Centauri B. The planet was reported to have an orbital radius of 6.0×10^9 m and an orbital period of 2.8×10^5 s. The scientists estimated the mass of the planet to be 6.6×10^{24} kg.

a) Calculate the mass of the star Alpha Centauri B.

Identifies the correct equation: $\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$ →*1 Mark*

Correctly substitutes into the equation: i.e. $M = \frac{(6.0 \times 10^9)^3 . 4\pi^2}{(2.8 \times 10^5)^2 . 6.67 \times 10^{-11}}$ →*1 Mark*

Obtains the correct answer: **1.6x10^{30} kg** →*1 Mark*

b) Calculate the gravitational force between the star and the planet.

Correctly substitutes into the correct equation:
i.e.:

$$F = \frac{6.67 \times 10^{-11} . 6.6 \times 10^{24} \times 1.63 \times 10^{30}}{(6.0 \times 10^9)^2}$$ →*1 Mark*

Obtains the correct answer: **2.0x10^{25} N** →*1 Mark*

Question 23 (7 marks) **Marks**

Discuss the effect of Einstein's Special Theory of Relativity on our understanding of the concepts of space and time.

For 7 Marks, boys needed to include in their answer:

- A clear understanding that, pre-Einstein, space and time were considered absolute quantities.
- An outline of the SToR, including its two postulates.
- A clear understanding that the SToR requires space and time to be quantities that vary relative to the frame of reference of the observer.

And then ***elaborate on these points in detail***, by including at least ***some*** of the following concepts:

- A description of the ***specific consequences*** for space and time predicted in the SToR:
    - Time dilation
    - Length contraction
    - Simultaneity
- An example of thought experiments used by Einstein to elucidate these consequences.
- Evidence in support of these concepts.
    - E.g. Muons in the atmosphere.
    - Atomic clocks flown on aeropanes
- Modern applications of these concepts
    - E.g. Definition of the metre.
    - GPS satellites.
    - Consequences for future space-travel

Most boys who obtained 6 Marks did so because, although their answers were reasonable, they did not consider the changes in our understanding of space and time in sufficient depth.

Once again, ***too many boys are not taking the trouble to answer the question***, e.g. by not spelling out how our understanding of space and time was changed by the SToR, or by not outlining what the SToR was.

Candidate Number: AAH

Question 24 (3 marks)

3

Explain what is meant by the term 'the escape velocity at the surface of the Earth' and calculate its value.

v necessary to escape earth's gravitational field (1)

$v = \sqrt{\frac{2GM}{r}}$

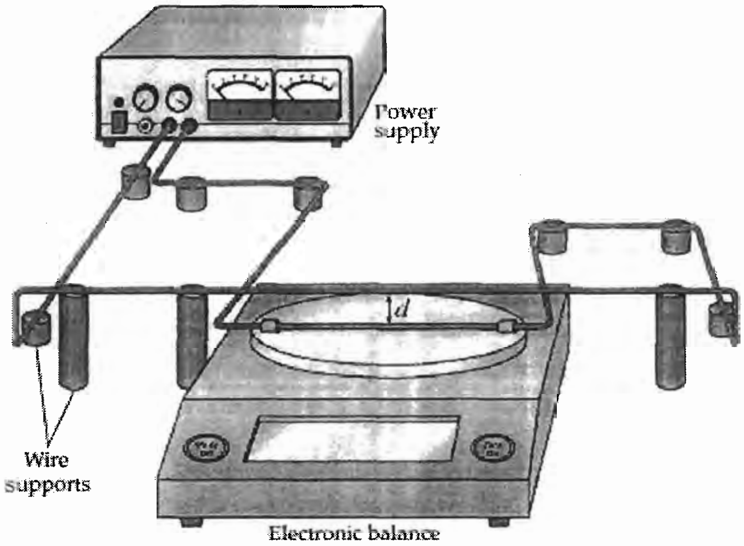
$= \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^{6}}}$ (1) method.

$= 11,183 \text{ ms}^{-1}$ (1)

Candidate Number:____________________________

Question 25 (8 marks) **Marks**

A physics practical was conducted to examine the force between two current carrying wires. The following equipment was set up using an electronic balance determine the force between the wires.



The electronic balance was zeroed before the current was switched on so that the reading was directly measuring the force between the wires. The effective length over which the wires interact was measured to be 0.0975 m.

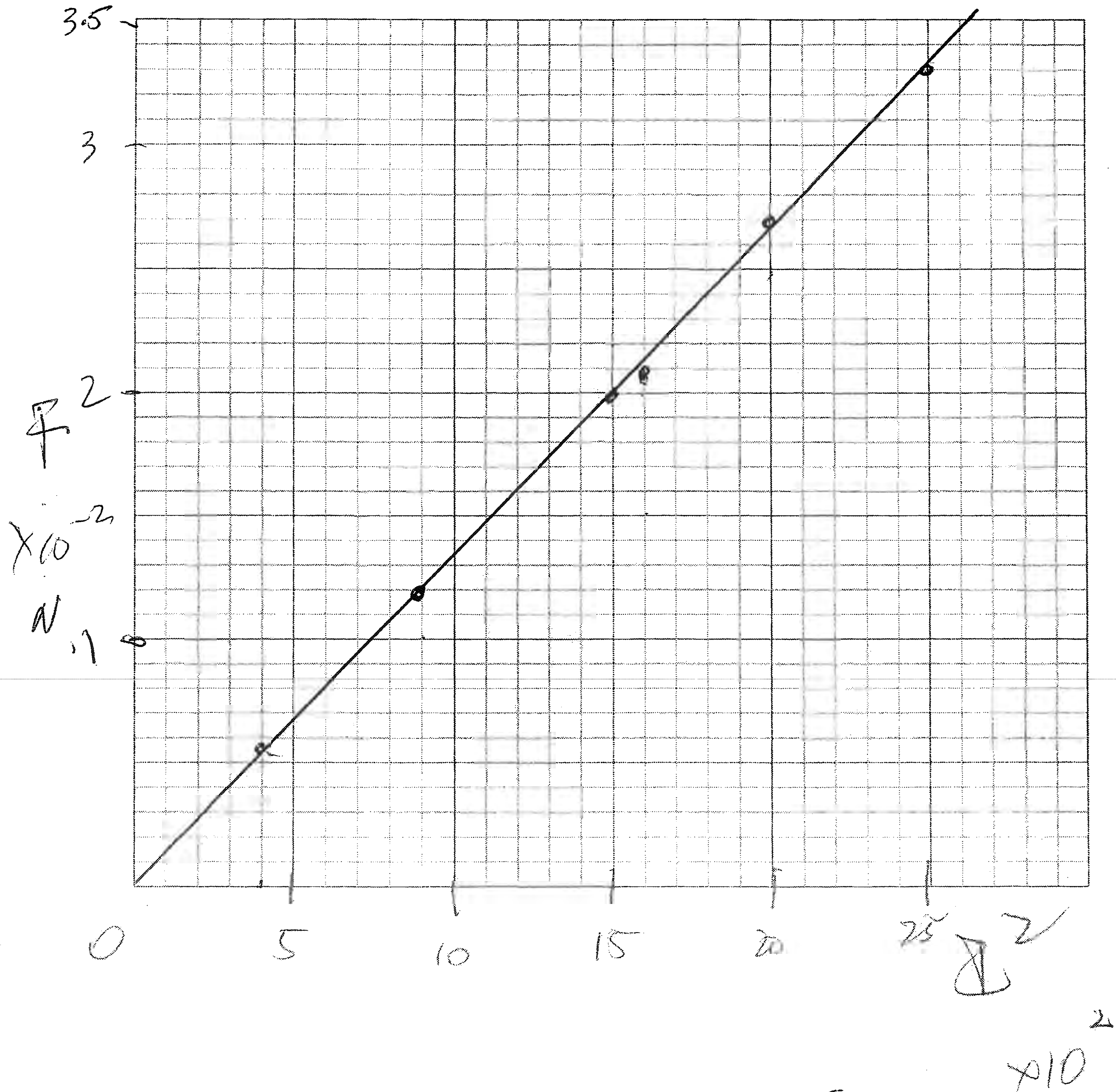
I (A)	Balance reading (g)	I^2 (A^2)	Force between wires (N)
20	0.55	4.0×10^2	5.4×10^{-3}
30	1.22	9.0×10^2	1.2×10^{-2}
40	2.18	1.6×10^3	2.1×10^{-2}
45	2.75	2.0×10^3	2.7×10^{-2}
50	3.40	2.5×10^3	3.3×10^{-2}

Question 25 continued on next page.

Candidate Number:____________________________

Question 25 continued. **Marks**

a) Use this data to draw a graph of the force between the wires (on the y-axis) against the current squared (on the x axis) on the grid provided below. **4**



Question 25 continued on next page.

4

−1 for anything wrong

Candidate Number:______________________________

Question 25 continued.

b) Determine the gradient of the graph. 2

$\frac{\text{rise}}{\text{run}} = \frac{2\times10^{-2}}{15\times10^{2}} = 1.3\times10^{-5}$

(1) (1)

c) Using your value for the gradient and any other relevant information, determine the separation, *d*, of the wires. 2

$\text{gradient} = \frac{kl}{d}$ (1)

$\therefore 1.3\times10^{-5} = \frac{2\times10^{-7}\times0.975}{d}$

$\therefore d = 1.5\times10^{-3}$ m (1)

Note If boys didn't use the gradient but simply substituted values into $F = \frac{kI_1I_2l}{d}$, the only (1) mark.

Candidate Number:______________________

Question 27 (3 marks) **Marks**

Explain how an AC induction motor operates 3

(1) Stator produces rotating $\vec{B}$

(1) Induces current in rotor (Faradays Law)

(1) Force on this induced current rotates the rotor (Lenz's Law)

Again, a good diagram was very helpful.

Candidate Number:________________________

Question 26 (3 marks)

Describe the application of the motor effect in a loudspeaker. 3

(1) Definition of motor effect.

(1) Correct description of ~~apparatus~~ the structure of a speaker.

(1) for variations in current in the voice coil (signal) cause vibrations in the cone which produces sound.

NB A good diagram aided answers immensly!

Candidate Number:__________________________

Question 28 (4 marks)

Discuss how energy losses in the transmission of electricity from the power station to the home are minimised.

4

AC used - more efficient + allows transformers to be used (1)

High V means low I to deliver same power ($P = IV$) (1)

low I means less ohmic heating ($P = I^2R$) (1)

NB Cause + effect must be clear

- High V means low I if same power

Candidate Number:____________________________

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Candidate Number:____________________________

Question 29 (3 marks) **Marks**

In the 19th Century experiments by Crookes using primitive cathode ray tubes failed to show the deflection of cathode rays by electric fields. Discuss how this and other observations resulted in a debate on the nature of cathode rays. 3

(1) Non deflection by Electric Fields suggests a wave property (or uncharged particle)

(1) But deflection by Magnetic fields suggests a charged particle

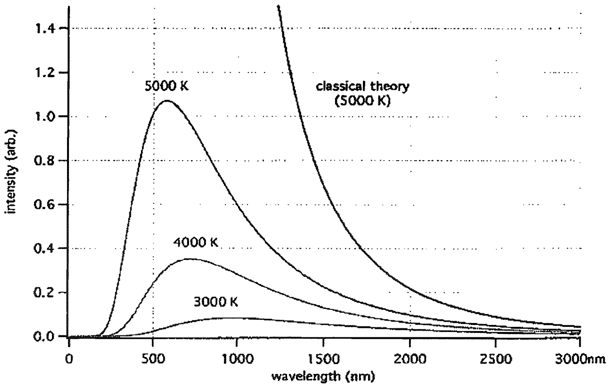
(1) Any other expt and what it suggests.

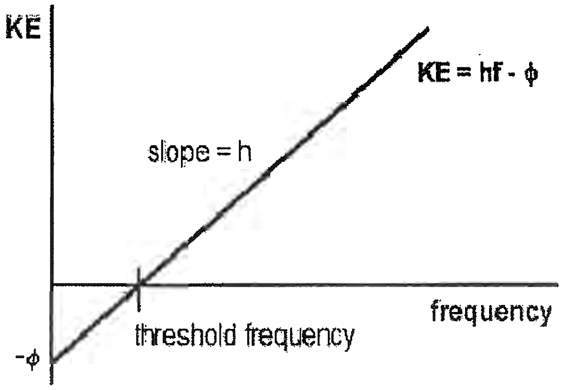
Many boys were very vague. They talked about expts but then didn't state what you could conclude.

Candidate Number:____________________

Question 30 (6 marks) **Marks**

Consider the following graphs which depict the results of experiments performed from the late 19th to early 20th century.





With reference to these graphs, discuss the importance of experiments in the development of quantum physics from classical physics. 6

To get 6 marks you need to address 3 areas for each graph.

① What was the classical model i.e energy was continuous or the energy of a classical wave was proportional to intensity

② What does each graph depict and why did the classical model fail.

③ What new concept did quantum physics introduce (i.e energy quantisation or photon model)

Many boys discussed the quantum model in detail but failed to explain what it replaced and why.

Candidate Number:_______________

Question 31 (6 marks) **Marks**

Two identical photons of wavelength 4.22×10^{-7} m are created when a certain amount of matter, M, is converted to energy.

a) Calculate the energy of one of these photons. 2

$E = hf = \frac{hc}{\lambda}$ (1)

$= 4.71 \times 10^{-19}$ J (1)

b) Calculate the mass, M. 2

$M = \frac{2(a)}{c^2}$ (1) $= 1.047 \times 10^{-35}$ kg (1)

common error $= 5.23 \times 10^{-35}$ kg (1)

c) If one of these photons collides with a piece of sodium of work function 3.65×10^{-19} J, calculate maximum kinetic energy of the electron emitted. 2

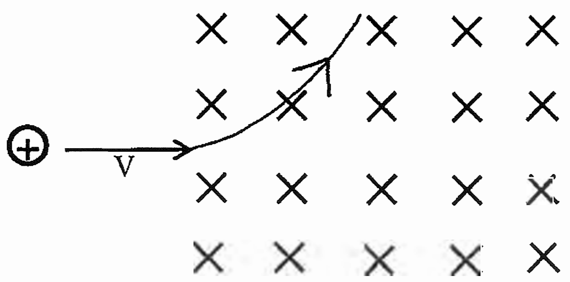
$KE = hf - 3.65 \times 10^{-19}$ J (1)

$= 1.06 \times 10^{-19}$ J (1)

Candidate Number:__________________________

Question 32 (4 marks) **Marks**

An experiment was performed in which a proton was fired into a magnetic field as shown below.



(1) any deflection

(1) curve upwards

(didn't accept ...)

a) Complete the diagram above to show the path of the proton in the magnetic field. **2**

b) Describe and explain the effect of increasing the initial velocity of the proton on its path in the magnetic field. **2**

$F = qvB = \frac{mv^2}{r}$ $\therefore r = \frac{mv}{qB}$ (1)

Increasing v increases r (1)

Question 36 – From Quanta to Quarks

(a) (i) allowed range $-1.8\,eV$ to $-1.4\,eV$ ✓① mk

(ii) $E_5 - E_3 = hf$ ✓① mk

$-0.60 - (-1.6) = 1.0\,eV$ (difference in energy)

$= 1.602 \times 10^{-19}\,J$.

(convert to Joule) ✓① mk

$E = hf$.

$f = E/h$

(substitute into $E = hf$ to find f) ✓① mk

$$= \frac{1.602 \times 10^{-19}}{6.626 \times 10^{-34}}$$

$= 2.42 \times 10^{14}\,Hz$.

OR/ $1/\lambda = 1.097 \times 10^{7} \left(1/3^2 - 1/5^2\right)$. ✓1mk

$1/\lambda = 780088.889$.

$\lambda = 1.282 \times 10^{-6}\,m$. ✓1mk

then $c = f\lambda$.

$f = 2.34 \times 10^{14}\,Hz$ ✓1mk

−1 mark for any mistake.

(b) (i) Marking code:

✓ ① mk D = statement of de Broglie's hypothesis with either $\lambda = h/mv$ or $mvr = \frac{nh}{2\pi}$.

e.g. De Broglie proposed that matter could exhibit wave-like properties. These two characteristics are linked through the equation $\lambda = h/mv$.

✓ ① mk S = mentions standing waves.

e.g He suggested that the stability of the electron orbits in the Bohr atom could be understood if the electrons were considered to be <u>standing waves</u>.

✓ ① mk λ = such waves would only exist if the circumference of the electron orbit was an integer number of wavelengths, i.e $n\lambda = 2\pi r$.

✓ ① mk N = numerical proof using the values given in the question.

$$\lambda = h/mv$$

$$= \frac{6.626 \times 10^{-34}}{9.109 \times 10^{-31} \times 2.36 \times 10^{6}}$$

$$= 3.08 \times 10^{-10}\ m.$$

$$\text{Circumference} = 2\pi r$$

$$= 2\pi \times 4.9 \times 10^{-11}$$

$$= 3.08 \times 10^{-10}\ m$$

∴ Circumference/λ = 1.

∴ whole number wavelength fits on circumference

∴ supports deBroglie proposal

- ① mk for any mistake.

(ii) Describe the process of nuclear fission and explain how it can lead to an uncontrolled chain reaction. **4**

This question was designed to assess your ability to synthesise information and present it logically. You should view questions like this as an opportunity to demonstrate your understanding of all **relevant** parts of the syllabus. In this case, that should include:

- **What the process of nuclear fission is including:**
  (1) Type of material
  (2) The role of neutrons
  (3) Splitting into two smaller fragments with release of more neutrons
  (4) How energy is released (e.g. $E=\Delta mc^2$)
- **The idea of a chain reaction** including the role of neutrons within fission.
- **The process of how an increased "neutron flux" causes an uncontrolled chain reaction.**

The question was marked holistically as follows:

Mark Range	Marking Criteria
4-3	An answer that: • demonstrates a good understanding of the process of nuclear fission (including the name or type of material that undergoes fission e.g. large or heavy nuclei, uranium-235). • demonstrates a good understanding of the principles by which a chain reaction occurs. • demonstrates a good understanding of the principles by which an uncontrolled chain reaction occurs.(i.e specifically the increase in number of neutrons causing an increase in fission reactions.) • is logical and clear and expressed in correct terminology.
2-1	An answer that addresses some of the points above including. • demonstrates a some understanding of the process of nuclear fission (including the name or type of material that undergoes fission e.g. large or heavy nuclei, uranium-235). • demonstrates a some understanding of the principles by which a chain reaction occurs. • demonstrates a some understanding of the principles by which an uncontrolled chain reaction occurs.(i.e specifically the increase in number of neutrons causing an increase in fission reactions.) (* i.e. essentially correct but lacking depth or detail)

NOTE: A GOOD, LABELLED DIAGRAM was a very effective way to illustrate the process of an uncontrolled chain reaction. **NOT ENOUGH BOYS ARE THINKING TO INCLUDE DIAGRAMS IN THEIR ANSWERS.**

Question 36 - From Quanta to Quarks

PARTS c) AND d)

a)

(i) Scientists estimate there may well be hundreds of millions of tonnes of Helium-3 in the rocks of the Moon, after being one of the isotopes ejected from the Sun's surface for billions of years. It is extremely rare on Earth, since our atmosphere and magnetic field prevent these solar particles reaching the surface.
Theoretically it could be used as a fuel for a fusion reactor as shown in this formula:

The masses of these species are given in the table:

Name	*Symbol*	*Mass (in amu)*
hydrogen-1	${}^{1}_{1}H$	1.007825
helium-3	${}^{3}_{2}He$	3.016029
helium-4	${}^{4}_{2}He$	4.002603

Determine the amount of energy released (in MeV) when two nuclei of helium-3 fuse together. **3**

Mass defect =(sum of mass of reactants)-(sum of mass of products)
Mass defect = 2*3.016029-(4.002603+2*1.007825) = 0.013805 amu

6.032058u (mass of reactants)-6.018253u (mass of products) = 0.013805 amu

Energy Produced 0.013805*931.5 = 12.8593575 MeV =
= 12.859 MeV
= 12.86 MeV
= 12.9 MeV
= 13 MeV

If the question asks that the answer be in MeV you are not answering the question if it not given in MeV.

Marking guidelines	
• Converts mass defect into change of binding energy or energy released in MeV AND • Correctly substitutes and calculates the mass defect AND • Demonstrates an understanding that the mass before the reaction is greater than the mass afterwards	3
• Correctly substitutes and calculates the mass defect AND • Demonstrates an understanding that the mass before the reaction is greater than the mass afterwards BUT • Cannot find the energy correctly	2
• Demonstrates an understanding that the mass before the reaction is greater than the mass afterwards	1

d)
(i) Describe an experiment you have performed to observe the spectrum of Hydrogen. 3

Marking guideline	
Identifies all components • High voltage induction coil • Vacuum/Discharge/emission tube with low pressure (near vacuum) hydrogen gas • Handheld spectrometer to view (identified and describing what it does) AND provides the method for observing the hydrogen spectrum (observations included or infered)	3
ONE aspect of the equipment is not adequately described or identified	2
TWO aspect of the equipment is not adequately described or identified	1

CREATION OF SPECTRUM: A **high voltage** (from a DC **induction coil**) was applied to a **low pressure vacuum discharge tube** containing only **hydrogen** gas.

VIEWING OF SPECTRUM: In a darkened room and with the induction coil turned on the light/glow from the discharge tube was viewed through a **handheld spectroscope**. This has a prism/diffraction grating that separated and **displayed the different wavelengths** of light making up the hydrogen spectrum.

Notes:

- As you are describing an experiment that you have done it should not be in the form of instructions.
- Safety notes such as (Care with high voltages and keeping distance from a possible x-ray source) are important and are a syllabus point that can be tested. But not in this case.
- "a current is passed through the vacuum tube" does not indicate **how** a current is passed through it and is therefore not a proper description of the experimental setup
- You should not simply say 'spectrometer' without some description or indication that you know what it is. Most spectrometers are large pieces of equipment that would take up a table. "Handheld spectrometer" is a better description of what was used. Describe what it does to demonstrate you -the pupil being examined -knows what it does-"it separates light into a spectrum"
- A gas tube is not 'filled' with hydrogen gas. There must be some indication that it is evacuated and mostly a vacuum.
- Good answers provided a diagram as this often compensated for their poor verbal descriptions.

ii) Explain how the spectrum of Hydrogen was significant in the development, acceptance and ultimate failure of the Bohr model of the atom. **7**

General Marking guideline	
• Complete answer that is well constructed in answering all aspects of the question and with no mistakes (some leniency given to m5)	7
• Describes development of Bohr model and how it explains the hydrogen spectrum • Describes validation of Bohr's model by deriving the Rydberg equation • Describes problems with the Bohr model	5-6
Some combination of • Identification of Bohr's postulates • Some description of how the hydrogen spectrum is produced • Identification of problems with the Bohr model	3-4
Identifies some facts about the Bohr model but is not specifically answering the question.	1-2

Notes: All parts of this answer should be related to the hydrogen spectrum

Specific Answer Analysis

Each answer was analysed to ascertain how well each aspect of the question was answered.

Note:

- This is not a definitive breakdown as some sections better answered could compensate for weaker areas
- It is expected that there was overlap with the following sections.

1. Significance of the hydrogen spectrum in the <u>development</u> of Bohr Model

D0	Various aspects or descriptions of the Bohr model are given (like compared to rutherfords model) but details are vague and not linking the hydrogen spectrum to the development of the model.
D1	May state details of the Bohr model but does not clear link to the significance of the hydrogen model OR Only identifies the discrete lines was what Bohr used to develop his model. OR Bohr's postulates not adequately described or linked to the development of the theory
D2	**Key Concept:** Bohr realised that the specific wavelengths emitted in the hydrogen spectrum (observation) were because of discrete transitions were occurring from different fixed energy levels (1st) that produced a photon of light (2nd postulate) • A thorough description of how the transitions are produced answers will include a • Bohr's postulates • Diagram of transitions.
D2*	A well answered section that may include • additional description of the Bohr model (central nucleus and electrons orbiting in shells) compared to the Rutherford model •

- Pupils who only describe Rutherford to Bohr model and state postulates are not properly answering this section.
- Hydrogen spectrum was empirically known (state Rydberg equation)
- Demonstration of how transitions produce the hydrogen spectrum

2. Acceptance of Bohr's Model by explaining hydrogen spectrum

- Bohr does not explain orbital stability or quantisation
- Bohr derives the Rydberg constant and equation using his postulates

A0	Answer does not cover how the Bohr model of the atom and his postulates explain the hydrogen spectrum
A1	Identifies that Bohr's model was accepted because it was able to explain the discrete lines in the hydrogen spectrum and justifies this by linking to his postulates BUT Does not clearly link how the Bohr model of the atom explains the hydrogen spectrum.
A2	**Key concept** Bohr uses his postulates to derive the Rydberg equation and Rydberg constant. This ability to explain and mathematically describe the hydrogen spectrum ALSO Can include how deBroglie later justifies the quantisation condition (3^{rd} postulate) Good answers will • Clearly link the postulates to the Rydberg equation • Include the Rydberg equation
A2*	A well answered description that also includes an description of how Bohr is able to derive the Rydberg equation (and constant) using his 3^{rd} postulate (quantised angular momentum)

Note: Lyman and Paschen series were known before Bohr's model. So Bohr did not predict their existence.

3. <u>Failure</u> of Bohr's model to explain aspects of hydrogen spectrum.
This section should be interpreted as: How was the hydrogen spectrum significant in the failure of the Bohr model?

- Aspects of Hydrogen spectrum not explained by Bohr model
  - Does not explain relative Line intensity
  - Does not explain hyperfine splitting
  - Does not explain Zeeman effect
- Other Aspects of Bohr model that led to its failure (not completely relevant)
  - Single electron systems only (but still the model explained hydrogen well)
  - DeBroglie later explains stability (Postulate1) and derives quantisation condition (Postulate 3)

- Quantum jumps not explained
- Postulates not justified
- Heisenberg and Schrodinger come up with more compete models of the atom
- Does not include Pauli exclusion principle or Heisenberg uncertainty principle

F0	
F1	Answers identify limitations but do not fully describe OR Are more general limitations of Bohr model not related to hydrogen spectrum
F2	Answers should include a description of at least 2 aspects of the hydrogen spectrum that could not be explained by Bohr's model.
F2*	Good answers with additional information

Codes
U - unnecessary/unneeded
E – Should have expanded this concept
CF – carried forward mistake
NAQ – Not answering the question
NA – not answered

Mistakes/Misconceptions
M1 - Confusing the Rutherford and Bohr model
M2 - Not understanding that the empirical Rydberg equation was proven by Bohr
M3 - Not clearly identifying who did what
M4 - Rydberg equation was an extension to Balmer equation was was developed before Bohr (the invisible spectrums were also measured before Bohr)
M5 - Lyman and Pachen series were known before Bohr's model. So Bohr did not predict their existence.
M6 – Rutherford's model did not fail to explain the hydrogen spectrum, it was not considered and it was known from its inception that it did not work because of the accelerating electrons emitting energy. Bohr was the one who realised that the hydrogen spectrum was giving clues to the structure of the atom by indicating that the electrons had fixed orbits.