SYDNEY GRAMMAR SCHOOL

CR1B

2006
FORM VI
TRIAL HSC EXAMINATION

Physics

General Instructions

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

Check List

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

Total marks (100)

Section I Pages 2 - 24

(75 marks)

This section has two parts, Part A and Part B

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

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

Section II Pages 25 – 28

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

Masters

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

SGS Answers 2006

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

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

Class

Candidate Number

Part B

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

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

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Marks

Question 16 (2 marks)

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

Explain why the modern metre is defined in this way.

The speed of light is constant for all observers… 1

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

NB general comments about 'accuracy' → max 1 mk

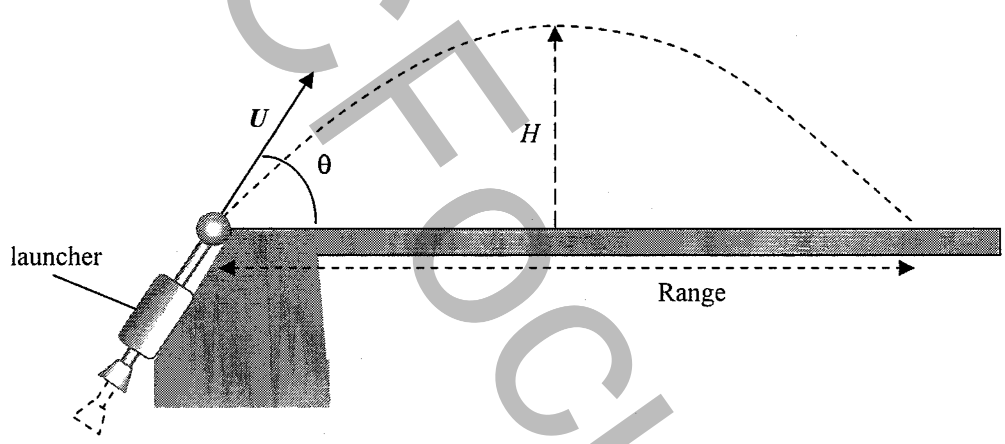
Class

Candidate Number

Marks

Question 17 (6 marks)

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



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

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

Result Table Test Run A

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

This question continues on the next page.

Class

Candidate Number

Question 17 (cont) **Marks**

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

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

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

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

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

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

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

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

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

$t = 0.46s$ (1 mark)

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

$Range = U_H x\ t$

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

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

Class

Candidate Number

Marks

Question 18 (6 marks)

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

Astronomers Announce the Most Earth-Like Planet Yet Found Outside the Solar System

Taking a major step forward in the search for Earth-like planets beyond our own solar system, a team of astronomers has announced the discovery of the smallest extra-solar planet yet detected. "We keep pushing the limits of what we can detect, and we're getting closer and closer to finding Earths," said team member Steven Vogt, a professor of astronomy and astrophysics at the University of California, Santa Cruz.

The newly discovered "super-Earth" orbits the star Gliese 876, located just 15 light years away in the direction of the constellation Aquarius. The team measured the mass of the planet to be 5.9 Earth masses, and its radius to be 2.2 times that of the Earth. It orbits Gliese 876 with a period of 1.94 days at a distance of 3.15×10^9 m.

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

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

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

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

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

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

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

This question continues on the next page

Class

Candidate Number

Question 18 (cont) **Marks**

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

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

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

$M = 4 \text{ x } \pi^2 \text{ x } (3.15x10^9)^3$ *(1 mark)*

$M = 6.6x10^{29}kg$ *(1 mark)*

Class

Candidate Number

Marks

Question 19 (6 marks)

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

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

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

Class

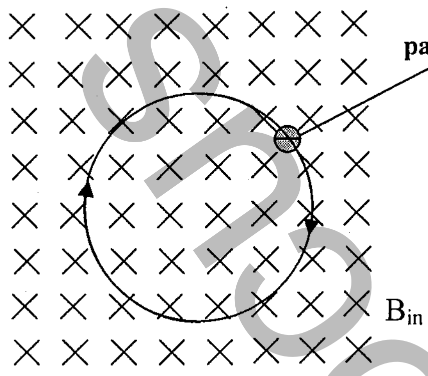
Candidate Number

Section I – Part B (continued)

Marks

Question 20 (4 marks)

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



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

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

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

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

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

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

Class

Candidate Number

Marks

Question 21 (4 marks)

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

FD = function difference

$$\left.\begin{array}{l}\textit{AC generator : mechanical energy} \rightarrow \textit{electrical energy} \\ \textit{DC motor : electrical energy} \rightarrow \textit{mechanical energy}\end{array}\right\} \textit{must have both for 1 mark}$$

SS = same structure

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

SD = different structure

split ring commutator versus slip ring commutator (1 mark)

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

Question 22 (3 marks)

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

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

$F/l = KI_1I_2/d$

$= \dfrac{2x10^{-7} \times 1.78x10^2 \times 1.78x10^2}{4}$ *1 mark for correct substitution into correct formula*

$= 1.58x10^{-3} Nm^{-1}$ *repulsion (1mark for answer and 1 mark for repulsion)*

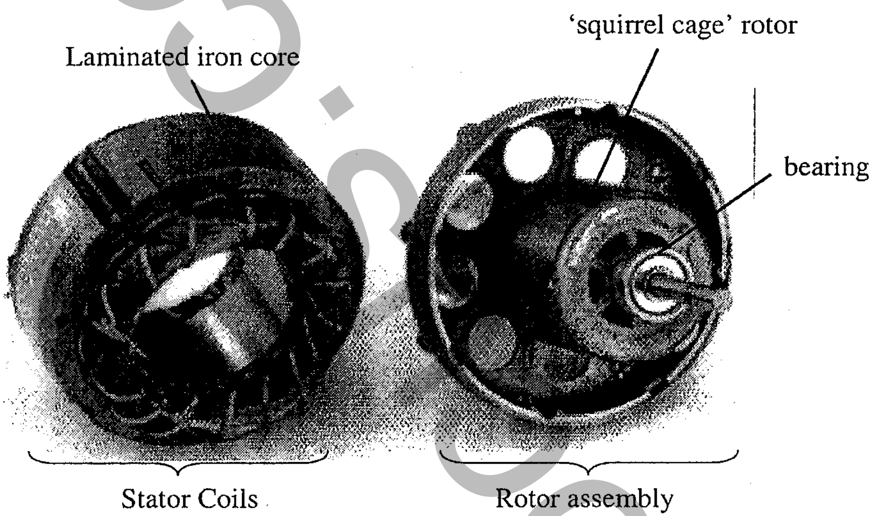
Class

Candidate Number

Marks

Question 23 (4 marks)

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



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

Produces a (rotating) magnetic field

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

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

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

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

Class

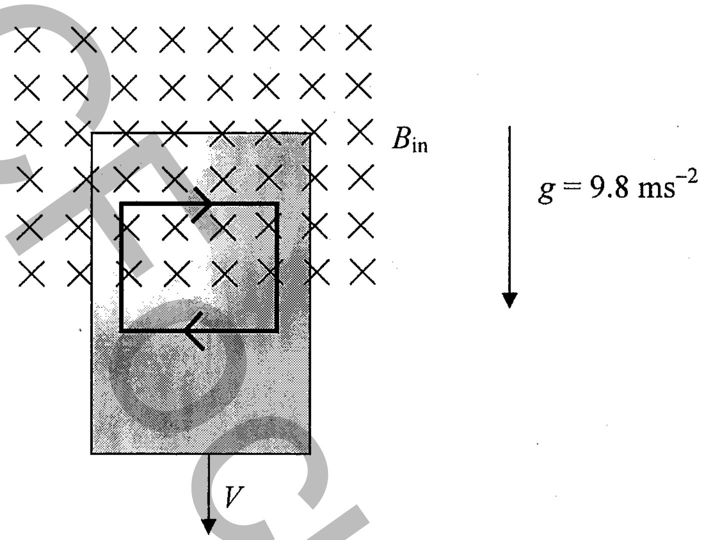
Candidate Number

Marks

Question 24 (5 marks)

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

loop must be in filed and outside field



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

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

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

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

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

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

Class

Candidate Number

Section I – Part B (continued)

Question 25 (3 marks)

Marks

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

radio waves travel at c (1 mark)

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

∴ light is e/m (1 mark)

Class

Candidate Number

Marks

Question 26 (4 marks)

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

Observations:

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

2 marks for well described observation

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

Einstein:

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

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

$\mathcal{E} = hf - hf_o$

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

1 mark for Einstein's photons

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

Class

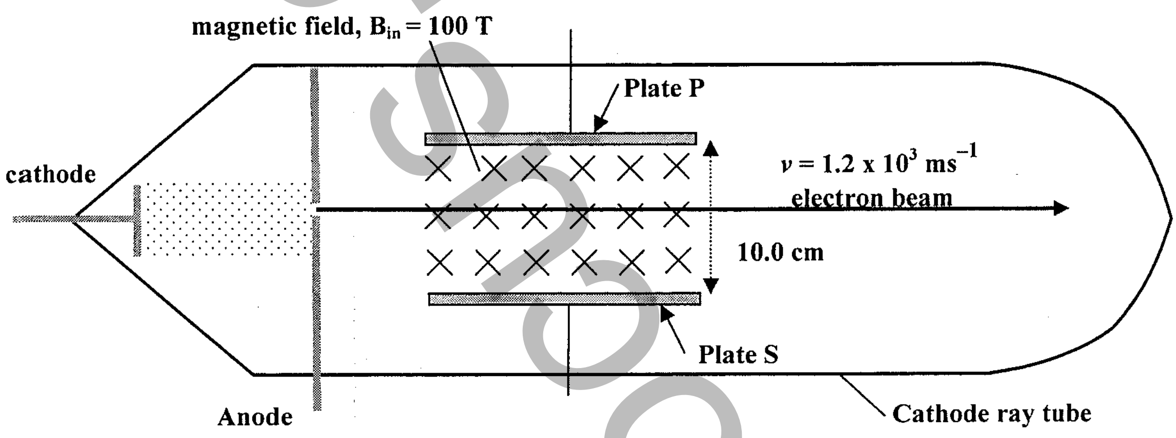
Candidate Number

Marks

Question 27 (6 marks)

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

The magnetic field has a magnitude of 100 T.



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

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

$F = Bqv$

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

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

This question continues on the next page

Class

Candidate Number

Marks

Question 27 (cont)

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

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

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

i.e. $1.92 x 10^{-14} N$ *Up (1 mark)*

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

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

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

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

Class

Candidate Number

Marks

Question 28 (7 marks)

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

3 for current savings

e.g. high voltage ∴ low current

reduce ohmic heating

AC is more efficient

laminations of cores in transformers

4 for superconductors

1 each for two advantages/features

1 each for two disadvantages

Note: max of 5 if no negatives of superconductors mentioned

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Section II

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

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

		Pages
Question 31	**Elective 1**	
Question 32	**Elective 2**	
Question 33	**Elective 3**	
Question 34	**From Quanta to Quarks**	**26**
Question 35	**Elective 5**	

Marks

Question 34 - From Quanta to Quarks (25 marks)

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

Typical answer

Iridium 192
Is used to inspect metal parts and welds for defects. The radiation passes through the object being inspected and an image is recorded on film.

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

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

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

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

Where:

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

Question 34 continues on the next page

Question 34 continued **Marks**

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

Typical answer

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

OR

When an electron makes a transition between one state an another, the event is accompanied by the emission or absorption of a quantum of radiation (a photon).

AND

***The energy change** is equal to the difference in energy between the two states **and this energy becomes a photon** with energy:*

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

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

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

Where:

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

SAMPLE ANSWER

Note: more mathematical steps may be shown.

- *Bohr postulated that when an electron in the hydrogen makes a transition from a higher energy state to a lower state that radiation is emitted in the form of a photon with an energy equal to the difference between the energies of the initial and final states.*
- *Using the energy state equation given:* $E_n = \frac{E_1}{n^2}$

  the equation for the change of energy when an electron makes a transition is:

  $$\Delta E = E_1\left\{\frac{1}{n_f^2} - \frac{1}{n_i^2}\right\}$$

- *the energy change above is equal to the energy of the photon emitted during the transition, therefore:*

  $$hf = E_1\left\{\frac{1}{n_f^2} - \frac{1}{n_i^2}\right\}$$

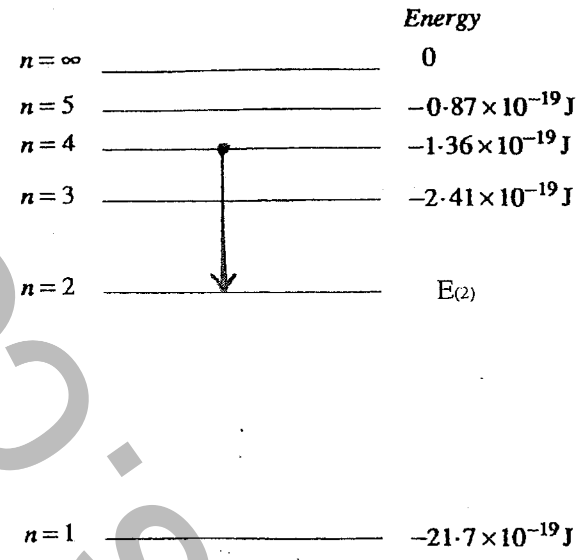
- *Expressing the energy change in terms of wavelength*

  Since $\Delta E = hf = \frac{hc}{\lambda}$ then $\frac{1}{\lambda} = \frac{E_1}{hc}\left\{\frac{1}{n_f^2} - \frac{1}{n_i^2}\right\}$

- *Bohr equation is a mathematical model that allows for the prediction of the wavelengths in the hydrogen spectrum. Bohr's equation has the same form as the empirical equation of Balmer for the hydrogen spectrum and the value of the Rydberg constant, determined empirically, can be evaluated from the theoretical constant of the Bohr equation. The values of the constant is the same in both equations. Thus the Bohr model of energy change during electron transitions accounts for the empirical equation of Balmer.*

- *Substituting* $n_f = 2$ *and the various values of* $n_i = 3, 4, 5$, *in the Bohr equation allows for the calculation of the wavelength of lines in the Balmer series. The predicted wavelengths calculated in this way are equal to the wavelengths measured in experiments. Thus the Bohr model of energy change during electron transitions accounts for emission lines in the Balmer series.*

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



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

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

$f = \frac{c}{\lambda}$ $\quad$ $f = \frac{3 \text{ x } 10^{8}}{4.86 \text{ x } 10^{-7}}$ **1**

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

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

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

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

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

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

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

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

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

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

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

<table>
<tr><td></td><td>Marking Criteria</td></tr>
<tr><td></td><td>Outlines two contributions made by Heisenberg to atomic theory

Examples are in the following list:
Developed matrix mechanics to apply quantum theory to the atomic model and replacing the ad hoc model of Bohr.
Developed the uncertainty principle that stated $\Delta x.\Delta p = \frac{h}{2\pi}$
Proposed an atomic nucleus consisting of protons and neutrons</td></tr>
<tr><td></td><td>Outlines two contribution made by Pauli to atomic theory

Examples are in the following list:
Proposed the exclusion principle that no two electrons in the same atoms can have the same quantum state (ie the same set of 4 quantum numbers).
Proposed the fourth quantum number for electron spin.
Derived the Balmer equation using quantum mechanics.
Predicted the existence to the neutrino to explain the conservation of energy and momentum in beta decay.</td></tr>
<tr><td></td><td>Assesses the contributions made by Heisenberg to atomic theory

Examples are in the following list:
Quantum theory and the uncertainty principle produced a model of the atom in which the electrons exist in electron orbitals that were more in the nature of probability clouds than simple circular orbits of Bohr.
The uncertainty principle was consistent with the idea that electrons have a wave nature when in a quantised energy state</td></tr>
<tr><td></td><td>Assesses the contributions made by Pauli to atomic theory

Examples are in the following list:
The exclusion principle explained the numbers of electrons in each quantum level of the atoms in the periodic table and explained chemical properties such as valency an group similarity of elements.
The four quantum numbers explained aspects of the hydrogen spectrum such as hyperfine spectral lines and Zeeman splitting due to strong magnetic fields
The existance of the neutrino explained the decay of a neutron into a proton and increased our knowledge of the substructure of the atom.</td></tr>
</table>