STANSW

Section I - Part A.

Total : 15 marks

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

Section I - Part B.

Total : 60 marks

16. (a) (1 mark)

MARKING GUIDELINES	
Criteria	**Marks**
Correctly states both period and amplitude	1

Specimen Answer:

The period is 1.80 s and the amplitude is 140 mm.

16. (b) (1 mark)

MARKING GUIDELINES	
Criteria	**Marks**
Shows correct equation and uses correct data for l and value of Period from (a). Correctly calculates answer based on values used.	1

Specimen Answer:

The acceleration due to gravity can be determined using;

$$T = 2\pi\sqrt{\frac{l}{g}} \quad \therefore g = \frac{4\pi^2 l}{T^2} \quad \therefore g = \frac{4\pi^2 \times 0.80}{1.8^2} \qquad g = 9.75 \text{ ms}^{-2}.$$

16. (c) (3 marks)

MARKING GUIDELINES	
Criteria	**Marks**
States that data collection will be repeated and different lengths will be included with results used to draw a graph where the line of best fit is used to calculate 'g' and improve the reliability of result.	3
States that data collection will be repeated and different lengths will be included	2
States that the collection of data would be completed more than once	1

Specimen Answer:

The reliability of the result could easily be improved by repeating the collection of the results and including several other different measured length pendulums. Using the data from the different lengths, a graph of the "Period squared" versus the "length" of the pendulum could be drawn. Using the slope of the line of best fit from the graph, and considering the relationship

$g = \frac{4\pi^2 l}{T^2}$ allows a more reliable value of gravity to be calculated using the graph of results.

17. (3 marks)

MARKING GUIDELINES	
Criteria	**Marks**
Clear description of relationship between kinetic energy, escape velocity, and the gravitational potential energy at the surface. Shows relevant equations and relates them to show how escape velocity can be calculated.	3
Clearly relates required kinetic energy to gravitational potential energy at surface and shows, by word or equations relationship.	2
Mentions kinetic and gravitational potential energy or shows relevant equations	1

Specimen Answer :

Newton considered that for an object to break free from Earth it would require need sufficient kinetic energy to carry the object far enough away to reduce the gravitational potential energy of the object to zero, i.e. it will be so distant that the gravity of Earth has no effect. Applying the ideas from his gravitational theory, Newton produced the relationship shown below; where E_P is the gravitational potential energy of the object on the surface of Earth, and E_k is the necessary kinetic energy to have the required escape velocity, v_{es}, to allow the object to leave the surface and break free from Earth's gravity.

$$E_P = -G\frac{m_E m_o}{r_E} = E_k = \tfrac{1}{2} m_o v_{es}^2 \quad \text{or} \quad \tfrac{1}{2} v_{es}^2 = -G\frac{m_E}{r_E}$$

$$\text{giving} \quad v_{es} = \sqrt{-2G\frac{m_E}{r_E}}$$

18. (a) (2 mark)

MARKING GUIDELINES	
Criteria	**Marks**
Correctly calculates acceleration	2
Applies F=ma but fails to consider weight	1

Specimen Answer:

Since mass of rocket and payload = 4.80×10^5 kg, then weight = 4.704×10^6 N.
The thrust is 1.43×10^7 N, therefore, resultant force UP = 9.596×10^6 N.

Now F= ma, therefore; $a = \frac{F}{m} = \frac{9.596 \times 10^6}{4.8 \times 10^5} = 20.0\, ms^{-2}$ up

Average acceleration of rocket over first second = $\underline{20.0 \text{ ms}^{-2}}$ up.

18. (b) (3 marks)

MARKING GUIDELINES	
Criteria	**Marks**
Explains how gravity provides centripetal force, showing relationship using appropriate equations, and clearly indicating how orbital velocity and known values allow the altitude to be calculated	3
Explains how gravity provides centripetal force and shows relationship using appropriate equations. Offers some explanation to show how orbital velocity allows radius of orbit to be calculated	2
States required centripetal force found using speed and radius of orbit and this is created by gravity	1

Specimen Answer:

The centripetal force to maintain the circular orbit of the satellite is provided by its gravitational attraction to the Earth, i.e. $F_c = F_g$. Relating equations produces,

$G\frac{m_E m_s}{r_s^2} = \frac{m_s v_s^2}{r_s}$ or $r_s = G\frac{m_E}{v_s^2}$ where r_s is the radius of the satellites circular orbit.

Now $r_s = r_E + \Delta h$, where Δh is the average altitude of the satellite above the surface of the Earth of radius r_E. Thus by using the known value for G the Universal Gravitation constant, and the data for the mass, m_E, and radius, r_E, of the Earth, these values and the known orbital velocity, v_s, can be substituted in to the equations shown to allow Δh, the altitude of the satellites orbit, to be calculated.

19. (6 marks)

MARKING GUIDELINES Criteria	Marks
Coherent answer with all detail on basis for experiment and "null" result. Includes detail on why the aether was proposed, its nature, and reasons for the supposed aether wind, Describes use of a sensitive interferometer to compare speed of light along two identical perpendicular paths to detect change in speed through an observable change in interference pattern. Suggests unsettled was to do with prevailing model of light and the existence of an aether and states that experiment did show speed of light was constant.	6
States that experiment was to detect aether wind and there was "null" result. Provides clear information on why the aether was proposed, its nature, and reasons for the supposed aether wind, Describes use of a sensitive interferometer to compare speed of light along two identical perpendicular paths with change in speed producing an observable change in interference pattern. Infers unsettled was to do with prevailing model of light and the existence of an aether. States experiment shows speed of light constant.	5
States that experiment was to detect aether wind and there was "null" result. Gives information on why the aether was proposed, and reasons for suggested aether wind, Describes use of a sensitive interferometer **and**// states or infers, to compare speed of light along two perpendicular paths to create an observable change in interference pattern. Attempts to discuss nature of "unsettled" and suggests speed of light doesn't change.	4
Mentions that experiment was to detect aether wind and there was "null" result. Gives information on why the aether was proposed and reasons for suggested aether wind, Describes use of a sensitive device **or**// interferometer **and**// states or infers, to compare speed of light along two paths **or**// observe change in interference pattern	3
Mentions that experiment was to detect aether and there was "null" result. Describes use of a sensitive device **or**// interferometer **and**// states or infers, to compare speed of light along two paths **or**// observe change in interference pattern	2
Mentions that experiment was to detect aether and there was "null" result. Used a sensitive device or// used an interferometer	1

Specimen Answer:

The Michelson-Morely experiment was a determined effort, using a very sensitive interferometer as part of the apparatus, in an attempt to detect the hypothesised "Aether wind". According to classical wave theory and Maxwell's electromagnetism, there should exist an all pervading medium occupying all free space, in order for light waves to be able to travel through the vacuum of space. This mysterious medium termed the aether had long been looked for, with it suggested that, because of the movement of the Earth on its axis and around the Sun, there should be an observable change in the speed of light created as the aether swept over the surface of the moving Earth creating the so called "Aether wind". Michelson's interferometer allowed the speed of light along two identical perpendicular paths to be compared. Any change in the speed of the light along one path would produce a clearly observable change in the interference pattern the interferometer produced. Despite the experiment being repeated many times in varied locations, there was never any change observed in the interference pattern. This "null" result was the issue "unsettled" by Michelson as many scientists, including Michelson, were confident that, based on what they thought was a complete understanding of light, the aether did exist and that the apparatus used would be sensitive enough to detect any aether wind. What the experiment did show, although at that stage it wasn't fully realised, was that the speed of light did not change and remained the same irrespective of the frame of reference from which it is observed. The issue was finally settled by Einstein as part of his Special Relativity theory in 1905.

20. (4 marks)

MARKING GUIDELINES Criteria	Marks
Coherent answer that states torque begins at maximum and correctly explains how torque changes as coil rotates with support from equation or equivalent in words and clearly explaining the influence of the coils motion on inducing a back-emf and reducing torque driving coil.	4
States torque begins at maximum and correctly describes how torque changes as coil rotates offering support from equation or equivalent in words. **but**// not clearly explaining the influence of the coils motion	3
States torque begins at maximum and correctly describes how torque changes as coil rotates **but**// language weak and failing to consider motion	2
States torque begins at a maximum and reduces to zero at 90^0 and then increases and decreases as the coil rotates	1

Specimen Answer:

The torque applied to the coil of a simple DC motor varies according to the equation, $\tau = n\ B\ I\ A \cos\theta$, where θ is the angle between the plane of the coil and the magnetic field. As θ is zero when the motor is first switched on, the torque acting on the motor coil will be at a maximum value and cause the coil to rotate clockwise (left side moves up). As the motor coil moves, the torque will begin to reduce and reach zero as $\theta = 90^0$. Although the torque is zero, the inertia of the moving coil maintains the rotation and at this point the split-ring commutator switches contacts and current begins to flow in the opposite direction in the coil. This causes the torque on the coil to act in the same direction. As the rotation continues the torque increases until, having completed 180^0, it will again be a maximum value. This pattern, of torque rising to a maximum when the plane of the coil is parallel to the magnetic field and then reducing to zero as the plane of the coil reaches 90^0, will be maintained as the coil speeds up, however, because the conductor of the motor coil is cutting magnetic flux an emf is induced according to Faraday's and Lenz's laws. This back-emf created increases as the speed of the rotating motor coil increases. This reduces the size of the current that flows through the coil. This leads to the maximum value of the torque reducing as the motor speeds up and then having a steady value once the motor achieves full speed.

21. (a) (2 mark)

MARKING GUIDELINES Criteria	Marks
States current N to M and shows equation with substitution of correct values.	2
Shows equation and substitution of data into equation.	1

Specimen Answer:

Considering the rod moves to the right, the current must flow N to M through the rod. The size of the force given by $F = B\ I\ l$ = 0.25 x 8.4 x 0.15 = 0.315 N to the right.

21. (b) (3 mark)

MARKING GUIDELINES Criteria	Marks
Explains how Faraday's law suggests motion of a conductor through a magnetic field will induces an emf and according to Lenz's law this opposes the motion by reducing the size of the current and as a result the magnetic force pushing the rod.	3
Describes how motion induces emf according to Lenz's law and this opposes the motion by reducing the size of the current and as a result the magnetic force.	2
Suggests motion will produce back-emf and force will be reduced	1

Specimen Answer:

According to Faraday's law the motion of the rod through the magnetic field will induce an emf across its ends. From Lenz's law the direction of this induced emf will oppose the change that created it, i.e., a back-emf will be produced as the rod begins to move. The size of the back-emf is proportional to the speed of the rod through the magnetic field. As the rod begins to move and its speed increases, the increasing back-emf generated will reduce the size of the current flowing, and, since $F = B\ I\ l$, this will reduce the size of the magnetic force pushing the rod along the rails until a constant speed is achieved.

22. MARKING GUIDELINES (4 marks)

Criteria	Marks
Coherent answer including clear description of transformer components and principles involved in inducing a voltage in the secondary coil. Describes "ideal" and supports statement with equation or equivalent in words. Comments on relationship between voltages and number of coils.	4
Describes transformer and components with some support from equation or words to describe "ideal". Describes magnetic linking of coils and use of AC to allow field to induce voltage in Secondary coil.	3
Offers some description of transformer and one relevant consideration to transform voltage	2
Mentions transformer and offers at least one relevant consideration to transform voltage	1

Specimen Answer:

To change the voltage of a source of electrical energy to a different voltage requires a transformer. A transformer consists of two coils of wire; the primary coil, attached to the source of electrical energy (voltage), and the secondary coil, which provides a different voltage to operate a second circuit. The primary and secondary coils are magnetically linked via a soft iron core (yolk). In an ideal transformer the output power from the secondary coil is equal to the input power to the primary coil, i.e. $V_1 I_1 = V_2 I_2$. To operate, the transformer must have the primary coil attached to a supply of AC. This is necessary as it results in changing magnetic fields being produced by the current in the primary coil that can influence the conductors in the secondary coil to induce a voltage. The size of the voltage induced in the secondary coil, V_2, compared to the voltage supplied to the primary coil, V_1, is determined by the ratio of the number of loops of wire in the primary coil, n_1, compared to the number in the secondary coil, n_2, and given by the relationship; $\frac{V_1}{V_2} = \frac{n_1}{n_2}$

23. MARKING GUIDELINES (7 marks)

Criteria	Marks
Coherent answer that relates choice of AC to ability to efficiently be transformed to use high voltage to increase efficiency of transmission over long distances, offering support through equations or relevant words. Outlines steps involved in large scale power supply to consumers including reasoning. Includes comment on both positive and negative effects on society **and**// both positive and negative effects on the environment.	7
Relates choice of AC to ability to efficiently be transformed to increase efficiency of transmission over long distances, offering support through equations or relevant words. Outlines steps involved in large scale power supply to consumers including reasoning. Includes comment on at least one positive and one negative effect on society **and**// one positive and one negative effect on the environment.	6
Relates choice of AC to ability to efficiently be transformed to increase efficiency of transmission over long distances, offering support through equations or relevant words. Outlines steps involved in large scale power supply to consumers. Includes comment on at least one positive and one negative effect on society and an effect on the environment.	5
Provides reasons for AC choice referring to transmission over long distances and use of transformers. Provides one relevant comment of effect on both society and environment	4
Weak answer but correctly referring to AC winning because of ability to e transformed. Makes a comment on one effect on society and environment	3
Very weak answer but with at least one relevant issue on **either**// AC vs DC/ Issue related to large scale power supply/effect of large scale power supply on society or environment	1 - 2

Specimen Answer:

The Westinghouse system used AC whereas the Edison system used DC. The main reason for the win to Westinghouse was the ability of AC to be efficiently transformed from one voltage to another, while transforming DC was very inefficient and problematic. The methods employed by the Westinghouse system paved the way to allow large scale electrical power supply to become a reality. The basis of the system provides for;

* Building large power stations in remote locations close to the source of energy to drive the generators
* Use of a step-up transformer to increase the voltage to transport the energy through transmission wires to the location of consumers. Since P=VI, this reduces the size of the current flowing through the wires and, because the power lost in a resistor is $P=R\,I^2$, significantly reduces the energy losses through the transmission wires.
* Use of step-down transformers close to the consumer to bring the voltage to a convenient and safer value for use by consumers.

This development of large scale electrical power supply has had both positive and negative effects on society and the environment. It has made possible many of the features of a modern society with electricity providing a very convenient power source to supply the needs of industry, business, commerce, scientific research facilities and an ever growing array of electrical devices, lighting, heating and transportation systems. This has made life much easier and, with the development of computers and communication technologies, allowed the information revolution and the rapid transmission of information around the world. It has however led to a much more sedentary lifestyle for many humans and the possible associated health problems that come from lack of exercise and growing exposure to electromagnetic radiations. It has also led in some cases to a total disregard for the Law of Conservation of energy with some societies increasing their electrical energy consumption at alarming rates and placing increasing demand on energy resources. When large scale electrical power supply developed there were initially some benefits to the environment; people no longer had to cut down trees for cooking and heating; and the previously local power stations were moved to more remote locations significantly reducing the amount of pollution in cities. In general, it can be suggested that the systems and the growing use of electrical energy by consumers have placed increasing demands on the environment as sources of energy are sought. This has led to increasing consumption of fossil fuels, the building of more and bigger dams, and the construction of nuclear facilities. The loss or disruption to the natural environment, the associated pollution and waste, and concerns with global warming, are all having a significant effect on the environment and are issues that modern humans will have to consider.

24. (a)

MARKING GUIDELINES	(1 mark)
Criteria	Marks
Correctly calculates magnetic field	1

Specimen Answer:

Since $F_{mag} = q\,v\,B$, then magnetic field, $B = 1.6 \times 10^{-15} / 2 \times 10^{5} \times 1.6 \times 10^{-19} =$ 0.05 T

24. (b)

MARKING GUIDELINES	(1 mark)
Criteria	Marks
States plate Y	1

Specimen Answer:

Plate **Y** will be positive.

24. (c)

MARKING GUIDELINES	(2 marks)
Criteria	Marks
States that electric force equals magnetic force and shows relation between Electric field strength and separation of plates. Correctly calculates voltage.	2
Infers or shows by equation that the Electric force must equal the magnetic force or// correctly calculates the voltage with no explanation	1

Specimen Answer:

In order for the cathode ray to travel through with no deflection the electric force, F_E, created by the electric field between the plates, must be equal to the magnetic force, acting, F_{mag}.

Since $F_E = q_e E$, and $E = V/d$, then; $V = \dfrac{F_E\ d}{q_e} = \dfrac{1.6\times10^{-15} \times 0.02}{1.6\times10^{-19}} = 200\,volts$

Required voltage across the plates = 200 V.

25. (a)

MARKING GUIDELINES	(2 marks)
Criteria	Marks
Shows or infers E=hf and v= fλ and correctly calculates energy of red photon.	2
Shows or states Energy = hf or// shows or infers v=fλ.	1

Specimen Answer:

Energy of photon given by E = hf and f = c/λ, therefore E = h c/λ. Substituting in values,

$$E = 6.626\times10^{-34} \times \frac{3\times10^{8}}{6.35\times10^{-7}} = 3.13\times10^{-19}\,J$$

Energy of each red photon from laser = 3.13 x 10^{-19} joules.

25. (b)

MARKING GUIDELINES	(2 marks)
Criteria	Marks
States electroscope will discharge through photoelectric effect if energy of photons is large enough and distinguishes between lower energy of laser compared to UV source.	2
States electroscope will discharge through photoelectric effect	1

Specimen Answer:

The students are likely to observe that; when shining the UV source on the zinc sheet the higher energy photons will have sufficient energy to release electrons from the zinc sheet through the photoelectric effect and the electroscope will discharge. When using the laser, because the energy of a red photon is likely to be too low (below required work function to release electrons from the zinc) the laser is likely to have no effect on the electroscope.

26.

MARKING GUIDELINES	(5 marks)
Criteria	Marks
Coherent answer using appropriate language to explain how extrinsic semiconductors have improved conduction through modification of the silicon lattice of the semiconductor with reference to valence and conduction bands. Describes p-type as doped with Gp3 element (& e.g.) and having positive holes while n-type are doped with Gp5 element (& e.g.) giving rise to extra electrons. Relates doping to the lower energy required to mobilise charge into conduction band producing a reduced resistance and states holes primary charge carrier in p-type and electrons as primary charge carriers in n-type.	5
Explains how extrinsic semiconductors have improved conduction through modification of the silicon lattice of the semiconductor. Describes p-type as doped with Gp3 element and having positive holes while n-type are as doped with Gp5 giving rise extra electrons. Relates doping to the lower energy required to mobilise charge and reduced resistance. States or infers states holes transfer charge in p-type while electrons transfer charge in n-type.	4
Explains p-type doped with Gp3 element and having positive holes while n-type are doped with Gp5 giving rise extra electrons. Relates doping to the lower energy required to mobilise charge and reduced resistance.	3
Explains p-type doped with Gp3 element and having positive holes while n-type are doped with Gp5 to give rise extra electrons	2
Describes p-type as having positive holes while n-type have extra electrons	1

Specimen Answer:

The p-type and n-type semiconductors are both extrinsic semiconductors that have improved conduction properties over intrinsic semiconductors created by the addition (doping) of particular impurities into the crystal lattice of silicon atoms. In p-type semiconductors, atoms of a Gp3 element from the Periodic table, e.g. gallium or boron, are combined into the silicon crystal lattice. Since silicon has four valence electrons and the Gp3 element only three valence electrons, a positive region termed a hole is left where silicon atoms are deprived of one of the electrons they need to bond with. The hole reduces the amount of energy required to mobilise charge into the conduction band of the semiconductor. When a p-type semiconductor experiences an electric field, an electron falls into a hole promoting the hole to the conduction band. The positive holes can then drift through the semiconductor lattice as a conventional current. In an n-type semiconductor the dopant element from Gp5 of the Periodic table, e.g. arsenic or phosphorus, has five valence electrons. This means that the extra electrons from the dopant element are not bound in the silicon lattice and are easily promoted into the conduction band when an electric field is applied. The electrons can then drift through the silicon lattice as a current. The conduction properties of n-type and p-type semiconductors are determined by the element that has been used to dope the silicon, giving rise to the primary charge carriers in a p-type being positive holes and in an n-type electrons.

27. (7 marks)

MARKING GUIDELINES

Criteria	Marks
Coherent, well organised answer including a description of the role of superconductors, cooled to very low temperature below critical temperature by refrigeration, in producing the required magnetic fields with DC to allow interactions with magnetic fields produced by coils in the track carrying regulated AC, to levitate and propel the train with much reduced friction to very high speeds. Mentions induction of currents in track coils assist in levitation and stability. Includes some description of how interactions occur making reference to levitation , propulsion, and stability coils in track. Refers to AC used in propulsion coils changing in frequency as speed of train increases.	7
Describes role of superconductors, cooled to very low temperature below critical temperature by refrigeration, in producing the required magnetic fields to allow interactions with magnetic fields produced by coils in the track to levitate and propel train, with the reduced friction allowing very high speeds. Includes some description of how magnetic interactions occur. Refers to AC used in propulsion coils changing in frequency as speed of train increases.	6
Describes superconductors, cooled to very low temperature below critical temperature, as producing strong magnetic fields that interact with magnetic fields produced by coils in the track to levitate the train above the track, with the reduced friction allowing it to reach very high speeds, refers to AC in track coils used to propel train.	5
Describes superconductors, cooled below critical temperature, as producing strong magnetic fields that interact with magnetic fields produced by the track to levitate the train above the track, with the reduced friction allowing it to reach very high speeds, mentions magnetism used to propel train	4
States that superconductors produce strong magnetic fields to repel the train and allowing it to levitate above the track, mentions magnetism used to propel train	3
Mentions superconductors used to produce powerful magnetic fields to levitate the train	1-2

Specimen Answer:

The Maglev train relies on the use of onboard "supermagnets" made from superconductor loops carrying large currents and producing very powerful magnetic fields. The interaction of the these onboard magnetic fields, and those produced by currents in an arrangement of coils in the special track (guideway), allow the train to be levitated, propelled, and stabilised on the track. In order for the superconductors to operate they must be cooled below their critical temperature. This requires the Maglev train to have onboard refrigeration units using liquid nitrogen (and liquid helium where Type I superconductors are used). For operation the Maglev train requires; A very large supply of electrical energy; A number of onboard refrigerated superconducting coils producing very strong magnetic fields (~ 5 teslas); A system of specially arranged metal coils lining a guideway (track) and; Large guidance magnets attached to the underside of the train.
There have been different forms of Maglev train developed but the basic operating principles are; - Onboard superconductor magnets produce a very strong magnetic field using DC current. - The levitation coils in the guideway are engaged to repel (or attract depending on model) the train causing it to levitate just above the track. (rubber wheels are used on one model until sufficient speed is produced to allow induced currents in coils in the track to create magnetic fields large enough to allow their interaction with the onboard magnets to fully levitate the train.) – The Propulsion coils in the guideway are supplied with AC to produce a unique magnetic field that both attracts and repels the onboard magnets. By controlling the frequency of the AC in the coils these magnets interact with the onboard magnets to accelerate the train to very high speeds, both pushing and pulling the train along the track, - There are also Stabilisation coils that act to attract or repel the train as it travels along the track, keeping it stable and allowing it to negotiate curves. Maglev trains are very expensive to build and maintain but they have shown that they can work very effectively. With their ability to hover just above the track they are very efficient when moving and have achieved very high speeds (over 500kph), relying for levitation, propulsion and stability, on the interactions of the magnetic fields produced by the onboard superconductor loops and the coils in the track.

Question 31 – Quanta to quarks

Total : 25 Marks

(a) (i) MARKING GUIDELINES (1 mark)

Criteria	Mark
States particle is a NEUTRON	1

Specimen Answer :

The particle is a NEUTRON.

(a) (ii) MARKING GUIDELINES (2 marks)

Criteria	Mark
States gluons bind both quarks **or**// most common forms of quark, **AND**// charges stated correctly for each particle	2
Describes gluons bind both quarks **or**// most common forms of quark, **or**// charges stated correctly for each particle	1

Specimen Answer :

Both Up and Down quarks exchange gluons in strong interactions and are the most common flavours of quark, together forming all the protons (UUD) and neutrons (UDD) found in normal matter. The UP quark has a charge of $+ {}^{2}/_{3}$, while the DOWN quark has a charge of $- {}^{1}/_{3}$. They have approximately the same mass with the UP quark just lighter.

(b) (i) MARKING GUIDELINES (2 marks)

Criteria	Mark
Mentions model was modified Rutherford nuclear model stating, or inferring, dense, tiny nucleus with majority of mass and all positive charge and outlines electrons in quantised energy levels with some mention of mathematical support **or**// detail on postulates.	2
Mentions model was modified Rutherford nuclear model stating, or inferring, electrons in quantised energy levels	1

Specimen Answer :

The model of the atom described by Bohr was a modified version of the Rutherford "Nuclear" model. The model had a nucleus at the centre of an atom where the majority of the mass, and all the positive charge, was located in an extremely dense, tiny region, only a fraction of the atom's size. Around the nucleus, and taking up the majority of the space occupied by the atom, were the orbits of tiny negatively charged particles, the electron. Bohr's modification to the Rutherford model was to suggest that the electrons, contrary to classical predictions, could be stable and orbit the nucleus in very particular positions, Bohr referred to as "stationary states", but were unable to exist anywhere else. Bohr postulated this stability was due to the angular momentum of the orbiting electron being quantised, and, that the energy radiated or absorbed by an atom, was an indication of the possible energy levels the electron could exist in. His model included mathematical equations to predict the energy levels of the orbiting electrons.

(b) continues on next page.

(b) (ii) MARKING GUIDELINES (2 marks)

Criteria	Mark
Describes how application of idea produced mathematical predictions of the spectra to be produced and this worked extremely well in accurately predicting known hydrogen spectrum and suggests that it was significant to support idea of quantised energy and inferring through description, or making reference to, Rydberg equation.	2
Suggests Bohr's idea worked well in predicting the spectra for hydrogen and mentions role of mathematics.	1

Specimen Answer :

Bohr had produced mathematical equations to predict the possible energy of the electron in the quantised states (possible energy levels). With hydrogen the simplest atom, the initial results were extremely promising and worked extremely well in accurately predicting the expected wavelengths for the already well known hydrogen spectrum. Bohr was able to use his idea to produce a mathematical relationship to show the origin of the Rydberg constant, already used in an equation to calculate the wavelengths of different spectral lines for hydrogen. The fact that it was shown to relate to the energy of the electron in the lowest energy level, the speed of light and the "quantum" constant produced by Planck. This was very valuable in providing support for the idea of quantised energy.

(c) (i) MARKING GUIDELINES (2 marks)

Criteria	Mark
Explains force at this distance is entirely due to like charges repelling and inversely proportional to the square of the distance of separation.	2
States or infers force is due to like charges repelling	1

Specimen Answer :

The repulsive force at 3.0 fm is due entirely to the coulombic electric force acting between the two protons. This force, calculated using Coulomb's law, is inversely proportional to the square of the distance separating the protons.

(c) (ii) MARKING GUIDELINES (4 marks)

Criteria	Mark
Coherent answer using correct terminology and language ,clearly describing initial Coulombic repulsion until protons come within range of nuclear strong force and are drawn powerfully together. Makes relevant comment on distances including repulsion increasing dramatically as the protons come very close to each other.	4
Relates that graph shows that as distance reduces repulsive force increases rapidly due to like charge but, when the protons come within range, the nuclear strong force begins to act to powerfully attract protons together. Comments on strong repulsion at very near approach.	3
Relates that graph shows that as distance reduces increasing repulsive force due to like charge is overcome and nuclear strong force begins to act to powerfully attract protons together.	2
Relates that graph shows that as distance reduces repulsive force is overcome and nuclear strong force begins to act to powerfully attract protons together	1

Specimen Answer :

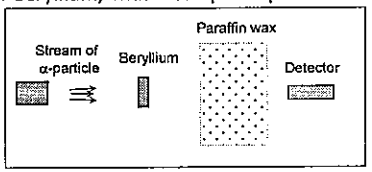
The graph shows that as the particles approach they are initially subject, due to their like electric charge, to Coulombic repulsion which increases quickly as the distance reduces. As the protons come closer together, at just over 1.5 fm, the protons begin to experience strong nuclear interactions and, as the distance reduces further, this attractive force eventually increases to such a large value that the repulsion of the like charge is overcome and the protons are strongly attracted toward each other. It is obvious that when the protons come within a distance of about 0.5 fm, the force again becomes repulsive and very rapidly increases as the distance reduces. The graph clearly shows why, when protons come close enough together, they are drawn powerfully together by the nuclear strong force, with Coulombic repulsion overcome and nuclear fusion occurring.

(d) MARKING GUIDELINES (5 mark)

Criteria	Mark
Concise answer using appropriate language and terminology with accurate description of Chadwick experiment with essential detail and mentions neutron scattering and at least two appropriate advantages of neutron as probe with reasons	5
Provides accurate description of Chadwick experiment with sufficient essential detail and mentions neutron scattering and at least two appropriate advantages of neutron as probe with reasons	4
Provides accurate but simple description of Chadwick experiment with little detail and mentions neutron scattering and one appropriate advantage with reason	3
Names or provides basic detail to recognise experiment by Chadwick and mentions neutron scattering and one appropriate advantage	2
Names or provides basic detail to recognise experiment by Chadwick **or//** mentions neutron scattering and one appropriate advantage	1

Specimen Answer :

The experiment to identify the neutron was carried out by James Chadwick in 1932. It involved directing α-particles at a sample of beryllium, with a sample of paraffin wax beyond the beryllium, and then a very sensitive detector beyond the paraffin, as shown. The α-particles were involved in a nuclear reaction with some of the beryllium atoms, i.e.



$$^{4}_{2}He + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$$

The neutrons produced by the reaction travelled on with large kinetic energy. Some of the neutrons were involved in head on collisions with the huge number of hydrogen nuclei (a proton) making up the paraffin wax with carbon atoms. This knocked the proton out of the paraffin molecule to go on to be detected, have its kinetic energy measured, and confirm the existence of the neutron.

The neutron is used as a probe to explore matter in "neutron scattering" experiments.

The main advantages of using the neutron as a probe include;

- being neutral, neutrons experience no electric forces with nuclei or electrons
- the mass of neutrons gives them wave properties whereby they generally have extremely small wavelengths allowing them to penetrate electron clouds to reveal fine detail on the structure of matter through their interactions with nuclei, or at 'thermal' speeds, the size and distribution of atoms in a molecule.
- The neutrons are very weak ionisers and, unlike X-rays, produce minimal interactions with electrons in atoms of target.

(e) MARKING GUIDELINES (7 marks)

Criteria	Mark
A coherent answer using the correct terminology and language, and clearly describing requirements for controlled fission reactions, providing suitable information on the role of each component. Outlines the three common roles for modern reactors with supporting information on how the reactors serve society.	7
A good description of requirements for controlled fission reactions providing basic information on the role of each component. Outlines the three roles for modern reactors with some supporting information.	6
Offers a good coverage of majority of requirements for controlled fission reactions but failing to give complete description of component role or lacking some important detail. Outlines at least two of the roles for modern reactors with some supporting information.	5
Includes majority of required components for controlled fission but without any reasoning or weak language and states two roles for modern fission reactors **or//** provides a fair description of only fuel and control rods needed for controlled fission reaction supported with an explanation and two roles for modern reactor.	4
Includes some of required aspects of controlled fission but without any reasoning or weak language and two roles for modern fission reactors **or//** provides a fair description of fuel and control rods needed for controlled fission reaction with some explanation and just one role for modern reactor	3
Includes some of required aspects of controlled fission but without any reasoning or weak language. Provides at least one appropriate role of modern fission reactor.	2
Weak answer with mention of fission of fuel but without detail of control features and providing at least one appropriate role of a modern nuclear fission reactor	1

Specimen Answer.

The basic requirements to produce controlled nuclear fission include;

- a suitable fissionable element, e.g. U-235, arranged in sufficient concentration in fuel rods.
- a initial source of neutrons to start the fission reactions. Once fission occurs the reactions yield more than enough neutrons to sustain fissions.
- A substance, e.g. heavy water, to act as a moderator through collisions to reduce the velocity of the neutrons produced during fission.
- A substance, e.g. cadmium, to absorb excess neutrons to control the number available to create fission reactions. This controls the rate at which the fission reactions occur.
- A heat extractor to remove the heat produced by the fission reactions and cool the fuel rods.

Presently fission reactors have three main applications,

- to provide a source of neutrons to carry on research like neutron scattering and to allow for the production of medical, industrial, agricultural, and scientific radioisotopes. These tend to be small reactors not producing enough energy for large scale power production.
- To provide heat to turn water to steam to drive electrical generators in a power station. These tend to be very large reactors with a large reactor core and producing substantially more wastes than research reactors.
- To produce plutonium and other transuranic elements for nuclear weapons. These tend to be larger reactors and run the fission reaction at higher temperatures to allow greater amounts of plutonium to form in the fuel rods from the fertile uranium 238.