PETRUS KY COLLEGE
NEW SOUTH WALES

in partnership with

VIETNAMESE COMMUNITY IN AUSTRALIA
NSW CHAPTER

JULY 2006

PHYSICS - SOLUTIONS

PRE-TRIAL TEST

HIGHER SCHOOL CERTIFICATE (HSC)

Student Number: | | | | |

Student Name: _____

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue 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 Centre Number and Student Number at the top of pages 1 and 8

TOTAL MARKS: 100

Section I

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 16–27

• Allow about 1 hour and 45 minutes for this part

Section II (Optional)

25 marks

• Attempt ONE question from Questions 28–32

• Allow about 45 minutes for this section

SUGGESTED SAMPLE ANSWERS

SECTION 1 – PART A

1 C Weight is mass time gravity ($W = mg$) where mass is the matter (that is unchanged) and gravity is the gravitational field of the Earth

2 B Low orbit satellites experience a friction drag due to higher gravitational force, must move fast hence experience a greater centripetal force. mv^2/r

3 D If the angle is too shallow it will bounce off and if too steep it will heat up to much.

4 A $\tau = Fd = (1.4\times10^{-4}\,N)(5.10^{-2}\,m) = 7.10^{-6}\,Nm$ each side. So total torque $= 2\tau = 1.4\,10^{-5}\,Nm$.

5 B Strongest magnetic field is when the flux is the highest

6 C Considering a DC supply, the surge of current on closing the switch will induce an emf as the field in the primary coil is established, but this will return to zero once the DC current establishes a constant magnetic field, i.e. ceases to change size.

7 A The direction of an electric field is that in a positive test charge it moves out and in a negative test charge it moves in. Long stroke of a battery diagram is positive & short stroke is negative

8 B Electrodes in the electron gun is the component that focus the beam, control brightness and accelerate electrons along the tube.

9 C The solid copper ring allows the emf induced to create eddy currents that will oppose its motion. Although charges in the other rings experience forces, in the plastic ring no charge is available to move, and because of the break in the copper ring, the emf although established, does not have a complete circuit, so current cannot flow.

10 B The orientation of the iron sheets is such that only very small eddy currents will be allowed to flow, (smaller than in other cores), and as such the energy losses due to the core heating will be reduced.

11 B The paddle wheel rotates due to the momentum imparted from the cathode rays.

12 A Max Planck was the first to provide a solution to correctly predict blackbody radiation curves using his idea of quantised energy to explain the results.

13 A The diagram is one that shows a dopant level that indicates a vacant position in the lattice, suggesting a p-type semiconductor doped with a Group 3 element. Boron is the only Group 3 element shown.

14 ~~A~~ From experiment (see Physics course)

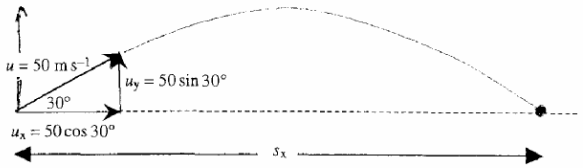
15 C Slope of the line is the Planck's constant, so it should be the same But different metal corresponds different frequency of light

SECTION 1 – PART B

Question 16

either:

The projectile is launched from the surface over horizontal ground.



Now $s_y = 0$ m, and $s_y = u_y t + \frac{1}{2} a_y t^2$, $\therefore 0 = 50 \sin 30° \, t - 4.9t^2$,

$\therefore t = \frac{2.5}{4.9} = 5.10$ s.

Now $s_x = u_x t = 50 \cos 30° \times 5.1 = 221$ m. Range = 221 m.

OR: For x component (horizontal) $u_x = 50 \cos 30°$, $a_x = 0$
For y component (vertical) $u_y = 50 \sin 30°$ $a_y = -g$. From $u_y = v_y + at \Rightarrow t = \frac{v_y}{a} = 2.55^s$

Time of flight $= 2t = 5.10$ s. S_x = Range $= v_x t = 50 \cos 30° \times 5.1 = 221$ m.

Question 17

(a) One prediction from special relativity was that time was relative and time dilation would occur when observing an object travelling at relativistic speeds. This would result in the time recorded by a stationary observer of a fast moving object being longer than the time for the same event measured by an observer in the moving frame of reference.

(b) A test for time dilation could involve measuring the time taken for an unstable particle, e.g. a muon, to decay when observed at rest compared to when travelling at very high speeds. This is possible as muons can be produced on Earth in particle accelerators and studied at rest, and their decay rate compared with the very high speed muons produced when high energy cosmic radiation encounters atmospheric gases about 100 km above the surface. The results show that at rest the decay rate is on average about 2.2 μs, while the information collected by sensitive detectors has shown that when travelling at very high speed, this decay rate is measured to be much longer, as predicted by special relativity.

(c) The technological advances since 1905 that have made this experiment possible are the development of the various technologies utilised in particle accelerators including the sensitive detectors used to study sub-atomic particles, combined with the development of the atomic clock to allow very small times to be accurately measured, and making it possible to examine time dilation relatively easily. In particle accelerators it became possible to produce carefully controlled electromagnetic fields to control the paths of matter particles and accelerate them to relativistic speeds. The study of collisions of particles in accelerators, particularly electrons, allowed the muon to be found and, with the advances in producing complicated magnetic fields and use of atomic clocks, they could be intensively studied at rest on the surface. When technological advances allowed sensors to detect muons being produced by cosmic radiation, and these muons were studied at different altitudes, the evidence for the relative nature of time and time dilation was strongly supported, with these very high speed muons decaying at a much slower rate when compared to those studied at rest on the surface.

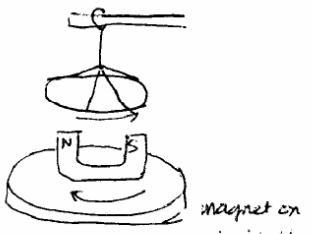
Question 18

The 'null' result of the Michelson-Morley experiment, where a very sensitive interferometer showed no change in the speed of light due to the predicted 'aether wind' thought to be created by the Earth's motion through space, was initially disappointing and confusing as many scientists believed that the existing model of light was complete and the very sensitive interferometer should be able to detect an aether wind. The result was ultimately to be explained by Einstein where he stated that there was no requirement for the aether and postulated that the speed of light was a constant, irrespective of the frame of reference where measured. The Relativity theories that Einstein developed were to revolutionise the scientific view of matter, space and time and lead to a completely different view. The 'null' result of the Michelson–Morley experiment could be seen as supporting Einstein's view and his Relativity theories gradually became accepted by physicists and adopted to further explore their full implications.

Question 19

a) When the turn table rotates clockwise as viewed, the aluminium disc will rotates anticlockwise.

b) Lenz's law states: The direction of the induced current is such that the magnetic effets produced by the current oppose the change in flux that cause the current. Note that it is the change in flux and not the flux itself that is opposed by the induced magnetic effects. In this case we only consider the direction of the flux that changes when the turn table is rotated.



magnet on turntable

Question 20

One application of induction investigated was the induction cook-top. This involves the cooking elements not being directly connected to the external power supply with their heating produced by currents induced in them by AC flowing in a separate circuit. Various secondary sources were used, including pamphlets from manufacturers, internet sites, encyclopaedias and notes provided during the course. The reliability of the information was assessed by careful checking of the various sources to find the authors of the material. Most internet sites were from engineering companies and sites produced for physics students. All the sources were discussed in class and it was decided that most were reliable and, although some did it more clearly, all provided information on how induction is applied to heat the cooking elements.

Another involved a first-hand investigation into the factors that affect how induction is applied in generators. This involved recording the induced voltage over a coil when a moving magnet travelled through the coil. In order to explore all aspects related to the theory found in textbooks, the speed, strength of magnetic field, and the pole of the magnet entering the coil were all varied. The reliability of the results was improved by conducting each of the trials several times. The information collected as results was assessed and it was found that they were consistent with the theory that the 'induced emf is directly proportional to the rate of change of magnetic flux'. Further class discussion of the results showed that each group had found that the repeat trials had produced virtually the same result and that the direction of the induced emf from every test was just as predicted by Lenz's law.

Question 21

(a) When the battery was connected the resulting DC current flowed in opposite directions in the metal tubes, creating a repulsive magnetic force between them. This magnetic force acts DOWN on the lower tube (unable to move), and UP on the upper tube that, because it is free to move, caused it to jump up in the direction of the magnetic force.

(b) To create the minimum force required for the tube to jump, the magnetic force acting between the wires must be just greater than the weight of the tube, i.e., $mg = 9.8 \times 10^{-2}$ N.

Applying Ampere's law and considering that the current in both tubes will be the same,

then, $F_{mag} = k_{mag}\frac{I^2 \Delta l}{d}$, then $9.8 \times 10^{-2} = \frac{2 \times 10^{-7} \times I^2 \times 1.0}{0.10}$, $\therefore I = 221.35$ A.

The minimum current for the tube to be observed to jump up would be just >221.35 A.

(c) An implication of this result is that transmission lines carrying very large currents, particularly long ones, will need to be as far apart as possible to reduce the forces they create on each other, or secured in position to prevent any movement.

Question 22

(a) Considering an ideal transformer, $\frac{V_1}{V_2} = \frac{n_1}{n_2}$, then, $\frac{V_1}{11\,000} = \frac{30}{1}$. $\therefore V_1 = 330\,000$ V or 330 kV.

(b) The main causes of loss of electrical energy during transmission are:

- the resistance of transmission wires leads to the current heating the wire, $P_{loss} = RI^2$;
- heating produced by eddy currents in the core of the transformer results in loss of energy.

(c) If superconductors could be applied and used as transmission lines, because they have negligible resistance, this means that they could carry large currents without any associated resistive heating losses, i.e. $P_{loss} = RI^2$. This means that the use of superconductors could significantly reduce the energy lost by the system.

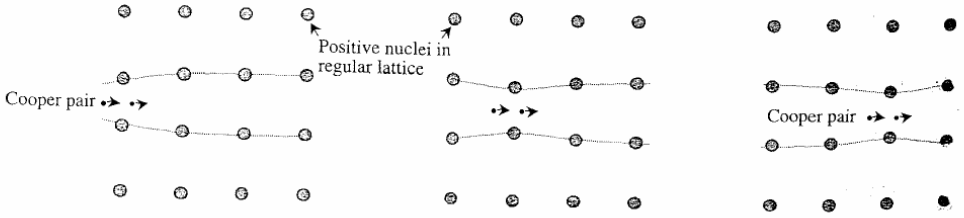
Question 23

At the start of the 20th century many scientists believed they completely understood light and could correctly explain its behaviour as an electromagnetic wave using 'classical' wave theory. Studies of 'blackbody radiation' involved the measurement of the energy radiated at different wavelengths from a specially prepared blackbody, a theoretical perfect absorber and radiator of energy, that was heated to high temperatures. The predictions from 'classical theory' suggested that as the temperature of the blackbody increased there would be an increasing intensity at shorter wavelengths, a possible contradiction of conservation of energy. The experimental results being collected were very different as they showed that the energy radiated dropped abruptly to zero for the UV (shorter) wavelengths. As a possible explanation Max Planck developed his idea of 'quantised energy' and was able to produce results which agreed with those observed in experiments. When in 1905 Einstein incorporated Planck's idea to propose 'photons' and provide a solution to explain experimental results involving the 'photoelectric effect', it led to a fundamental change in scientific thinking with 'quantum theory', developed to explain blackbody radiation, growing to become accepted and the basis for future ideas.

Question 24

According to the BCS theory, when a superconductor is cooled to below the critical temperature the very low thermal energy leads to a quantum state where an electron can lead to a distortion in the lattice of positive nuclei to give rise to a localised positive region which attracts a second electron in to combine with the first as a 'Cooper pair'. The 'Cooper pair' then seems to be able to interact with the lattice nuclei, resulting in no destructive interference, and it is able to move through the lattice with no loss of energy.

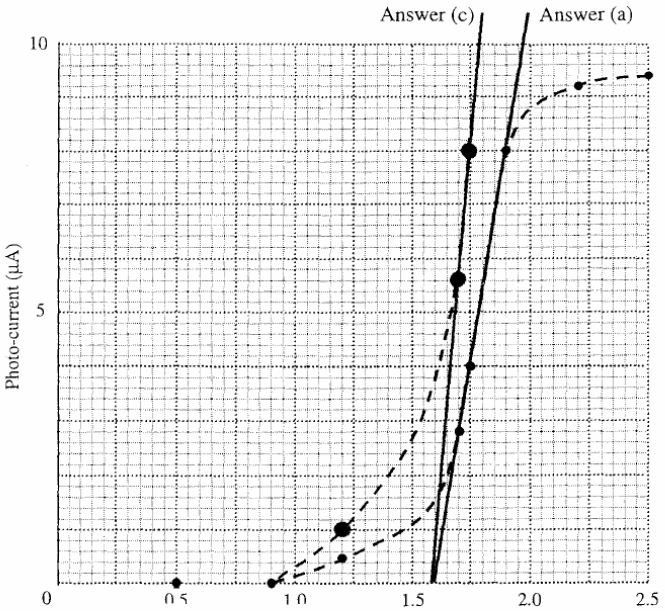
Based on the very low thermal energy giving rise to a quantum state where the first electron can distort the lattice resulting in a second electron falling in to form the Cooper pair, the BCS theory is able to explain how, through the exchange of 'phonons' and the slight lattice distortions, a superconductor below the critical temperature has zero resistance to flow of electric current.



Below T_c movement of the first electron distorts the lattice of positive nuclei to attract a second electron in to form a Cooper pair.

The very low energy of the nuclei allows the distortion of the lattice to continue and the Cooper pair loses no energy as it travels through the lattice.

Question 25



(a) See straight line labelled (a) on the graph.

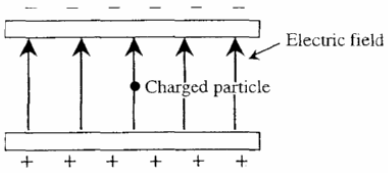
(b) From the straight line, the work function is ~ 1.6 eV. (From the actual data, a photocurrent registers at a lower photon energy, indicating that the work function is more accurately predicted from the dashed 'line of best fit', i.e. the actual work function, where photoelectrons just begin to be released, is just over 0.9 eV.)

(c) See the line labelled (c) on the graph. (Straight line consistent with Answers (a), (b).)

(d) Doubling the intensity of the light means that there are TWICE as many photons in the beam. This means that for the photons with an energy equal to or greater than the work function, TWICE as many electrons will be released, resulting in the photocurrent doubling. The line on the graph labelled (c) reflects this.

Question 26

(a)



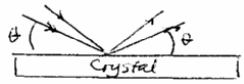
(b) Considering voltage = 49 V, and separation = 2.0 cm, then:

$\vec{E} = \frac{V}{d} = \frac{49}{0.02} = 2450 \text{ V m}^{-1}$.

(c) Forces balanced, i.e., $mg = q\vec{E}$. Therefore, $q = \frac{9.6 \times 10^{-6} \times 9.8}{2450} = 3.84 \times 10^{-8}$ C.

Question 27

a) the angle of incidence (the angle θ), measured in degrees, that is the angle between the incident ray and the surface of the crystal. Also called diffraction angle



b) In the equation

$n\lambda = d\sin\theta$

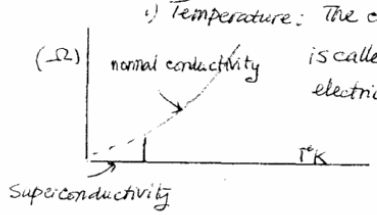
Measurement of the angles allows the spacing and arrangement of the crystal to be determined. The metallic lattice therefore also is determined.

c) The classical model of metals describes valence electrons a being common property of all of the atoms in the metal. These electrons are said to be "delocalised".

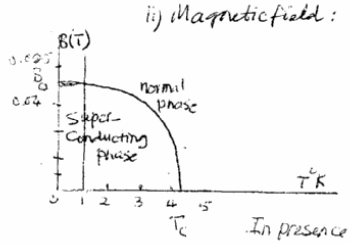
X ray diffraction is by far the most important experimental tool in the investigation of crystal structure of solids: Atomic spacings in crystals can be measured precisely, and the lattice structure of complex crystals can also determined

X ray diffraction also plays an important role in studies of the structures of liquids and of organic molecules (ie double helix structure of DNA).

d) i) Temperature: The characteristic temperature at which a metal becomes superconducting is called its critical temperature T_c. Superconductors, by definition, carry electric current with zero resistance, it is remarkable.



ii) Magnetic field: Superconductors also have extraordinary magnetic properties. As the external field magnitude B_e increased, the superconducting transition occurs at lower temperature. when $B_e \geq 0.0T$ no superconducting transition occurs, The minimum magnitude of magnetic field needed to eliminate superconductivity is called the critical field, B_c.



In presence of B_c all magnetic flux is expelled. This is called the Meissner effect.

Elective:

Question 30 – Astrophysics

Question 30(A)

Adaptive optics uses a fast feedback system to attempt to correct for effects of atmospheric turbulence. ie Anglo-Australian Telescope.

(See Supplement)

Question 30(B)

(X) Incandescent lamp → spectroscope → continuous spectrum (X)

(Y) Sodium vapour lamp → spectroscope → emission spectrum (Y)

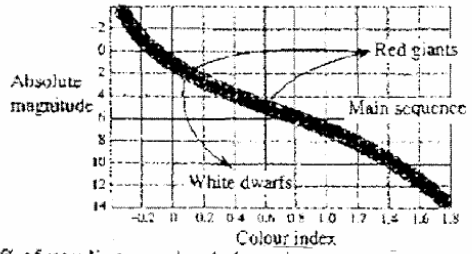
(Z) Incandescent lamp → Sodium vapour → Spectroscope → Absorption spectrum (Z)

Type of spectrum	Produced by	Celestial produced by
* Continuous Hot	Materials under pressure	Galaxies
* Emission	Incandescent low density	Emission nebulas quasars
* Absorption Cool	gases in front of continuous spectrum	Atmosphere of stars

Question 30(C)

The Hertzsprung-Russell (HR) diagram was the initial and most important diagram in developing our understanding of the life of stars. It illustrates the progress of stars from dust cloud to supernova or white dwarf. Above all it is an essential part of the language that astronomers use to describe the similarities and differences between stars and star clusters.

The HR diagram shows the relationship between the surface temperature and luminosity of stars.



99% of stars lie on one band, the main sequence. This suggests that stars spend 99% of their time on this band. This obvious relationship between temperature and luminosity led astronomers to develop their understanding of how the rate of nuclear reactions in the star could be governed by temperature. This is turn helped to explain the stable time of a star when the nuclear reactions causing the star to expand were balanced by the force of gravity which caused the star to contract.

No one has been watching stars long enough to follow the path of one star through its evolutionary sequence. However, by mapping large numbers of stars a number of patterns have been established that suggest this sequence.

For example:

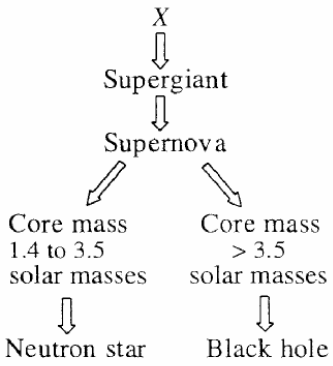
- Stars in a particular galactic or globular cluster can be graphed on the HR diagram. All the stars in that cluster are assumed to be around the same age, and therefore the relative positions on the diagram of stars of different size have revealed a great deal on the evolutionary sequence.
- Old clusters have much of the upper main sequence missing, indicating that more luminous stars spend less time on the main sequence than the less bright ones.
- Clusters with lots of white dwarf stars have very short main sequences. This suggests that old stars eventually evolve to the white dwarf region.
- Mapping clusters on this diagram now help astronomers to find the age of newly discovered clusters.

The death of stars is also mapped on the HR diagram. Astronomers have developed models to explain the changes in a star's position as it becomes a red giant, and have shown these stages on an HR diagram. Again, older clusters (globular clusters) show stars that match each of the stages. Computer simulations of stellar evolution now match the HR diagrams of clusters observed by practical astronomers.

(d) (i) There are still B stars present, indicating a young cluster because B stars are short lived.

(ii) 1. Fusion reactions in X — the CNO cycle dominates. In Z the proton–proton chain dominates. This is because X is a larger hotter star than Z.

2. X will become a supernova after going through a red giant stage. The result of this supernova will depend on the mass of the core remnant (shown below):



(e) Information from visible light has provided a great deal in increasing our understanding of the universe. Initially all information that allowed the identification of patterns of movement of celestial objects came from visual observations. With the development of the ability to create and analyse the spectra of light received from specific celestial objects, a number of pieces of information were able to be deduced to enable a better description of bodies and changes occurring in the universe. These include the use of spectra to determine the surface temperature of stars; this led to a classification of stars and to a greater understanding of the life cycles, taking into account the presence of elements and molecules in their structure; and the use of spectra to determine red and blue shift in spectra from objects to determine whether they are moving away from or towards us. This also allowed the speed of the motion to be determined.

The red shift of celestial objects has provided evidence of the expansion of the universe; spectra from specific stars can be used to determine their speed of rotation and this increases our understanding of the processes involved in stellar lives; spectra from solar system members which have atmospheres have enabled us to determine the composition of those atmospheres, giving us a greater understanding of the structure of the solar system. This information has also provided detail to allow scientists to use the information to model the formation of the solar system.

Question 31 – Quanta to Quarks (25 marks)

(a) (4 marks)
(i) (2 marks)
Outcomes Assessed: H7
Targeted Performance Bands: 2-3

Criteria	Marks
• Satisfactorily completed table for BOTH particles	2
• Any FOUR table entries correct	1

Sample answer

	Charge	Mass	Contribution to Mass Number	Contribution to Atomic Number
Proton	+1	1 amu	+1	+1
Neutron	No charge	1 amu	+1	0

(ii)(2 marks)
Outcomes Assessed: H7, H10, H13
Targeted Performance Bands: 3-4

Criteria	Marks
• Explain process with balanced equation	2
• Either explanation or balanced equation	1

Sample answer
In β-decay, a nuclear neutron decays producing a proton and a high energy electron which is known as a β-particle.

$$^{90}_{38}Sr \longrightarrow {}^{90}_{39}Y + \beta$$

(b) (3 marks)
Outcomes Assessed: H2, H7-8, H10, H13-14
Targeted Performance Bands: 2-4

Criteria	Marks
• Accurate and complete description of experiment	3
• Essentially correct description	2
• Elementary description of experiment	1

Sample answer
We attached a glass tube containing hydrogen gas and two electrodes to an induction coil in a darkened room. The induction coil was attached to a power supply and the tube began to glow. We took a hand spectroscope and examined the light from the glow and saw that it consisted of four or five lines in the visible spectrum. It was hard to see this, so we placed a cardboard box over the equipment and put the spectroscope through the hole. This worked much better.

(c) (3 marks)
Outcomes Assessed: H1, H2 H7, H9-10
Targeted Performance Bands: 2-4

Criteria	Marks
• Clear and complete explanation of Bohr model and relationships to deBroglie	3
• Competent description of Bohr model some attempt to relate to deBroglie	2
• Description of Bohr model only	1

Sample answer
The Bohr model places electrons in fixed orbits about the nucleus of the atom (hydrogen). The number of electrons in a level was controlled and inner levels were to be filled before the higher energy outer levels. Electrons were not allowed between levels but the Bohr model could not explain why. DeBroglie predicted that electrons had specific wavelengths and could only exist in levels around the nucleus when the length of the orbit was a whole number multiple of the wavelength of the electron.

(d) (7 marks)
Outcomes Assessed: H1-5, H6-10, H16
Targeted Performance Bands: 3-6

Criteria	Marks
• Complete assessment of impact of splitting the atom on society with at least THREE different examples both positive and negative	6-7
• Coherent assessment of impact on society with several examples and explanation	4-5
• Assessment of impact with one example only	2-3
• Simple statement of opinion without substantiation	1

Sample answer
There could be a wide variety of answers to this question depending on the student's point of view. This could be one answer.
The Manhattan project was an exercise carried out by the United States whose aim was to produce the atomic bomb. This was a contentious issue and caused much discussion in the scientific community at the time but it was kept top secret because of the war. The impact of the production of the atomic bomb has been immense and far reaching and still impacts on our society today. Not only did the bomb bring a swift end to the war but it also set up a political cold war that was to be maintained for some forty years. Political power was held by those countries that had nuclear weapons and smaller countries chose to ally themselves to one or the other super power. The threat of nuclear war changed the nature of international political debate as was seen in the Cuban Crisis. On the other hand the humanitarian developments of the Project are manyfold and there are people walking around today who have benefited from the medical applications in the treatment of such conditions as cancer and other malignant tumours. Our understanding of the world of Chemistry has been enhanced by being able to tag atoms and watch their progress through reactions and through industrial applications. The development of the atomic bomb did have its down side in that it caused the death and suffering of thousands but many more have benefited from its discoveries and continue to do so now and into the future.

(e) (4 marks)
(i) (2 marks)
Outcomes Assessed: H6-7, H9-10
Targeted Performance Bands: 3-4

Criteria	Marks
• Correct calculation	2
• Indication of knowledge of correct process without correct answer	1

Sample answer
The Oxygen-16 atom contains 8 protons each of mass 1.673×10^{-27} kg for a total mass of 1.3384×10^{-26}kg
and 8 neutrons each of mass 1.675×10^{-27}kg for a total mass of 1.34×10^{-26} kg
This gives the atom a calculated mass of 2.6784×10^{-26}kg
The given mass is 15.994915amu which equals 2.6567×10^{-26}kg
This produces a mass defect of 2.165×10^{-28}kg

(ii) (2 marks)
Outcomes Assessed: H6-7, H9-10, H13
Targeted Performance Bands: 3-5

Criteria	Marks
• Relate the position of ^{56}Fe to the fact that this is the limit of atoms that can be sustainably produced by nuclear fission	2
• Observe that this isotope has the highest amount of binding energy per nucleon	1

Sample answer
The position of iron indicated that it has the highest binding energy per nucleon of all atoms. This means that it is the most stable nucleus, with nucleons bound by the strongest average force. Elements lower than iron cannot be produced by sustainable nuclear fission reactions because average binding energy per nucleon decreases, hence energy is not released.

(f) (4 marks)
Outcomes Assessed: H6-7, H9-10, H14
Targeted Performance Bands: 3-6

Criteria	Marks
• Outline Rutherford-Bohr model and describe at least TWO observations that can be explained and TWO that cannot be explained. Analysis	4
• Outline R-B model, list several observations with some explanation. Include at least ONE observation that cannot be explained. Analysis	3
• Outline the model with EITHER some attempt to explain observations OR state TWO observations that cannot be explained	2
• Any TWO statements which show an understanding of the R-B model/energy levels	1

Sample answer
The Rutherford-Bohr atom explained well the production of spectral lines as electrons moved from one energy level to a lower level but it could not explain why the energy levels were in the place where they were nor why there were no energy levels between them. It further has no explanation for the existence of superfine lines in the spectra.