ARC Academic Resources Centre
Harcourt Education

Student Number: ……..……..…..

2006
HIGHER SCHOOL CERTIFICATE
Sample Examination Paper

PHYSICS

General Instructions

- Reading Time – 5 minutes
- Working Time – 3 hours
- Write using blue or black pen
- Write your student number at the top of this page

Total marks – 100

Section I
75 marks
This section of the paper 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
25 marks
- Attempt ONE question from Questions 28–30
- Allow about 45 minutes for this section

Directions to school or college

To ensure maximum confidentiality and security, examination papers used for trial examinations must NOT be removed from the examination room or used with students for revision purposes until Monday 4 September 2006.

All care has been taken to ensure that this sample examination paper is error free and that it follows the style, format and material content of the current NSW syllabus. Candidates are advised that the authors of this examination paper cannot in any way guarantee that the actual Board Of Studies Examination will have a similar content or format.

 Product code: 734838

Section I
75 marks

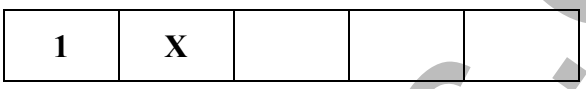
Allow about 2 hours and 15 minutes for this section

This section has TWO parts

Part A – 15 marks Questions 1–15
Part B – 60 marks Questions 16–27

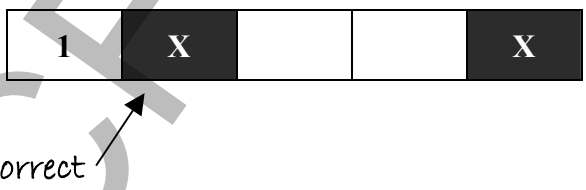
Part A
15 marks

Select the alternative A, B, C, or D that best answers the question. Fill in the response sheet clearly.



If you think you have made a mistake, blank out the incorrect answer and fill in the new answer.

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word *correct* and drawing an arrow.



Section I

Part A – 15 marks

Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple choice answer sheet

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1 A simple pendulum can be used to find the acceleration due to gravity.

What are the key variables that determine the period of a simple pendulum?

A The mass of the pendulum bob and the acceleration due to gravity.

B The amplitude of the swing and the acceleration due to gravity.

C The length of the pendulum and the acceleration due to gravity.

D The acceleration due to gravity alone.

2 Geostationary satellites have a much greater orbital radius than low Earth orbit satellites.

For a geostationary satellite and a low Earth satellite of the same mass, which of the following alternatives best describes the energy of each satellite?

A Geostationary satellites have greater kinetic energy but less potential energy than low Earth orbit satellites.

B Geostationary satellites have less kinetic energy but greater potential energy than low Earth orbit satellites.

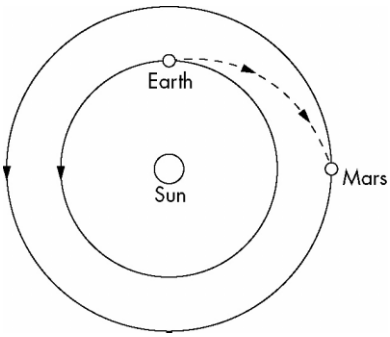
C Geostationary satellites have greater kinetic energy and greater potential energy than low Earth orbit satellites.

D Geostationary satellites have less kinetic energy and less potential energy than low Earth orbit satellites.

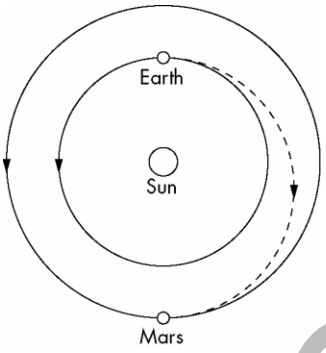
3 It is very expensive to send interplanetary probes to other planets and for this reason trajectories are chosen to minimise the energy required.

The diagrams below show the position of the Earth when the probe was launched and the position of Mars when the probe reaches Mars. The direction of the orbital rotation of both planets is also shown. Which of the trajectories would minimise the energy required to travel from the Earth to Mars?

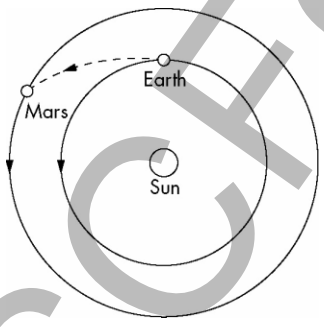
A



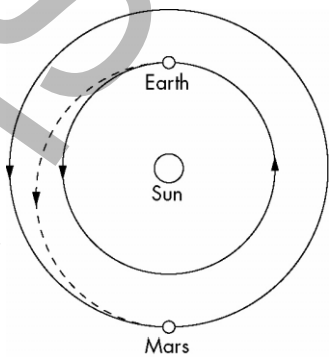
B



C



D



4 Planet Y has twice the mass and half the diameter of planet X.

If the escape velocity from planet X were v, what would the escape velocity from planet Y be?

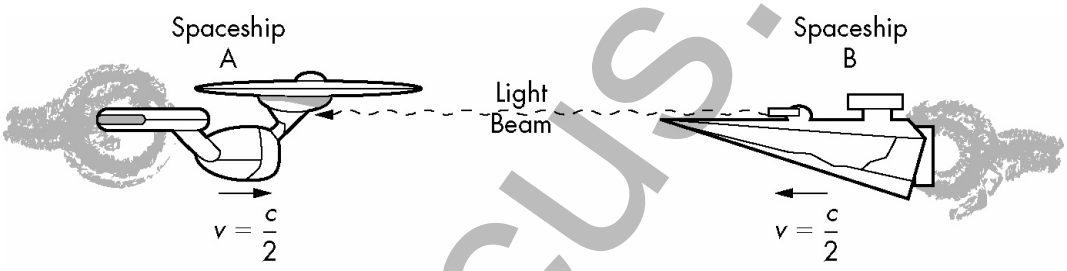
A 2v

B v

C √2v

D 4v

5 An observer in spaceship A travelling at half the speed of light (c/2) measures the speed of a light beam that was sent from spaceship B that was travelling at half the speed of light in the opposite direction.



What value would an observer in spaceship A measure for the speed of the light beam sent from spaceship B?

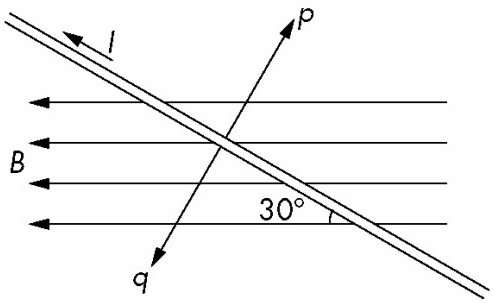
A c/2

B 2c

C 3c/2

D c

6 A straight length of wire carrying current is placed in a magnetic field as shown below.



In which direction will the wire experience a force?

A out of the page

B in the direction marked p

C in the direction marked q

D into the page

7 It requires more torque to turn a generator when the generator is connected to an external circuit that uses electrical power than when the generator is not connected to an external circuit.

Why does it require more torque to turn the generator when it is supplying electrical power?

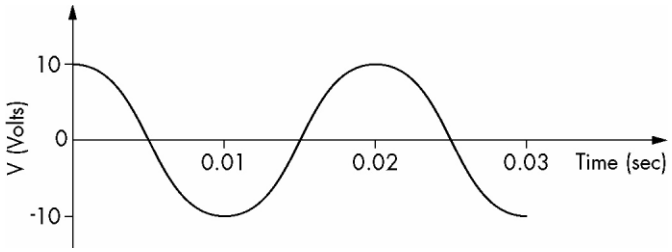
A When it is connected to the external circuit the current passing through the rotor coils produces an opposing torque that makes the generator more difficult to turn.

B When it is connected to the external circuit, the generator starts producing voltage and this will make the generator more difficult to turn.

C When it is connected to the external circuit, more current flows through the rotor coils and this produces a back EMF that makes the generator more difficult to turn.

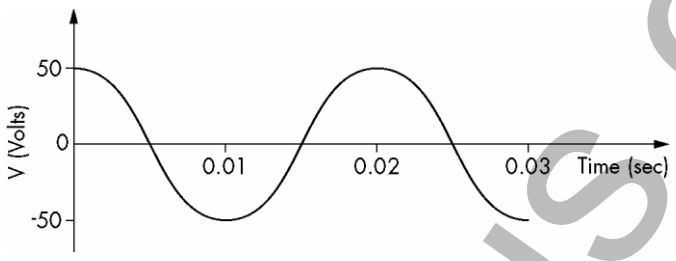
D The generator is more difficult to turn because a torque in the direction of rotation increases when it is connected to the external circuit.

8 A transformer is made up of a primary coil with 200 turns and a secondary coil with 1000 turns. The input voltage applied to the transformer is shown in the diagram below.

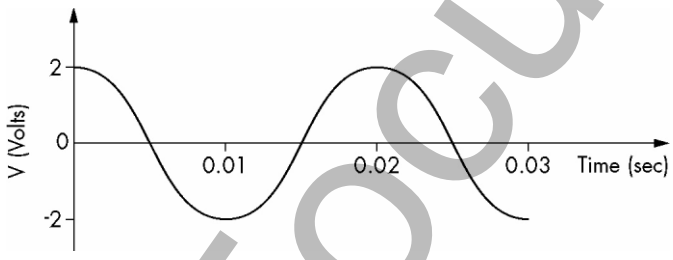


Which of the following sketches best represents the output voltage that would be produced by this transformer?

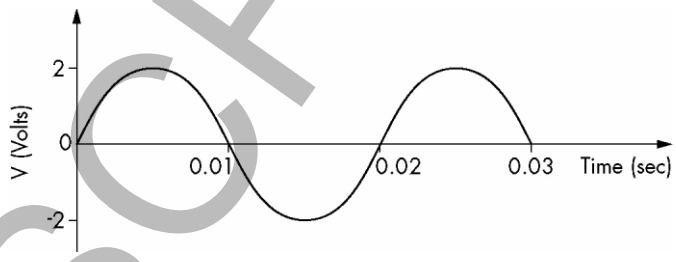
A



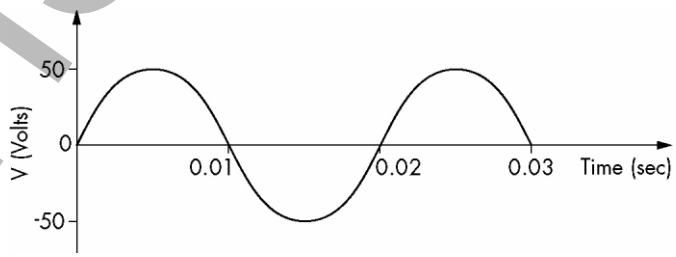
B



C



D



9 Both DC and AC systems were used in early electricity generation and distribution systems in the United States. Competition between the supporters of AC and DC systems raged for over twenty years.

Who championed AC systems during this period of intense competition?

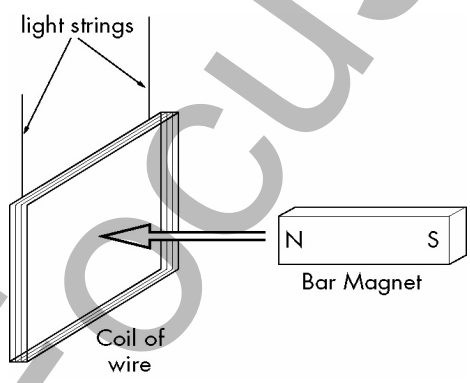
A Edison

B Westinghouse

C Faraday

D Oersted

10 A permanent magnet is moved rapidly towards a coil of wire suspended from lightweight strings as shown below. The wires from each end of the suspended coil are connected together.



What will happen to the coil when the magnet is moved towards it?

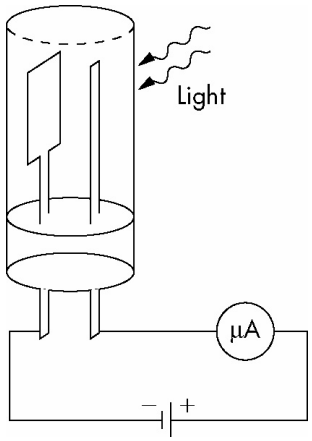
A A current will be induced in the coil in a clockwise direction and the coil will be repelled by the approaching magnet.

B A current will be induced in the coil in a clockwise direction and the coil will be attracted by the approaching magnet.

C A current will be induced in the coil in an anticlockwise direction and the coil will be repelled by the approaching magnet.

D A current will be induced in the coil in an anticlockwise direction and the coil will be attracted by the approaching magnet.

11 A simple photocell is shown in the diagram below.



Why is the current in the circuit proportional to the intensity of the light incident upon the cell?

A The current is proportional to the number of electrons that are ejected per second from the negative cathode by the incident light photons.

B The current is proportional to the total number of electrons that are ejected from the negative cathode by the incident light photons.

C The current is proportional to the number of electrons per second that are ejected from the positive anode by the incident light photons.

D The current is proportional to the number of electrons per second that are ejected from the positive cathode by the incident light photons.

12 Braggs used X-ray diffraction to probe the crystal structure of matter.

What is the best definition of diffraction?

A The change in direction of propagation of a wave when it moves from one medium to another.

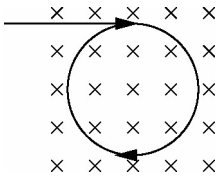
B The superposition of waves emitted from two or more independent sources.

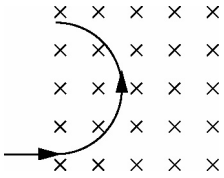
C The spreading out of waves when they encounter objects or gaps comparable in size to the wavelength.

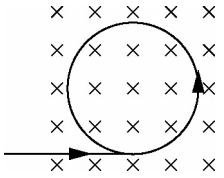
D The intensity pattern formed when waves emerge from a transparent crystalline solid.

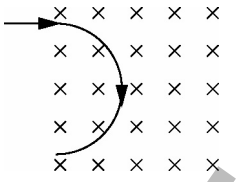
13 An electron travelling at high speed enters a magnetic field of strength 0.1 T directed into the page.

Which of the following diagrams best represents the path that the electron would take after it enters the magnetic field?

A 

B 

C 

D 

14 'Doping' intrinsic semiconductors with impurity atoms produces the more commercially important extrinsic semiconductors.

If silicon is doped with one gallium atom per million silicon atoms, what characteristics will the new extrinsic semiconductor have?

A An increased number of free electrons per unit volume, but no change in the net charge of the semiconductor.

B An increased number of free holes per unit volume, but no change in the net charge of the semiconductor.

C An increased number of free electrons per unit volume that would give the semiconductor a small net negative charge.

D An increase in the number of holes per unit volume that would give the semiconductor a small net positive charge.

15 Consider two beams of electromagnetic radiation: one beam consists of red light and the other consists of X-rays.

When both beams have the same intensity, the X-ray source is considered to be more dangerous than the red light source.

Why is this so?

A The photons in each beam have the same energy, but the X-ray beam contains more photons per second.

B Both beams contain the same number of photons each second, but each X-ray photon has more energy than each red light photon.

C The X-ray beam contains fewer photons per second, but each X-ray photon has more energy than each red light photon.

D Both beams contain the same number of photons per second, but the X-ray photons travel at higher velocity.

End of Part A

Section I (Continued)

Part B – 60 marks
Attempt Questions 16–27
Allow about 1 hour and 45 minutes for this part

Answer the questions in the space provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (6 marks)

A 2000 kg satellite is to be placed in a circular orbit 8000 km above the surface of the Earth. Assume the Earth's radius is 6370 km.

(a) Calculate the gravitational potential energy of the satellite before it is launched. **1**

(b) Calculate the gravitational potential energy of the satellite when it is in orbit. **1**

(c) Calculate the amount of work that would be done against gravity to raise the satellite from the surface of the Earth to a height of 8000 km. **1**

Marks

(d) Explain why the energy required to place a satellite in orbit is much greater than the work required to lift the satellite to the correct height. **3**

Question 17 (5 marks)

A United Nations plane travelling horizontally with a velocity of 120 ms^{-1}, at an altitude of 320 m above the ground, drops a food parcel when it is directly above a small village. (Neglect air friction in your calculations.)

(a) Calculate the time for the parcel to reach the ground. **1**

(b) Calculate how far from the village the parcel will land. **1**

Marks

(c) Sketch a graph of the vertical displacement (y) of the parcel against the square of the time of flight (t^2). Include the values where the line intercepts each axis. **3**

Question 18 (5 marks)

The moon is a natural satellite of the Earth and the Earth is a natural satellite of the Sun. Artificial satellites have been placed in orbit around the Earth, the Sun and a number of the other planets.

Discuss the importance of Newton's Law of Universal Gravitation in understanding and calculating the motion of satellites. **5**

Marks

Question 19 (4 marks)

Einstein's special theory of relativity changed the way we view our universe.

(a) State the two postulates upon which Einstein's theory of relativity was based. **2**

(b) Calculate the velocity of an electron if a stationary observer measured the moving electron's mass to be three times greater than the electron's mass at rest. **2**

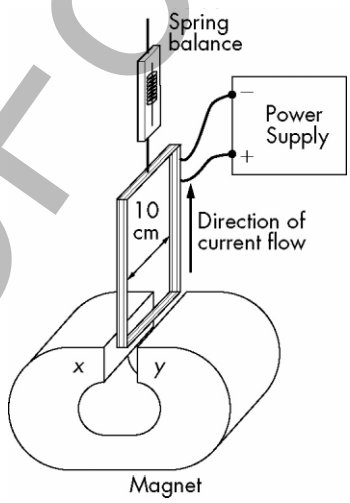
Marks

Question 20 (4 marks)

Compare step up and step down transformers and give an example of where each type of transformer is used. **4**

Question 21 (6 marks)

A student sets up an experiment to measure the strength of a magnetic field using the motor effect.



In the experiment, a coil of wire with 50 turns is suspended from a spring balance. A 10 cm long, straight section of the coil is placed at an angle of 90^{o} to the unknown magnetic field. The spring balance reads 2 newtons before the current is switched on and 5 newtons when a current of 5 amps flows through the coil.

Marks

(a) Calculate the mass of the coil. **1**

(b) Calculate the strength of the unknown magnetic field and determine which side of the magnet is the north pole. **3**

(c) Explain why the student used a coil of fifty turns rather than a coil with a single turn of wire. 2

Question 22 (4 marks)

During your studies, you conducted a first-hand investigation to demonstrate the principle of the AC induction motor.

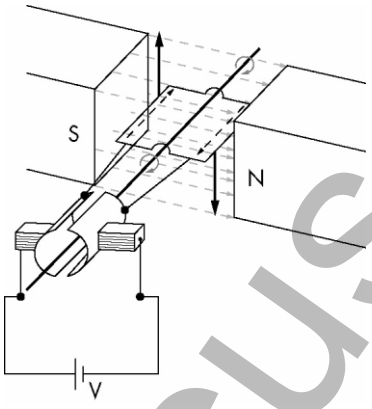
Briefly describe the experiment you conducted and explain how it demonstrated the principle of the AC induction motor. **4**

Space for your answer continues on the next page

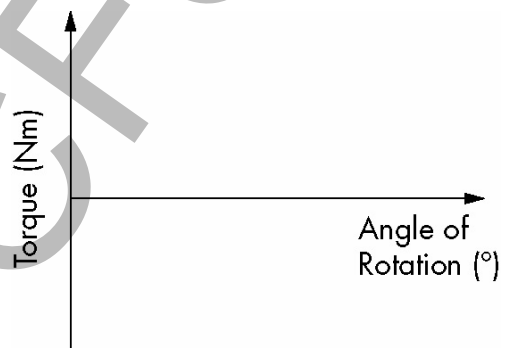
Marks

Question 23 (6 marks)

A simple dc motor is shown below. The motor develops 2 Nm of torque when the coil is in the position shown.



(a) Sketch a graph of the torque developed against the angle between the plane of the coil and the magnetic field for one complete oscillation of the motor. **2**



(b) Suggest a change that could be made to this motor to ensure the torque remained high for a greater portion of each rotation. **1**

Marks

(c) Explain why a dc motor may burn out if it is prevented from turning. **3**

Question 24 (6 marks)

Metals are good conductors but, at room temperature, all metals still resist the flow of electrons to some degree.

(a) State the two principal causes of electrical resistance in metals. **2**

(b) State what happens to the resistance of a metal when its temperature is increased and explain why the resistance changes in this way. **2**

Marks

(c) Compare the movement of electrons passing through a copper wire at room temperature with the movement of electrons passing through a superconductor cooled below its critical temperature. **2**

Question 25 (4 marks)

Planck's work on black body radiation and Einstein's investigation of the photoelectric effect led to a new model of light.

(a) Define black body radiation. **1**

(b) Describe Planck's hypothesis regarding the emission and absorption of electromagnetic radiation by black bodies. **1**

(c) Describe the extension to Planck's hypothesis made by Einstein in 1905. **2**

Marks

Question 26 (4 marks)

Solid-state devices have largely replaced thermionic devices in electronics.

(a) Describe the difference between a thermionic device and a solid-state device. **2**

(b) State two impacts that the development of solid-state devices has had on society. **2**

Question 27 (6 marks)

"A controversy between competing scientific theories can sometimes be resolved by a single experiment".

Evaluate this statement with reference to J. J. Thomson's experiment to determine the charge to mass ratio of the electron and the experiment conducted by Michelson and Morley to detect the motion of the Earth through the aether. **6**

Space for your answer continues on the next page

End of Part B
End of Section I

Section II
25 marks

Attempt one question from Questions 28–30
Allow about 45 minutes for this section
Answer the question in a writing booklet and show all relevant working in questions involving calculations.

Marks

Question 28 – Medical physics (25 marks)

(a) Transmission ultrasound is a new form of ultrasound scanning currently being developed. This technology utilises the ultrasound waves transmitted through the body, as opposed to traditional ultrasound that uses the reflection of ultrasound waves.

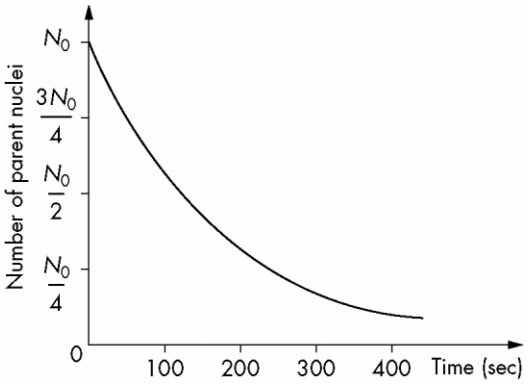
(i) Why is a gel used on the skin when ultrasound scans are being performed? **1**

(ii) Use your knowledge of reflection ultrasonics to calculate the percentage of the incident ultrasound intensity that would be transmitted when an ultrasound wave passes from bone (acoustic impedance = 4.7×10^6 $kgm^{-2}s^{-1}$) into the brain (acoustic impedance = 1.60×10^6 $kgm^{-2}s^{-1}$). **2**

(iii) Explain how the Doppler effect is used, in traditional reflection ultrasonics, to measure flow characteristics of blood moving through the heart. **4**

(b) Optic fibre endoscopes can be used to illuminate and image internal organs in the body. Explain how such endoscopes illuminate internal organs and how they produce images of internal structures in the body. **3**

(c) Oxygen-15 is one of the positron emitters that can be used in PET scans. The decay curve for oxygen-15 is shown below.



Marks

(i) Use the decay curve to determine the half-life of oxygen-15. **1**

(ii) PET scans utilise the interaction between electrons and positrons. What products are created when an electron and a positron collide with one another? **1**

(iii) Explain how a PET scan pinpoints the position of radioactive isotopes within the body. **3**

(d) By utilising the precession of certain atomic nuclei, Magnetic Resonance Imaging (MRI) can be used to produce detailed structural images of soft tissue.

(i) Patients who work with metals must be X-rayed before being given an MRI to ensure they have no metal splinters in their bodies. Explain why this safety precaution is necessary. **1**

(ii) From the number of protons and neutrons in the nucleus determine if a helium-4 nucleus has a net spin **1**

(iii) State which scan is safer for the patient, an MRI scan or a CAT scan and explain why the scan you chose is safer. **2**

(e) "The discovery of X-rays by Wilhelm Roentgen in 1895 was to have a huge impact on medicine and on society." Evaluate the validity of this statement in the light of your studies of the use of X-rays in medical physics. **6**

End of Question 28

Marks

Question 29 – Astrophysics (25 marks)

(a) A recent scientific article on the possible benefits of setting up a permanent base on the moon suggested the moon would be an ideal place for astronomers to locate their telescopes.

(i) State one reason why the moon would be a more suitable site than the Earth for astronomical telescopes. **1**

(ii) Explain why a large, visible light telescope on the moon would require active optics but would not require adaptive optics. **2**

(iii) If a telescope on the moon were to be used to measure parallax shifts, explain why it would be better to continue to use the Earth's orbital diameter as the baseline rather than the moon's orbital diameter. **2**

(b) Spectral analysis of the light from stars, galaxies and nebulae can provide a huge amount of information.

(i) Describe the technology needed to measure astronomical spectra. **3**

(ii) Compare and contrast the emission spectra from a main sequence star with a surface temperature of 6000 K with the emission spectra from a black body at the same temperature. **2**

(c) The star, Deneb, has an absolute magnitude of –7.2 and is 492 pc from Earth, while the star, Altair, has an apparent magnitude of 2.2 and is located 5.1 pc from the Earth.

(i) Without doing any calculations, explain how the information above can be used to determine which of the two stars has the greatest luminosity. **1**

(ii) Calculate the apparent magnitude of Deneb and hence determine which star is the brightest when viewed from the Earth. **2**

(iii) Calculate the brightness ratio for these two stars, when they are viewed from the Earth. **1**

(d) Astronomers have gathered a great deal of information about the evolution of stars and the universe itself by studying different types of stars.

(i) Describe how astrometric binary stars are detected. **2**

(ii) Explain how cepheid variable stars in other galaxies can be used to determine the distance to those galaxies. **3**

Marks

(e) Evaluate the importance of the Hertzsprung-Russell diagram to our understanding of the 'life cycle' of stars. **6**

End of Question 29

Marks

Question 30 – Quanta to quarks (25 marks)

(a) To investigate atomic structure, Rutherford's co-workers, Marsden and Geiger, bombarded a very thin piece of gold foil with high-speed alpha particles and measured the angles at which the alpha particles were deflected. Some of the results they obtained are shown in the table below.

Angle of deflection (^{o})	Number of alpha particles deflected at this angle
5	8 289 000
15	120 570
45	1435
75	211
120	52
150	33

(i) Explain how the new atomic model proposed by Rutherford accounted for the experimental results shown above. **2**

(ii) Bohr's atomic model replaced Rutherford's atomic model. State two advantages of Bohr's model over Rutherford's model. **2**

(b) de Broglie proposed that all sub-atomic particles had an associated wavelength.

(i) Given that the mass of an electron is 9.1×10^{-31} kg, calculate the velocity of an electron with a wavelength of 0.14 nm. **1**

(ii) Describe the experiment conducted by Davisson and Germer and explain how it supported de Broglie's hypothesis. **4**

(c) The first three wavelengths and the associated photon energies of the visible spectrum (Balmer series) of hydrogen are listed below.

Transition	Wavelength of emitted photon (nm)	Energy of photon (J)	Energy of photon (eV)
$n_3 \rightarrow n_2$	656 nm	3.03×10^{-19}	1.89
$n_4 \rightarrow n_2$	486 nm	4.11×10^{-19}	2.57
$n_5 \rightarrow n_2$	434 nm	4.58×10^{-19}	2.86

(i) Calculate the wavelength and photon energy in electron volts, for the $n_2 \rightarrow n_1$ transition in hydrogen. **2**

(ii) Use the results of your calculation and the data in the table above to draw to scale and label an energy level diagram for the first five electron energy levels of the hydrogen atom. **3**

Marks

(d) Measurements of the kinetic energy of the decay products when a nucleus of uranium-237 undergoes an alpha decay indicate that the reaction releases 0.03 MeV of energy.

(i) Write a nuclear equation showing the chemical symbols, atomic numbers and mass numbers, for this nuclear reaction. **1**

(ii) Calculate the difference between the mass of the products and the mass of the reactants in this nuclear reaction. **1**

(iii) Explain why this reaction is called a 'natural transmutation'. **2**

(e) "Nuclear fission has brought huge benefits to society and terrible suffering." Discuss this statement. **7**

End of Question 30

End of paper

Formula Sheet

$$v = f\lambda$$

$$I \propto \frac{1}{d^2}$$

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$

$$E = \frac{F}{q}$$

$$R = \frac{V}{I}$$

$$P = VI$$

$$Energy = VIt$$

$$v_{av} = \frac{\Delta r}{\Delta t}$$

$$a_{av} = \frac{\Delta v}{\Delta t} \text{ therefore } a_{av} = \frac{v-u}{t}$$

$$\Sigma F = ma$$

$$F = \frac{mv^2}{r}$$

$$E_k = \frac{1}{2}mv^2$$

$$W = Fs$$

$$p = mv$$

Impulse = Ft

$$E_p = -G\frac{m_1 m_2}{r}$$

$$F = mg$$

$$v_x{}^2 = u_x{}^2$$

$$v = u + at$$

$$v_y{}^2 = u_y{}^2 + 2a_y\Delta y$$

$$\Delta x = u_x t$$

$$\Delta y = u_y t + \frac{1}{2}a_y t^2$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$F = \frac{Gm_1 m_2}{d^2}$$

Physics Data Sheet

Numerical values of several constants

Charge on an electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 ms^{-1}
Earth's gravitational acceleration, g	9.8 ms^{-2}
Speed of light, c	3.00×10^{8} ms^{-1}
Magnetic force constant, k	2.0×10^{-7} NA^{-2}
Universal gravitational constant, G	6.67×10^{-11} Nm^2kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck's constant, h	6.626×10^{-34} Js
Rydberg's constant, R_H	1.097×10^{7} m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg
	931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, r	1.00×10^{3} kgm^{-3}
Specific heat capacity of water	4.18×10^{3} $Jkg^{-1}K^{-1}$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number — 79 — Symbol of element
Atomic Weight — 197.0 — Name of element
Au — Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Ununbium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [146.9] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinides

89 Ac [227.0] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237.0] Neptunium	94 Pu [239.1] Plutonium	95 Am [241.1] Americium	96 Cm [244.1] Curium	97 Bk [249.1] Berkelium	98 Cf [252.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium

Where the atomic weight is not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.
The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.

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Section I – Multiple choice

Answer sheet

	A	B	C	D
1				
2				
3				
4				
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14				
15				

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Mapping grid

Question	Mark	Syllabus Content	Outcome	Band
1	1	9.2.2 col 2 dot 9 and 9.2.1 col 2 dot 3	H7	3–4
2	1	9.2.2 col 2 dot 3	H6	5–6
3	1	9.2.2 col 2 dot 6	H6	4–5
4	1	9.2.1 col 3 dot 1	H6	2–3
5	1	9.2.4 col 2 dot 6	H6	3–4
6	1	9.3.1 col 3 dot 3	H9	4–5
7	1	9.3.2 col 2 dot 5	H7	4–5
8	1	9.3.4 col 3 dot 1 & 2	H9	5–6
9	1	9.3.3 col 3 dot 3	H1	2–3
10	1	9.3.2 col 2 dot 5 & col 3 dot 1	H9	4–5
11	1	9.4.2 col 3 dot 4	H10	4–5
12	1	9.4.4 col 2 dot 1	H8	3–4
13	1	9.4.1 col 2 dot 5	H9	4–5
14	1	9.4.3 col 2 dot 6	H10	4–5
15	1	9.4.2 col 3 dot 4	H10	5–6
16	6	9.2.1 col 2 dot 2 & 3	H3, H7 & H14	4–5
17	5	9.2.2 col 3 dot 1	H2 & H6	3–5
18	5	9.2.3 col 2 dot 3	H1 & H9	4–6
19	4	9.2.4 col 2 dot 5, 6 and col 3 dot 5	H6 & H2	3–5
20	4	9.3.4 col 2 dot 2	H9 & H3	3–5
21	6	9.3.1 col 2 dot 4 col 3 dot 2 & dot 3	H2 & H9	4–5
22	4	9.3.5 col 3 dot 1	H2, H9, H13 &H14	3–4
23	6	9.3.1 dot 3, 5 and 6 col 3 dot 4	H9 & H2	3–5
24	6	9.4.4 col 2 dot 2, 3, 4, 5 & 6	H10	2–4
25	4	9.4.2 col 2 dot 4, 5, 6 & col 3 dot 2	H1 & H10	3–5
26	4	9.4.3 col 2 dot 8 col 3 dot 3	H1 & H3	2–4
27	6	9.4.1 col 1 dot 1 and 9.2.4 col 2 dot 2 & 3	H1, H2 & H6	4–6
28a	7	9.6.1 col 2 dot 3 & 8 and col 3 dot 5	H8 & H14	3–5
28b	3	9.6.2 col 2 dot 5, 6 & 7	H8	2–5
28c	5	9.6.3 col 2 dot 1, 4 & 5	H7 & H10	3–5
28d	4	9.6.4 col 2 dot 3 & col 3 dot 4	H9 & H10	3–4
28e	6	9.6.4 col 3 dot 5	H3, H4 & H13	3–6
29a	5	9.7.1 col 2 dot 2, 5 & 9.7.2 col 2 dot 2 &3	H3 & H8	3–5
29b	5	9.7.3 col 2 dot 1, 2, 4 & col 3 dot 2	H2 & H8	3–5
29c	4	9.7.4 col 2 dot 2 & col 3 dot 1	H7 & H14	3–5
29d	5	9.7.5 col 2 dot 1 & 4	H2 & H8	3–4
29e	6	9.7.6 all col 2 (except dot 5) col 3 dot 2 & 3	H1, H2 & H13	4–6
30a	4	9.8.1 col 2 dot 1 & 5 col 3 dot 2	H10 & H14	2–4
30b	5	9.8.2 col 3 dot 1 & col 2 dot 3	H2 & H8	3–5
30c	5	9.8.1 col 3 dot 3 & col 2 dot 3	H7 & H10	3–5
30d	4	9.8.3 col 2 dot 3 & 4 col 3 dot 2	H7 & H10	2–4
30e	7	9.8.3 col 2 dot 5, 6,7 & 8 and 9.8.4 col 3 dot 1	H1, H4, H13	2–6

Suggested Answers and Marking Guidelines

Section I – Part A
Multiple Choice Answers

Question	Answer	Comment
1	C	$T = 2\pi\sqrt{(l/g)}$
2	B	Geostationary satellites move more slowly and are higher.
3	D	Transfer orbit in the direction of the Earth's orbital motion.
4	A	$v_{esc} = \sqrt{(2Gm/r)}$
5	D	The speed of light is independent of speed of source or observer
6	A	Right hand rule (Using the component of the current perpendicular to the B field)
7	A	Application of Lenz's law to conservation of energy
8	D	Same frequency, $V_s = 5V_p$, 90^o phase change as EMF = $-\Delta BA/\Delta t$
9	B	Westinghouse fought for AC and Edison fought for DC
10	C	Using Lenz's law, a current will be induced to oppose the change
11	A	Electrons are ejected from the negative cathode on a photocell
12	C	Standard definition of diffraction
13	D	Standard hand rule (remember electron is negative) and r = mv/q
14	B	Neutral p-type semiconductor produced as no net charge added

Question	Answer	Comment
15	C	Intensity = No. photons emitted per second × energy of each photon

Section I – Part B

Question 16 (a)

Criteria	Marks
• Correct numerical answer.	1

Answer: GPE = $-Gm_1m_2/r_e = -1.26 \times 10^{11}$ J

Question 16 (b)

Criteria	Marks
• Correct numerical answer.	1

Answer: GPE = $-Gm_1m_2/(8000000 + r_e) = -5.57 \times 10^{10}$ J

Question 16 (c)

Criteria	Marks
• Correct numerical answer (or difference between the values obtained by student in parts (a) and (b) even if these were not correct).	1

Answer: $\Delta GPE = -5.57 \times 10^{10} - (-1.26 \times 10^{11}) = 7.0 \times 10^{10}$ J

Question 16 (d)

Criteria	Marks
• Clear statement relating the energy required to place a satellite in orbit to the various types of work that must be done. Hence, in addition to the energy required to lift the satellite to correct height, (PE) energy is also required; to give the satellite the correct velocity to keep it in orbit (i.e. KE), to overcome air friction when travelling through the atmosphere, and some energy is lost as heat (because rocket engines are not 100% efficient).	3
• Clear statement that energy is required for <u>one</u> of above in addition to the energy required to raise the satellite to the correct height (PE) or a poorly expressed response that mentions <u>two</u> of the factors above.	2
• A response that mentions <u>one</u> of the factors above in addition to PE.	1

A good response would include:

- In addition to the work required raising the satellite to the correct height, work must be done to give the satellite the correct horizontal velocity to keep it in orbit at this height.
- Work must also be done to overcome air friction and some energy is lost as heat because the rocket engines are not 100% efficient.

Question 17(a)

Criteria	Marks
• Correct numerical answer.	1

Answer: $t = \sqrt{(2y/g)} = 8.08$ seconds

Question 17 (b)

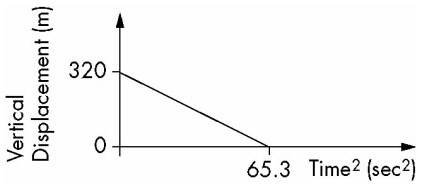
Criteria	Marks
• Correct numerical answer.	1

Answer: $x = v_x t = 970$ metres

Question 17 (c)

Criteria	Marks
• Shows a **straight line** graph with **labelled axes** with **units** and **correct intercept values.**	3
• Shows a straight line graph with two of the above correct.	2
• Shows a straight line graph with <u>**one**</u> of the above correct or a curve with all else correct.	1

Answer:



Question 18

Criteria	Marks
• A coherent, well-structured answer that illustrates the importance of Newton's Universal Law by identifying four or more of the points below.	5
• A well-structured answer about the importance of Newton's Law that identifies two of the points below or a less well-structured answer that includes three of the points below.	3–4
• A less well-structured answer that includes one or two of the points below.	1–2

A good response would include:

- A definition of (or equation expressing) Newton's Law of Universal Gravitation.
- Newton's diagram of the cannon fired horizontally from a high mountain placing a cannon ball in orbit.

- A clear statement explaining that the gravitational attraction expressed by Newton's Law provides the centripetal force that enables satellites to remain in their orbits.
- Newton's law alone cannot be used to calculate the motion of satellites, but by equating it to the centripetal force, the values that describe the motion can be calculated (and/or relevant equations, i.e. $mv^2/r = Gm_1m_2/r^2$).
- A statement (or equations) showing that combining Newton's Law and centripetal force can be used to calculate period and/or the velocity of a satellite.
- A statement or equations showing that combining Newton's Law and centripetal force shows that the period of a satellite is independent of the satellite's mass.

Question 19 (a)

Criteria	Marks
• A clear expression of both postulates.	2
• A clear expression of one postulate.	1

Postulates:
- All inertial frames are equivalent (or there is no absolute rest frame in the universe).
- The speed of light is an absolute constant that is independent of the speed of the source or the observer.

Question 19 (b)

Criteria	Marks
• Shows working and gives correct numerical answer **or** working shown and correct answer in terms of c.	2
• Gives correct numerical answer but no working shown or incorrect answer but mass dilation equation rearranged for velocity correctly.	1

Answer: $v = c\sqrt{(1 - (m_o/m)^2)} = c\sqrt{(1 - 1/3^2)} = 2.83 \times 10^8$ ms^{-1} or 0.94 c

Question 20

Criteria	Marks
• Clearly describes how step down and step up transformers are similar **and** how they are different from one another and gives correct examples of where each type of transformer would be used.	4
• Describes similarities **or** differences between step up and step down transformers with examples of use given or describes similarities and differences but fails to give two examples.	2–3
• Describes step up **or** step down transformer only, or only gives an example where one or both types of transformers would be used.	1

A good response would include:
- A comparison of the transformers

- Both used to change AC voltage.
- Both use primary and secondary coils wound onto a laminated iron core

- Step down transformer has fewer turns on the secondary coil than primary coil; hence reducing the voltage and increasing the current.
- Step up has more turns on the secondary coil than primary coil; hence increases the voltage and decreases the current.

- Step down transformers used in homes to reduce 240V mains voltage for a range of electronic equipment including computers, mobile phones, CD players etc.
- Step up transformers in CRT television to accelerate electrons and to increase the voltage leaving power stations to reduce losses during transmission.

Question 21 (a)

Criteria	Marks
• Correct numerical answer.	1

Answer: m = Weight/g = 2/9.8 = 0.204 kg or 204 g

Question 21 (b)

Criteria	Marks
• States correct direction, strength and units.	3
• States correct strength but wrong direction or units.	2
• States wrong strength but correct direction.	1

Answer: B = F/nIl = (5 – 2)/(50 × 5 × 0.1) = 0.12 T from side X of the magnet to side Y. Hence, side X is north pole.

Question 21 (c)

Criteria	Marks
• Correct statement about the relationship between the number of turns and the magnetic force and about the sensitivity of the spring balance.	2
• One of the above.	1

A good response would include:
- The strength of the magnetic force on the coil is proportional to the number of turns of wire in the coil.
- The spring balance would not have been sensitive enough to measure the current if a single turn was used.

Question 22

Criteria	Marks
• Clear description of experiment conducted **and** how it demonstrated the principle of the AC induction motor.	4
• Reasonable description of experiment and connection to AC motor principle.	2–3

Criteria	Marks
• Poor description of AC motor principle and description of an experiment. Or description of AC motor principle only or experimental description only with no clear connection to AC motor principle.	1

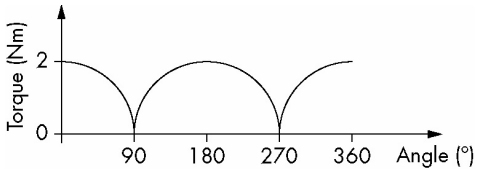
A good response would include:

- A definition of the AC motor principle. That is, when a magnet is moved near a conductor eddy currents are induced in the conductor that in turn produce a Lenz's law force that causes the conductor to experience a force that moves it in the same direction that the magnet is moving. (The induced current direction is such as to oppose the magnet moving past the conductor.)
- A clear description of the experiment undertaken (i.e. enough detail for the reader to be able to repeat the experiment).
- A statement showing the connection between the experiment and the AC motor principle.

Question 23 (a)

Criteria	Marks
• Correct curve and phase.	2
• Correct curve but wrong phase or correct phase, but curve with negative section not inverted.	1

Answer:



Question 23 (b)

Criteria	Marks
• One correct change given.	1

Responses could include:

- Add additional coils to the rotor at different angles (the commutator would also need to be changed to do this) **or**
- Using curved poles on the magnets.

Question 23 (c)

Criteria	Marks
• Clearly describes concept of back EMF. Statement relating lack of back EMF to increased current through the rotor coils when the motor is prevented from turning. Relationship between increased current and heating of windings described.	3
• Imprecise explanation of the back EMF concept and how it affects the current in the motor when the motor is stopped from turning.	2
• Vague answer that mentions back EMF **or** increased current when the motor is prevented from turning.	1

A good response would include:

- When a motor turns a voltage is induced in the rotor coil that opposes the applied voltage.
- The back EMF generated when the motor is turning reduces the current passing through the rotor windings.
- When the motor is prevented from turning the back EMF is reduced to zero,
- This increases the current in the windings.
- Increased current causes resistance heating in the windings and may result in the insulation around the wires melting (or the wires melting) and the motor burning out.

Question 24 (a)

Criteria	Marks
• Both reasons correctly stated.	2
• One of the reasons correctly stated.	1

Responses should include:

- Collisions with impurity atoms/deformations in the lattice.
- Scattering of electrons by lattice vibrations (collisions with lattice atoms).

Question 24 (b)

Criteria	Marks
• States increase in resistance and gives correct reason.	2
• States one of the above.	1

A good response would include:

- The resistance of a metal increases when the temperature of the metal is increased.
- Higher temperatures cause the lattice to vibrate more intensely which in turn causes more collisions with electrons as they move through the lattice. The shorter 'mean free path' between collisions increases the resistance, because electrons have more frequent collisions as they move through the lattice.

Question 24 (c)

Criteria	Marks
• Clear, well-structured comparison that mentions Cooper pairs and zero resistance in superconductors and single electron movement with associated collisions in metals.	2
• Comparison of resistance **or** single electron movement & Cooper pairs.	1

A typical response would include:

- A comparison of the resistance – superconductor has none while a metal has resistance.
- A comparison of the electron movement – individual electrons taking an erratic path because of collisions with the lattice atoms in a metal. Cooper pairs travelling unimpeded through the lattice in a superconductor.

Question 25 (a)

Criteria	Marks
• Correct definition of black body radiation.	1

A typical response would be:
Black body radiation is the electromagnetic radiation emitted from a body due to the temperature of the body alone. A perfect black body would therefore absorb all the radiation that falls on it and reflect none.

Question 25 (b)

Criteria	Marks
• Clear statement that includes something about black body emission being quantised or the oscillators emitting the radiation in a black body being quantised.	1

A typical response would be:
Radiation is emitted and absorbed by a black body in discrete multiples of energy or quanta (i.e. E = nhf where n is an integer).

Question 25 (c)

Criteria	Marks
• Clear statement that should mention the photoelectric effect and the quantisation of light.	2
• Answer that includes the photoelectric effect **or** the quantisation of light.	1

A typical response would include:

- Einstein used Planck's quantum hypothesis to explain the photoelectric effect.
- In his explanation Einstein proposed that light could be thought of as a stream of quanta (or photons) with energy that is related to the frequency of the light by E = hf.

or

- To explain black body radiation Planck quantised the oscillators that were thought to emit and absorb energy in a black body. To explain the photoelectric effect Einstein extended Planck's ideas to quantise the radiation field itself.

Question 26 (a)

Criteria	Marks
• Clearly explains the characteristics of each type of device and the difference between each type of device.	2
• Poor explanation of the difference **or** only the characteristics of one type of device discussed **or** discussion limited to why one type of device is better or worse than the other.	1

A good response would include:

- Thermionic devices are electronic components that use a hot cathode to emit electrons that pass between electrodes in an evacuated (usually glass) tube.
- In contrast, solid-state electronic devices perform the same functions as thermionic devices, but utilise the flow of electrons through solids (usually semiconductor solids).
- Solid-state devices have proved to be superior to thermionic devices because they are cheaper, can be miniaturised, are more efficient and are less fragile.

Question 26 (b)

Criteria	Marks
• States two impacts.	2
• States one impact.	1

A typical response would include:

- Solid-state devices have led to a **communications revolution**. They have enabled the creation of the Internet, mobile phones, satellite TV etc. that have brought the world much closer together and changed society by increasing the connectivity between individuals and between cultures and countries.
- Solid-state devices have led to an **information revolution**. Microprocessors and the Internet have brought a huge amount of information into homes that previously could only be accessed through libraries and other information depositories. This has changed society in many ways, for example, by allowing many more people to work from home and enabling students to search for information at home rather than spend large amounts of time in libraries.

Question 27

Criteria	Marks
• A comprehensive discussion of the competing theories that were resolved by each scientist that includes how each controversy was resolved and an evaluation of the statement based on these examples.	6
• A clear discussion of the competing theories resolved by both experiments, but no evaluation of the statement **or** a discussion of the competing theories resolved by both experiments and an evaluation statement, but no discussion of how the experiments resolved the competing theories.	5
• A clear description of the competing theories and how the competing theories were resolved by **one** of the scientists and an evaluation statement. Or a description of both experiments with (4) or without (3) an evaluation statement.	3–4

Criteria	Marks
• A statement of the competing theories resolved by only **one** of the scientists **or** a description of one of the experiments. With or without an evaluation statement.	1–2

A good response would include:

- Both of the experiments ended debate about competing scientific theories and hence add support to the statement.
- In the case of J. J. Thomson the debate concerned the nature of cathode rays. One theory suggested cathode rays were waves like electromagnetic waves, while the other suggested they were particles. Thomson's experiment resolved the controversy by proving that cathode rays travelled at velocities below the speed of light and that they had a charge to mass ration.
- The Michelson and Morley experiment was designed to confirm the existence of the proposed aether, but achieved a null result. Most scientists before Michelson and Morley believed that light waves required a medium in which to travel and supported the aether model. But some scientists (including Einstein) believed the aether might not exist. The Michelson and Morley experiment ended this controversy.
- The statement is therefore quite correct and it reflects an important truth about the development of science. A single experiment can end the scientific controversy between competing theories. Both these examples illustrate how the controversy between competing scientific theories can be resolved by a single experiment. In both cases, the experiment proved one of the theories to be incorrect. This falsification is a key feature of the development of scientific theories. A large number of experiments might add support to a theory, but it only takes one experiment that contradicts a theory to prove the theory incorrect.

Section II

Question 28 – Medical physics

Question 28 (a) (i)

Criteria	Marks
• Correct answer.	1

A good response would include:

- The greater the difference in the acoustic impedance between two materials, the greater the proportion of the incident sound reflected.
- The gel minimises the difference in impedance between air between the transmitter/detector and the skin, which minimises the reflection of the ultrasound waves at this boundary. (Without the gel the waves would be largely reflected by the air/skin boundary.)

Question 28 (a) (ii)

Criteria	Marks
• Correct use of equation and correct numerical answer.	2
• Failure to convert to a percentage **or** percentage reflected rather than percentage transmitted calculated.	1

Answer:
$I_r = 100 \times (4.7 \times 10^6 - 1.6 \times 10^6)^2 / (4.7 \times 10^6 + 1.6 \times 10^6)^2 = 24.2$ % reflected.
Therefore $I_t = 100 - 24.2 = 75.8\%$

Question 28 (a) (iii)

Criteria	Marks
• A well-constructed coherent answer that defines the Doppler effect **and** explains how it is used in Doppler ultrasound of the heart.	4
• An explanation that explains the Doppler effect but fails to explain the relationship between the speed of the blood flow and the frequency of the reflected ultrasound wave.	3
• A vague answer with some correct statements about Doppler ultrasound.	1–2

A good response would include:

- The Doppler effect states that the observed frequency of waves emitted by, or refected from, a moving object will be increased if the object is moving towards the observer and decreased if the object is moving away from the observer.
- Doppler ultrasound uses this effect to measure the velocity of blood in arteries.
- The frequency of the ultrasound before reflection and after being reflected from moving blood cells is compared. Computers are used to calculate the velocity of the blood in real time from the difference between incident and reflected ultrasound frequencies.

Question 28 (b)

Criteria	Marks
• Clear explanation of total internal reflection, coherent bundles and illumination.	3
• Reasonable explanation of two of the above.	2
• Answer that only looks at one of the above.	1

A good response would include:

- Endoscopes consist of a coherent bundle of optical fibres to transfer an image from the tip of the endoscope to the viewing end. They also often use an incoherent bundle of fibres to transfer light to the tip of the fibre for illumination (using fibres means the heat emitted from the light source is not transferred to the patient).
- Total internal reflection occurs in the optic fibres because the light is reflected at angles of incidence greater than the critical angle in the fibre that has a graded refractive index, which decreases outwards from the centre of the fibre.

- A coherent bundle is a group of fibres that is bound together so that the relative position of each fibre in the bundle is maintained while, in an incoherent bundle, the position of each fibre is not maintained.

Question 28 (c) (i)

Criteria	Marks
• Correct numerical answer from the graph and units.	1

Answer:
From the graph the half-life of oxygen-15 is 120 seconds.

Question 28 (c) (ii)

Criteria	Marks
• Correct statement that two gamma rays are produced.	1

Answer:
When a positron meets an electron they annihilate each other and produce pure energy in the form of two gamma rays travelling in opposite directions (to conserve momentum).

Question 28 (c) (iii)

Criteria	Marks
• Clear explanation of the way the emitted gamma rays in a PET scan are used to pinpoint the position of the radioisotope in the body.	3
• Partial explanation that fails to explain clearly how the emission point can be located.	2
• Poor answer with a correct statement about the PET scan process.	1

A good response would include:
- In a PET scan, a positron-emitting isotope is introduced into the body that accumulates more readily in specific types of tissue.
- When the isotope emits a positron, it immediately interacts with an electron and produces two gamma rays that travel in opposite directions.
- Multiple detectors are placed around the body in a PET scan to pick up the emitted gamma ray pairs.
- A computer uses the positions at which the gamma rays emerged from the body and the time lapse between the detection of each gamma ray in the emitted pair to pinpoint the position at which they were created in the body.
- Because the gamma rays travel in straight lines the emission must occur on a line that joins the two relevant detectors and the position along the line is calculated from the time difference between the arrival of each gamma ray at the detector. (Students could also use a diagram to explain this.)

Question 28 (d) (i)

Criteria	Marks
• Correct explanation.	1

Answer:
MRI scans require the patient to be placed in a very large magnetic field. In a large magnetic field, a splinter of ferromagnetic metal (e.g. steel) in the body might move and injure the patient.

Question 28 (d) (ii)

Criteria	Marks
• Correct answer of zero spin.	1

Answer:
The helium-4 nucleus has **no net spin** and hence no net magnetic field (moment) because all nuclei with an even number of protons and an even number of neutrons have no net spin.

Question 28 (d) (iii)

Criteria	Marks
• States that MRI is safer and clearly explains why.	2
• States MRI safer but does not clearly explain why.	1

A typical answer would include:
- MRI scans are safer for the patient than CAT scans.
- This is because MRI scans do not use any ionising radiation, while CAT scans require the use of multiple X-rays. Even though the intensity of the X-rays is low, X-rays are ionising radiation and, as such, constitute a health risk.

Question 28 (e)

Criteria	Marks
• Clear evaluation of the statement supported by evidence of the extensive use of X-ray radiographs and the use of X-rays in CAT scans. The answer should also evaluate the impact of the use of X-rays in medicine and on society and support the evaluation with examples of its effects on society.	5–6
• An answer which includes an evaluation of the use of X-rays and the affect of their use on society but fails to support the evaluation with evidence **or** an answer which looks at the medical use of X-rays and its effect on society, but fails to make an evaluation.	3–4
• A description of how X-rays are produced or used in medicine **or** a description of some of the impacts X-rays have had on society.	1–2

A good response could include:
- EVIDENCE OF IMPACT ON MEDICINE.
- The X-ray is one of most commonly applied medical procedures and almost every person in the developed world will have had several X-ray radiographs during their lives. Radiographs are used routinely around the world to analyse fractures and for

dental work and to scan for a variety of other diseases. More recently, the diagnostic power of X-rays has increased greatly with the development of Computed Axial Tomography (CAT) scans to produce three-dimensional images of the body.

- X-rays are ionising radiation and, as such, are potentially dangerous. The early use of X-rays may have overexposed patients and caused some damage to patients, but this danger is now recognised and exposure to X-rays is carefully monitored to keep it at 'safe' levels. There is still a tiny risk in using X-rays, but doctors consider this risk to be far outweighed by the benefits of using X-rays.
- EVIDENCE OF IMPACT ON SOCIETY.
- The invention of X-rays has had a huge impact on society. The use of X-rays has enabled an incalculably large number of fractures, injuries and diseases to be diagnosed and effectively treated. Many lives have been saved and permanent disabilities prevented by the use of X-rays for diagnosis. Without X-rays the death rate would be higher and society would have to deal with the problems associated with more sick people, more people with permanent disabilities and more regular misdiagnoses by doctors. The probability of each individual living a healthy, productive life has been increased by the use of X-rays in medicine and this has had a very positive impact on society. In terms of the social cost of illness and the positive affect of helping to make our lives happier and more productive, X-rays have had a very significant affect on society.
- EVALUATION OF VALIDITY OF STATEMENT.
- The discovery of X-rays has therefore had a very positive and significant impact on medicine and upon society and the statement is quite valid.

Question 29 – Astrophysics

Question 29 (a) (i)

Criteria	Marks
• Statement that the moon has no atmosphere.	1

Typical response would include:

- Unlike the Earth the moon has no atmosphere.
- The Earth's atmosphere absorbs many wavelengths and distorts the rays that are transmitted. Neither of these problems would occur on the moon.

Question 29 (a) (ii)

Criteria	Marks
• Both parts of answer correct.	2
• Only one part correct.	1

A good response would include:

- The moon has no atmosphere so there is no need for adaptive optics, which correct for atmospheric distortion.
- The mirror would, however, still be mechanically stressed when the direction of the telescope was changed and because of temperature changes etc., so active optics (which control the mirror's shape) would still be needed.

Question 29 (a) (iii)

Criteria	Marks
• Stating the Earth's orbital diameter is much larger and that parallax shifts are very small and must be maximised by maximising the size of the baseline.	2
• One of the above points.	1

A good response would include:

- The Earth's orbital diameter is much greater than the moon's orbital diameter.
- Parallax angles are very small and this limits how far from the Earth they can be used to measure distances to stars.
- To maximise the parallax shift the widest baseline should be used and for this reason it would be much better to use the Earth's orbital diameter rather than the moon's orbital diameter.

Question 29 (b) (i)

Criteria	Marks
• Clear coherent answer stating that a telescope is used to collect the light and explaining how a spectrometer is used to disperse the light from the telescope and how the spectra is recorded.	3
• Clear explanation of the spectrometer but no mention of the telescope or including the telescope and spectrometer but not explaining how the spectra is recorded.	2
• A vague answer with some correct statement/s about stellar spectral analysis.	1

A good response would include:

- A telescope is used to collect light from a star and to focus it onto the input slit of a (diffraction grating or prism) spectrometer.
- The spectrometer uses a diffraction grating or prism to disperse the incident light into its constituent wavelengths (a diagram could be used here).
- The spectrum is then viewed manually, or photographed/recorded electronically for later analysis.

Question 29 (b) (ii)

Criteria	Marks
• Answer stating at least two of the points listed below.	2
• Answer stating one of the points below.	1

A good response would include:

- The stellar spectra would be similar to that from a black body with a temperature of 6000^{o}
- But it would contain many absorption lines caused by light being absorbed by gas atoms and molecules in the star's outer atmosphere.
- The peak emission would occur in the yellow region (just like that from our sun).

Question 29 (c) (i)

Criteria	Marks
• Correct explanation.	1

Answer: As Altair is closer to the Earth than 10 pc its absolute magnitude must be greater than 2.2. Deneb is therefore more luminous (greater intrinsic brightness) because it would have a lower absolute magnitude than Altair.

Question 29 (c) (ii)

Criteria	Marks
• Correct numerical answer and correct statement about which star is brighter.	2
• Incorrect numerical answer, but correct statement about which star is brighter based on the results of the student's calculation.	1

Answer:
$M = m - 5\log(d/10)$ $\therefore$ $m = M + 5\log(d/10) = -7.2 + 5\log(492/10) = 1.26$
Hence, Deneb is the brighter star when viewed from the Earth as it has a lower absolute magnitude than Altair.

Question 29 (c) (iii)

Criteria	Marks
• Correct numerical answer.	1

Answer: $I_{Deneb} = I_{Altair}(100)^{\wedge}(2.2 - 1.26)/5 = 2.4$. Hence, Altair appears 2.4 times brighter than Deneb when viewed from the Earth.

Question 29 (d) (i)

Criteria	Marks
• Correct description including both points below.	2
• Only one of the points below included.	1

A good response would contain:
In an astrometric binary only one of the two stars in the system is visible when viewed through a telescope.
Measurements of the motion of the visible star around the centre of mass of the system are used to prove that the visible star is part of a binary pair.

Question 29 (d) (ii)

Criteria	Marks
• Correct description that mentions all three points below.	3
• Description that clearly describes two of the points below.	2

Criteria	Marks
• Vague answer that describes two of the points below or a good description of one of the points below.	1

A good response would contain:
The luminosity of cepheid variable stars varies periodically.
The absolute magnitude of a cepheid is related to, and can be determined from, the period of oscillation of the luminosity. This relationship was determined by comparing the period of luminosity of 'nearby' cepheids with their absolute magnitude.
By measuring the apparent brightness from the Earth, and using the absolute magnitude determined from the period/luminosity relationship, the distance to the cepheid star can be calculated using $M = m - 5\log(d/10)$.

Question 29 (e)

Criteria	Marks
• Extensive and coherent answer that describes the important features of H/R diagrams, outlines stellar evolution paths for stars with different initial masses, explains how they are represented on an H/R diagram and includes an evaluation of the diagram's importance to understanding stellar evolution.	5–6
• Less extensive answer that still contains a significant amount of the above information or a content-rich answer that fails to make the link between stellar evolution and the H/R diagram or to evaluate its importance.	3–4
• A vague answer that makes some correct points.	1–2

A good response might include:

- The H/R diagram plots absolute magnitude against spectral class (or temperature).
- The H/R diagram is used to plot star characteristics in order to group stars into different categories based on the energy they radiate per second and their spectral class (surface temperature).
- On an H/R diagram, main sequence stars, red giants, white dwarf stars appear in different regions (students could show this with a labelled diagram).
- **Stellar evolution can be represented on an H/R diagram because stars pass through various stages that can be represented on the diagram.** All stars form in huge clouds of gas and dust. When gravity accumulates enough material for the fusion of hydrogen into helium a protostar is born and the star becomes a main sequence star that can be plotted on the H/R diagram.
- Stars like our sun (1 solar mass stars), will initially join the main sequence (fusing hydrogen to helium in their core) where they will remain until they run out of hydrogen in their core. They will then start to burn helium in their cores and expand to become red giant stars. When the helium in the core is used up, fusion will cease because they are not big enough to fuse heavier elements and the star will shrink to become a white dwarf. (Students could show this using a labelled H/R diagram.)
- Larger stars may fuse heavier elements after helium and after becoming red giants undergo nova, or if they are large enough (10 solar masses) super nova explosions. Depending on how big the core is after the super nova explosion, these large stars may collapse to become neutron stars or black holes.

- The H/R diagram enables different star types to be readily seen and the evolution of stars to be plotted and examined. The H/R diagram has therefore been, and continues to be, an extremely important tool for studying and understanding the evolution of stars.

Question 30 – Quanta to quarks

Question 30 (a) (i)

Criteria	Marks
• An explanation of how Rutherford's planetary model accounts for the experimental results.	2
• Answer includes a description of Rutherford's nuclear model.	1

A typical response would include:

- Rutherford proposed a planetary model in which the electron orbited a small positive nucleus. (He suggested electrostatic forces held the electron in its orbit.)
- Rutherford's model explained the results because most of the atom was empty space, so most of the alpha particles passed through without being deflected significantly. A small number of alpha particles, however, would have had near 'head on' collisions with the nucleus, causing them to be deflected by a large amount.

Question 30 (a) (ii)

Criteria	Marks
• Two advantages with the model correctly stated.	2
• One advantage clearly stated.	1

A good response would include:

- Rutherford's model was unstable because the orbiting electrons would have been accelerating and would therefore have emitted electromagnetic radiation, causing the electron to slow down and spiral into the nucleus. Bohr's model in contrast was stable because it assumed electrons could only orbit in specified non-radiating orbits.
- Bohr's model explained atomic emission and absorption spectra while Rutherford's could not.

Question 30 (b) (i)

Criteria	Marks
• Correct answer.	1

Answer: $v = h/m\lambda = 5.2 \times 10^6$ ms^{-1}

Question 30 (b) (ii)

Criteria	Marks
• A clear description of the Davisson and Germer experiment and a clear explanation of how it supported de Broglie's wave hypothesis.	4
• A clear description of the experiment, but no explanation of how it supported the wave hypothesis **or** a vague description of the experiment and how it supported the hypothesis.	2–3
• A confused answer with some correct statement about the experiment.	1

A good response would include:

- Davisson and Germer accelerated electrons to high speed and then directed the electron beam at a nickel crystal. They then detected and measured the direction at which electrons left the crystal. (A diagram could be used to support the answer.)
- They found the electrons were diffracted in the same way that X-rays with the same wavelength as the electrons, were diffracted. By measuring the angle of diffraction, knowing the crystal lattice spacing and using Bragg's law they determined the wavelength of the diffracted electrons and found it agreed with the theoretical value calculated using de Broglie's equation $\lambda = h/mv$. This experiment proved not only that electrons behaved like waves, but also that they had the wavelength predicted by de Broglie's theory.

Question 30 (c) (i)

Criteria	Marks
• Both calculations correct.	2
• One calculation correct or correct substitution in Rydberg's equation only.	1

Answer:

- $\lambda = 1/(R\,(1/1 - 1/2^2)) = 121.5$ nm
- $E = hc/\lambda = 1.636 \times 10^{-18}$ J $= 10.21$ eV

Question 30 (c) (ii)

Criteria	Marks
• Correct diagram, to scale, with each energy levels labelled (with energy or principal quantum number).	3
• Correct diagram with two correct from the following: diagram drawn to scale, energy axis labelled, levels labelled (with energy or principal quantum number).	2
• Correct form of diagram with one correct from the following: diagram drawn to scale, energy axis labelled, levels labelled (with energy or principal quantum number).	1

A good response is shown below:

Question 30 (d) (i)

Criteria	Marks
• Correct calculation.	1

Answer: $^{237}_{92}U \rightarrow {}^{233}_{90}Th + {}^{4}_{2}He$

Question 30 (d) (ii)

Criteria	Marks
• Correct numerical answer.	1

Answer: $0.03/931.5 = 3.2 \times 10^{-5}$ atomic mass units or 5.4×10^{-32} kg

Question 30 (d) (iii)

Criteria	Marks
• Correct explanation of both 'natural' and 'transmutation'.	2
• Correct explanation of one of the above.	1

A good response would include:

- This reaction is a natural transmutation because:
- Energy is released in this nuclear reaction and therefore it may occur spontaneously as a 'natural' radioactive decay.
- Uranium is 'transmuted' (i.e. changed) into a different element in this reaction.

Question 30 (e)

Criteria	Marks
• Extensive and coherent answer that describes power generation by nuclear fission and fission weapons and links both to specific benefits and problems for society.	7
• An extensive answer that well describes nuclear fission power generation and weapons but fails to link them adequately to social effects **or** an extensive answer on the social effects that lacks sufficient detail about fission power or fission weapons.	5–6
• A less extensive answer that describes some aspects of fission power and weapons and their affect on society **or** a good answer that concentrates on controlled nuclear power and its effect on society (but fails to address nuclear weapons) **or** a good answer that concentrates on the "suffering" or the "benefit" aspect of the statement.	3–4
• A poorly constructed answer that makes some correct statements about controlled and/or uncontrolled fission power and/or their effect on society.	1–2

A good answer might include:

- Nuclear fission was discovered just before the Second World War began.
- Nuclear fission occurs when a large nucleus absorbs a neutron and splits into two smaller nuclei, emitting some neutrons. In this process, mass is converted into energy and because neutrons are released in the reaction they can be used to initiate further fission reactions, producing a chain reaction.
- During the Second World War, scientists in the USA developed controlled nuclear reactors that could be used to produce energy in a controlled fashion and fission weapons that could be used to release energy explosively. The War in the Pacific was ended when the USA dropped 'atomic bombs' on Hiroshima and Nagasaki, killing over one hundred thousand people.
- Since the War, controlled nuclear fission reactors have been used to produce electricity in a number of countries and today are responsible for about 10% of the world's electricity generation.
- Nuclear fission, as the statement suggests, has been a two-edged sword for society bringing the benefits of electricity production without greenhouse gas emissions or burning fossil fuels on the one hand, while being responsible for many deaths during the War and the arms race and fear of nuclear destruction after the War on the other hand.

- Some would argue that even nuclear power generation itself is a two-edged sword for humanity. Nuclear power has brought societies a huge amount of 'clean' power, but with a cost of suffering caused by nuclear accidents, the threat of future accidents and terrorist attacks on power stations and no absolute safe way to store radioactive wastes.
- Others would argue that in recent times, improved reactor designs have made nuclear power generation much safer and fission is bringing huge benefits to energy-starved societies, particularly in the developing world.
- But some people today still consider nuclear power too great a risk and express concern about countries with unstable governments using fission power generation as a 'stepping-stone' to making fission weapons.
- The statement therefore is quite valid and reflects the history of the use of fission by society. One would hope that in the future the benefits of fission to society will far outweigh the terrible suffering that fission has caused in the past, but only time will tell.

End of answers