Section II

Total marks (25)
Attempt ONE question from Questions 38-40
Allow about 45 minutes for this section

Answer the Question in the Option Answer Booklet. Extra booklets are available.

Show all relevant working in questions involving calculations.

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Question 38 — Medical Physics (25 marks)

(a) *Compare* the properties of ultrasound waves to those sound waves which are in the audible range of humans. **1**

(b) There is a very large range of frequencies used in ultrasound imaging. By using an example, *account* for the for the use of a particular of frequency. **1**

(c) *Explain* how the piezoelectric effect is used in the production of ultrasounds in medical instruments. **2**

(d) Refer to the table below.

Medium	Density ($kg\ m^{-3}$)	Ultrasound Velocity ($m\ s^{-1}$)
Air	1.3	330
Skin	1 070	1 565
Bone	1 400	4 080

(i) *Calculate* the acoustic impedance of bone. **1**

(ii) *Calculate* the percentage of reflected intensity when an ultrasound passes from air to skin. **1**

(iii) *Explain* why a coupling gel is placed on the skin of a patient when an ultrasound is being performed. **1**

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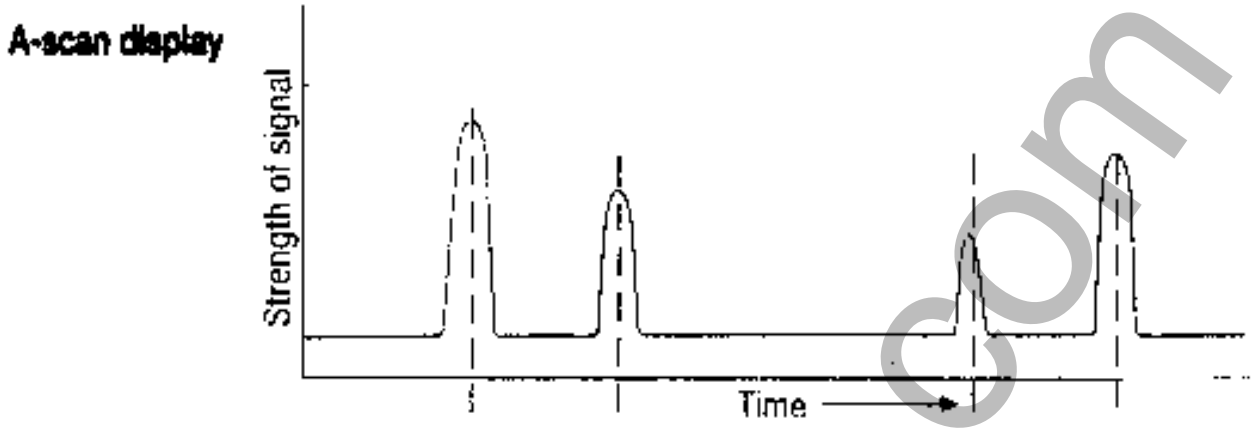
(e) The diagram below shows the results of an ultrasound scan.



(i) *Identify* the type of scan shown. **1**

(ii) *Explain* why the peaks of the graph vary in height. **1**

(f) (i) *Briefly describe* an experiment you performed to demonstrate the Doppler effect in sound. **1**

(ii) *Outline* the principles used in Doppler imaging. **2**

(iii) *Identify* ONE cardiac problem that can be diagnosed through using the Doppler imaging technique. **1**

(g) (i) *Outline* the two ways in which X-rays can be produced. **2**

(b) *Compare* soft X-rays and hard X-rays and identify when each are used for diagnostic purposes. **3**

(h) *Critically analyse* the use of a CAT scan for imaging a broken leg. **3**

(i) *Compare* coherent and incoherent bundles of fibres. **1**

(j) *Discuss* the benefits of endoscopes in medical work. **3**

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Question 39 — Astrophysics (25 marks)

(a) The resolving power of a telescope is its ability to produce sharp, detailed images and to separate close objects. *Identify* four factors which affect the quality of the image produced by a telescope? **2**

(b) Briefly *outline* the advantages of **2**

(i) multiple mirror systems used in large, ground-based reflecting telescopes

(ii) charged-couple devices (or CCD's) used in such large telescopes?

(c) *Describe* **4**

(i) two of the features of a star's absorption spectrum

(ii) a feature of the spectrum of EACH OF an M-class star and an O-class star

(d) A cloud of gas and dust has two major effects on our observations of a star beyond the cloud in its line of sight. If the cloud was removed, *explain* how these two observations about the star would change. **2**

(e) Study the table below which gives information about two main sequence stars. **5**

Star	Apparent magnitude	Absolute magnitude
α Logos	6.3	3.7
β Logos	2.8	6.9

(i) *Calculate* the luminosity ratio of α Logos to β Logos.

(ii) *Calculate* the parallax angle of β Logos.

(iii) Estimate the colours and surface temperatures of these two stars.

(f) *Describe* and *explain* the methods used to identify binary stars. **5**

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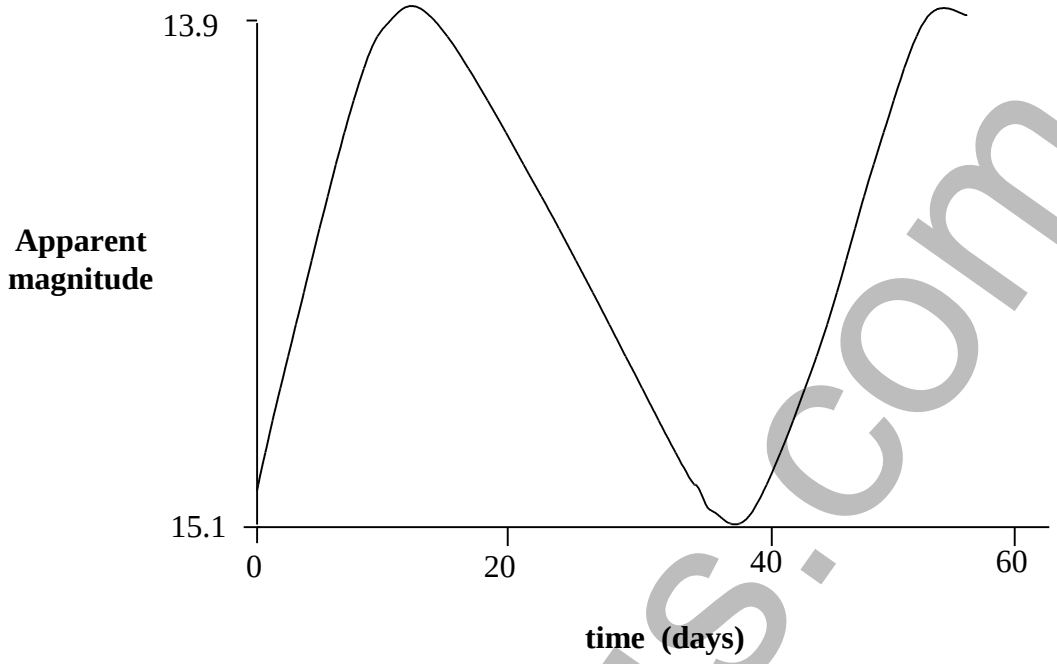
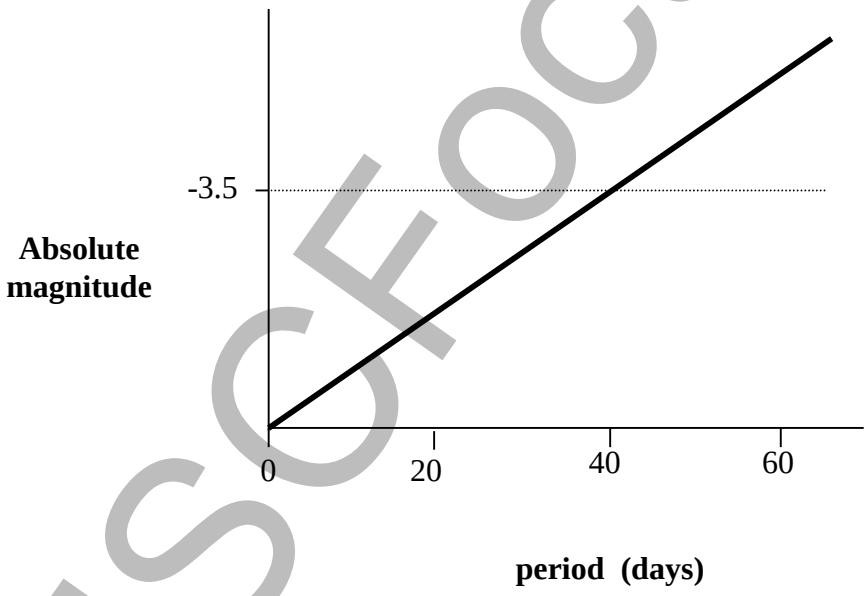
(g) A type I Cepheid variable has a light curve as shown below: **2**



Using this graph and the period – luminosity relationship for type I Cepheids (given below) *calculate* the distance to the Cepheid. *Explain* each step of your reasoning.



(h) *Construct* a Hertzsprung-Russell diagram. Give each axis a label and a scale. **3**
Clearly mark the region where you would find

(i) M-class main sequence stars

(ii) Red giants

(iii) Cepheid variables

(iv) White dwarfs

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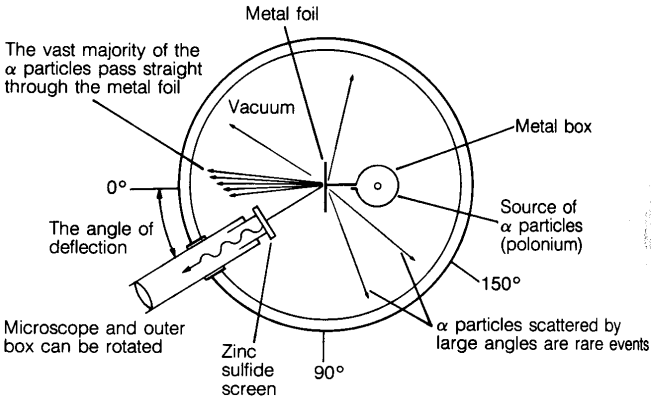
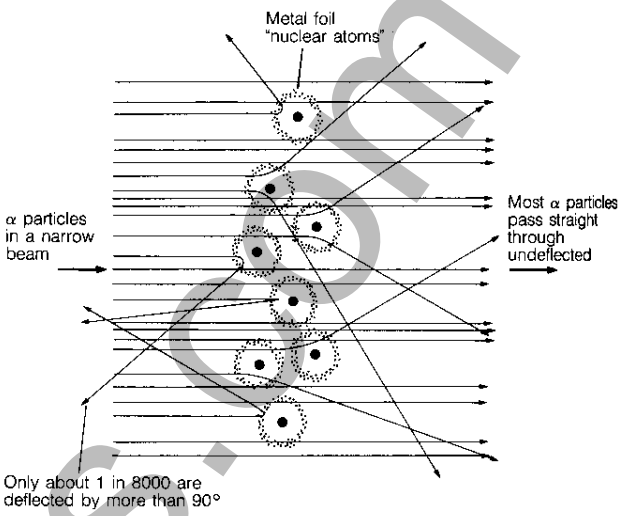
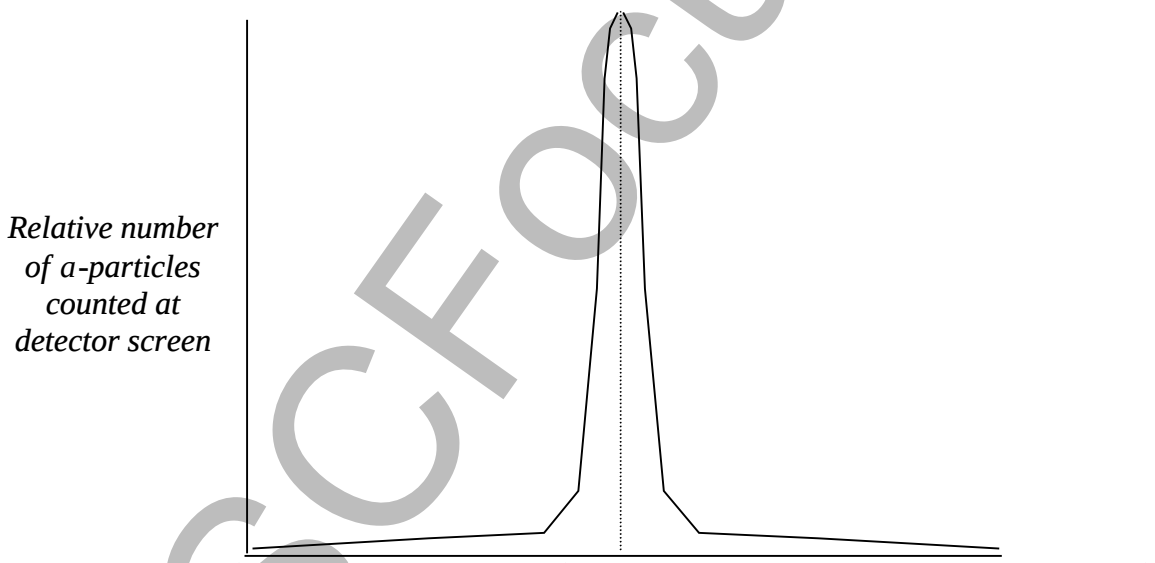
Question 40 — From Quanta to Quarks (25 marks)

(a) The following diagram is a representation of the apparatus used by Geiger and Marsden, students of Rutherford, to investigate the nature of gold atoms.





The data from this experiment yielded the following graph:



(i) *Explain* why the graph leads to the conclusion that the nuclei of gold atoms have negligible volume compared to the volume of the atoms as a whole. **1**

(ii) *Outline* a major problem with Rutherford's description of the electrons that led Niel's Bohr to propose an atomic model with quantised electron energies. **1**

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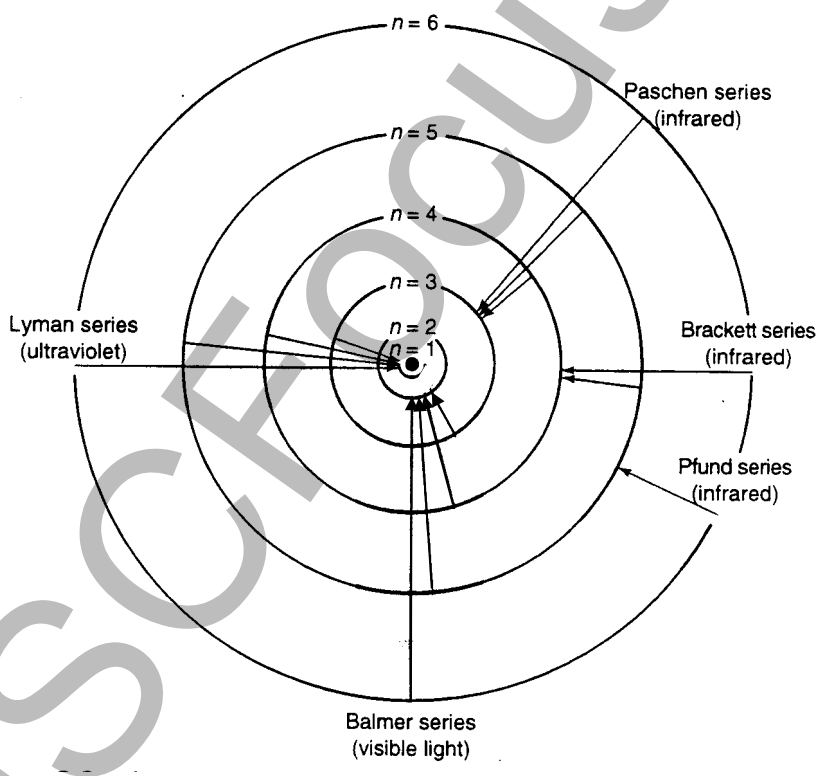
(b) *Explain* how Niels Bohr's atomic model incorporated *each* of the following phenomena. For *each* phenomenon, also *state* the relevant postulate of Bohr that incorporates it. **4**

(i) Planck's conclusion, from his analysis of black body radiation, that electromagnetic radiation is quantised in such way that the energy of radiation depends on its frequency.

(ii) Balmer's discovery of 4 lines in the visible spectrum of hydrogen, whose wavelengths corresponded to the relationship:

$$\lambda = k\frac{m^2n^2}{n^2 - m^2}$$ where m = 2 and n = 3, 4, 5 or 6 and $k = 9.1 \times 10^{-8}$ m

(c) The so-called Balmer series of spectral lines for hydrogen was explained by Niels Bohr in his atomic model.
The Balmer series and the infra-red Paschen series are represented in the following diagram.



An electric field is applied to a sample of hydrogen to stimulate the Balmer transition from n = 2 to n = 4.

(i) Use the wavelength of this transition (4.9×10^{-7} m) to *calculate* the corresponding energy difference between these quantum levels. **1**

(ii) Use the energy of this transition to *calculate* the corresponding voltage applied to stimulate the transition. **1**

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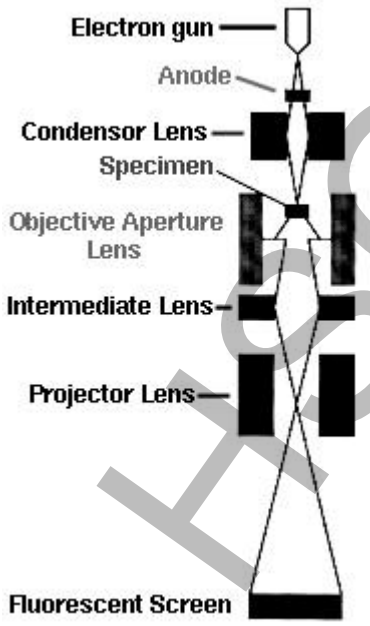
(ii) An infra-red line of wavelength 1 094 nm is also seen in the emission spectrum of hydrogen, as part of the Paschen series. Use the diagram and Rydberg's equation to deduce which two principal quantum levels are involved in the production of this line. **2**

(d) *Identify* ONE difficulty with the Rutherford-Bohr atomic model in explaining atomic spectra. **2**
Explain why this spectral feature, not predicted by the model, occurs according to quantum theory.

(e) *Explain* how de Broglie's theory about the nature and behaviour of electrons helped to overcome the inability of Bohr's model to justify the postulate that the angular momentum of electrons is quantised. **3**

(f) *Assess* the importance of Werner Heisenberg's contribution to atomic theory by way of his Uncertainty Principle. **3**

(g) The following diagram shows the components of a typical transmission electron microscope.



This microscope accelerates electrons through a potential difference of 5.00×10^3 V.

(i) *Calculate* the velocity of each electron after it has been accelerated. **2**

(ii) *Calculate* the maximum possible resolution of the microscope from the wavelength of the electrons. **2**

(iii) *Outline* one factor linked to the magnetic "optics" of the microscope that affects the resolution. **1**

(iv) *Assess* why the development of electron microscopes has been so important for the rapid growth of concepts in cell biology during the second half of the 20^{th} century. **2**

Source: **http://www.sv.vt.edu/classes/MSE2094_NoteBook/96ClassProj/experimental/electron.html**

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