IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M07/4/PHYSI/SP3/ENG/TZ2/XX+

22076518

PHYSICS
STANDARD LEVEL
PAPER 3

Thursday 3 May 2007 (morning)

1 hour

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet.

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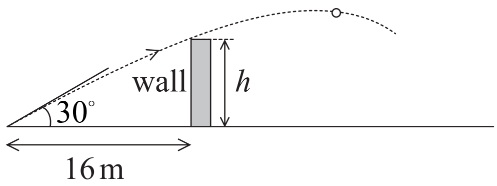
Option A — Mechanics Extension

A1. This question is about projectile motion.

A ball is projected from ground level with a speed of $28\,\text{m s}^{-1}$ at an angle of 30° to the horizontal as shown below.



There is a wall of height h at a distance of 16 m from the point of projection of the ball. Air resistance is negligible.

(a) Calculate the initial magnitudes of

(i) the horizontal velocity of the ball. *[1]*

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(ii) the vertical velocity of the ball. *[1]*

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(b) The ball just passes over the wall. Determine the maximum height of the wall. *[3]*

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A2. This question is about equilibrium.

(a) State the **two** conditions necessary for a body to be in equilibrium. *[2]*

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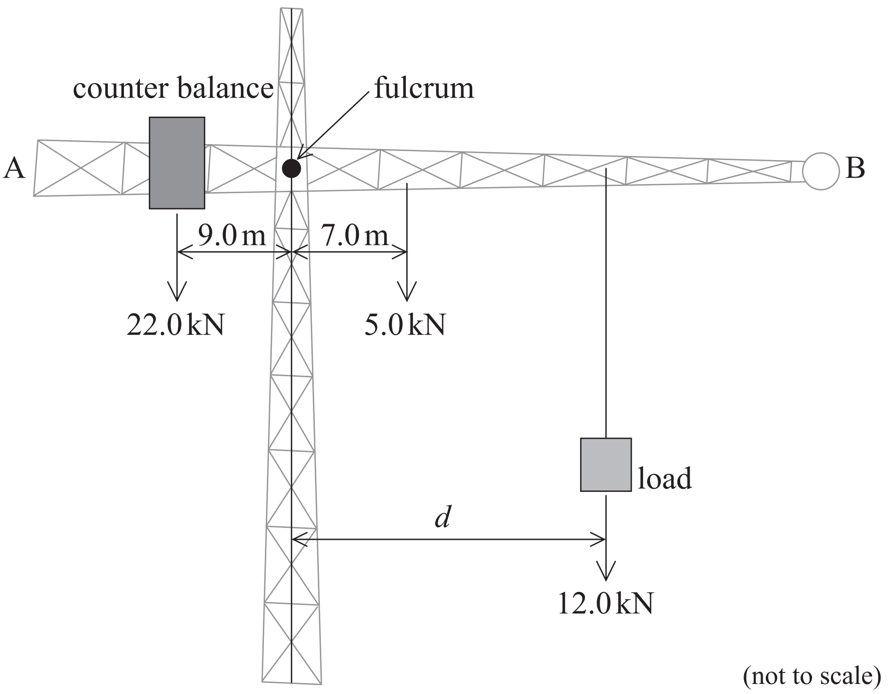
(b) A crane is used to raise a load of weight 12.0 kN as shown below.



The jib (horizontal section AB) of the crane has a weight of 5.0 kN and its centre of gravity is 7.0 m from the fulcrum. The weight of the counterbalance is 22.0 kN and it acts 9.0 m from the fulcrum. The counterbalance keeps the load and the weight of the jib of the crane in equilibrium.

Determine the distance *d* of the load from the fulcrum. *[3]*

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A3. This question is about gravitational potential.

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(a) Define *gravitational potential at a point*. *[2]*

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(b) A meteorite moves towards the Moon from a long distance away.

(i) On the axes below, sketch a graph to show the variation with distance from the centre of the Moon of the gravitational potential of the meteorite as it approaches the Moon. The radius of the Moon is r. *[2]*

(ii) The radius r of the Moon is 1.7×10^{6} m and its mass is 7.3×10^{22} kg.

Estimate the impact speed with which the meteorite hits the surface of the Moon. *[3]*

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(iii) Suggest **one** factor that will make the impact speed greater than your estimate. *[1]*

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(This question continues on the following page)

(Question A3 continued)

(c) A similar meteorite moves towards the Earth from a long distance away.

Suggest how the **total** energy of the meteorite varies with distance when the meteorite is

(i) outside the Earth's atmosphere. *[1]*

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(ii) inside the Earth's atmosphere. *[1]*

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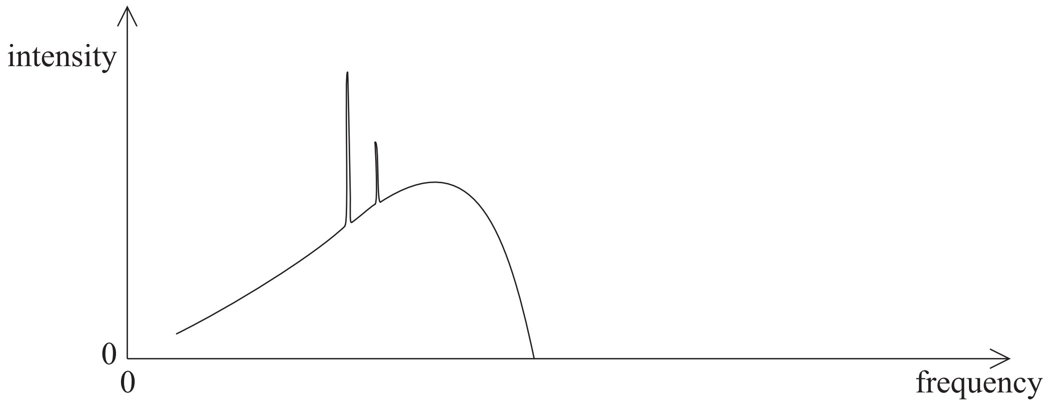
Option B — Quantum Physics and Nuclear Physics

B1. This question is about X-ray spectra.

The diagram shows the X-ray spectrum produced when electrons are accelerated from rest through a potential difference of 25 kV and are then incident on a metal target.



(a) Calculate the minimum X-ray wavelength. *[3]*

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(b) The electrons are now accelerated through a potential difference of 50 kV. On the diagram above draw the new X-ray spectrum. *[2]*

B2. This question is about atomic line spectra.

(a) Explain how the wavelengths of an atomic line spectrum relate to atomic energy levels. *[3]*

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(b) The wavelengths in the line spectrum of atomic hydrogen are 656 nm and 486 nm.

(i) A photon of wavelength 656 nm has an energy of 1.88 eV.

Deduce that a photon of wavelength 486 nm has an energy of 2.54 eV. *[1]*

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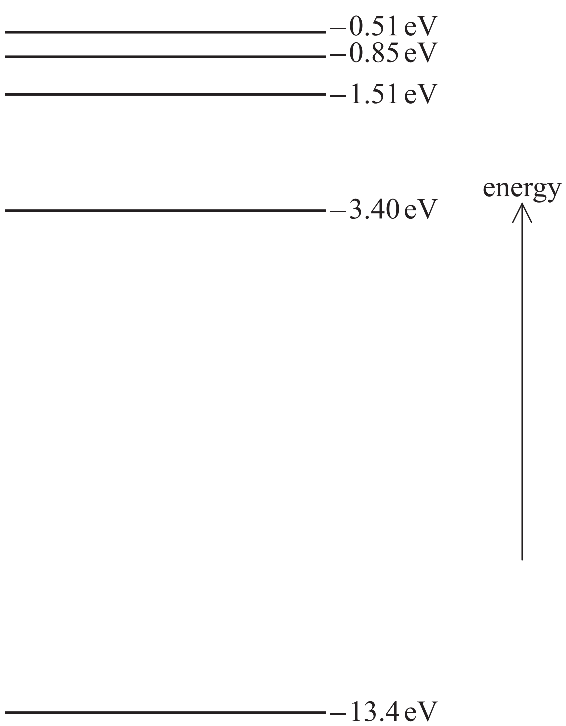
(ii) The diagram below shows some of the energy levels of atomic hydrogen.



On the diagram above, draw arrows to represent the electron transitions that produce these two wavelengths. *[2]*

B3. This question is about radioactivity.

(a) The nuclear decay equation for the radioactive isotope carbon-14 is shown below.

$$^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e} + \text{X}$$

State the name of

(i) particle X. *[1]*

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(ii) the class of fundamental particle to which ${}^{0}_{-1}\text{e}$ belongs. *[1]*

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(b) Wood in a living tree contains the isotope carbon-14. When the tree dies the amount of carbon-14 in the wood from the tree decreases.

(i) The half-life of carbon-14 is 5700 year. Deduce that the decay constant of carbon-14 is 1.2×10^{-4} year^{-1}. *[1]*

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(ii) The activity of carbon-14 in 1.0 g of living wood is 0.24 Bq. The activity of an ancient bowl made from the same type of wood is 0.075 Bq per gram.

Determine the age of the bowl. *[3]*

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(This question continues on the following page)

(Question B3 continued)

(c) Outline how the half-life of carbon-14 may be determined experimentally. *[3]*

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Option C — Energy Extension

C1. This question is about thermodynamic processes.

(a) State what is meant by an *adiabatic change*. *[1]*

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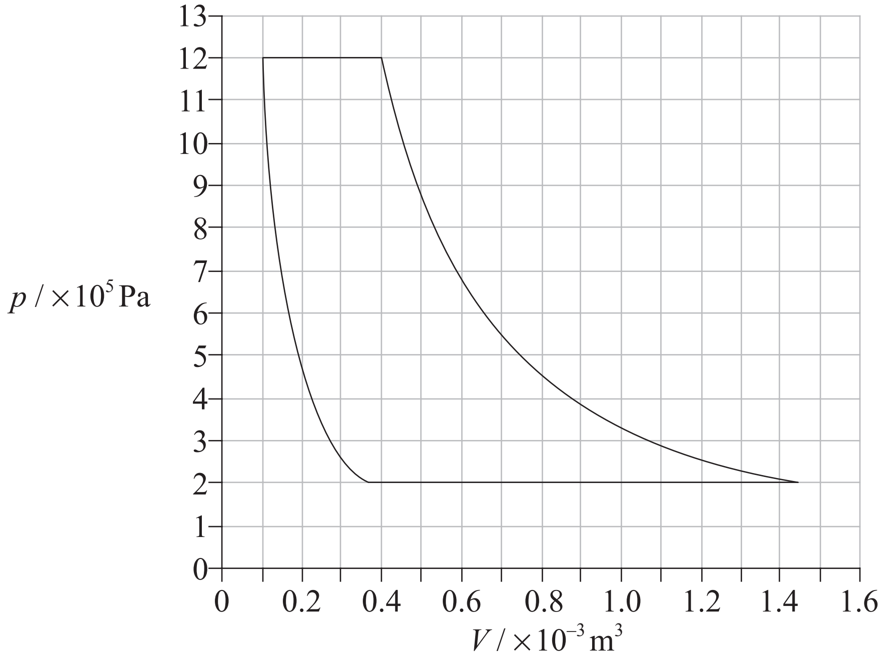
(b) The diagram below shows the pressure-volume (p-V) changes for one cycle of the working substance of a refrigerator.



On the diagram above,

(i) draw arrows to show the direction of the changes. *[1]*

(ii) label with the letter A an isobaric change. *[1]*

(iii) label with the letter B the change during which thermal energy is transferred to the working substance. *[1]*

(This question continues on the following page)

(Question C1 continued)

(c) Use data from the diagram in (b) to estimate the work done during one cycle of the working substance. *[3]*

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(d) (i) By reference to entropy change, state the second law of thermodynamics. *[1]*

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(ii) The cycle of the working substance in (b) reduces the temperature inside the refrigerator. Explain how your statement in (d)(i) is consistent with the operation of a refrigerator. *[3]*

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C2. This question is about nuclear fission.

(a) Outline whether nuclear fission constitutes a renewable **or** non-renewable source of energy. *[1]*

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(b) State **two** advantages of nuclear fission over the burning of fossil fuels for the production of electrical energy. *[2]*

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(c) Explain how a chain reaction maintains the production of energy in a nuclear fission. *[2]*

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(d) When a uranium nucleus fissions, approximately 180 MeV of energy is released. The overall efficiency of a nuclear reactor is 23 % and its output power is 450 MW.

Calculate the number of fissions required per second. *[4]*

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Option D — Biomedical Physics

D1. Dog A has a mass of 20 kg and dog B has a mass of 35 kg.

Determine the ratio

$$\frac{\text{rate of energy loss per unit mass for dog A}}{\text{rate of energy loss per unit mass for dog B}}.$$ *[4]*

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D2. This question is about hearing.

(a) State the range of frequencies audible to a normal adult human ear. *[1]*

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(b) Outline the role of the middle ear in the detection of sound. *[1]*

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(c) Structures within the cochlea have different lengths and stiffness. Outline how these structures enable different frequencies present in a sound wave to be distinguished. *[2]*

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(d) Explain how speech discrimination can be affected by changes in the functioning of the cochlea. *[3]*

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This question continues on the following page)

(Question D2 continued)

(e) A person with defective hearing can hear sounds with a minimum intensity of $6.0\times10^{-9}\,W\,m^{-2}$ at 3.0 kHz.

Determine the loss of hearing in dB of this person at this frequency. *[2]*

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D3. This question is about the absorption of X-radiation in body tissues.

(a) State **two** attenuation mechanisms by which X-rays are attenuated in body tissue. *[2]*

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(b) (i) Outline the basis of computed tomography (CT) imaging. *[3]*

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(ii) Describe how a standard X-ray photographic image differs from a computed tomography image. *[2]*

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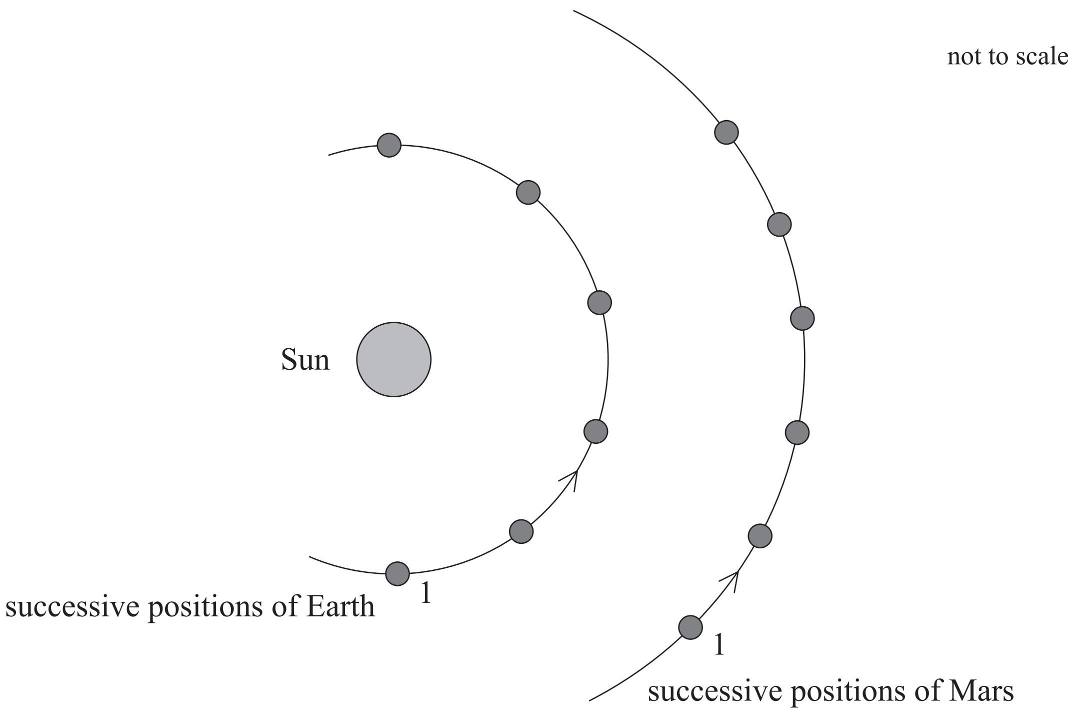
Option E — The History and Development of Physics

E1. This question is about planetary motion.

(a) The diagram below shows successive positions of the Earth and Mars in their orbits about the Sun. The positions are plotted at equal time intervals starting from the time when the Earth and Mars are in position 1.



(i) State what is meant by *retrograde motion*. *[1]*

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(ii) Use the diagram to explain retrograde motion. *[2]*

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(This question continues on the following page)

(Question E1 continued)

(b) Suggest why, from the Earth,

(i) only one side of the Moon is visible. *[3]*

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(ii) the Moon rises in a different position each day during a lunar month. *[2]*

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E2. This question is about Newton's law of gravitation.

Newton is said to have developed his law of gravitation after watching an apple fall from a tree.

(a) Explain why this law is said to be *universal*. *[1]*

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(b) Describe the contribution Newton's law of gravitation made to the acceptance of Kepler's laws of planetary motion. *[2]*

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E3. This question is about Thomson's experiment to measure the ratio of the charge to mass of an electron.

In his experiment to measure the electron charge-mass ratio, Thomson needed to know the speed of electrons as they passed through an electric field.

Outline how this speed was measured. *[4]*

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E4. This question is about models of the nuclear atom.

Thomson and Rutherford both suggested models of the atom.

(a) Compare the atomic models of Thomson and Rutherford. *[3]*

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(b) The existence of the neutron was suggested in the early part of the twentieth century. Suggest why the neutron was not detected until 1932. *[2]*

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Option F — Astrophysics

F1. This question is about the brightness of stars.

(a) (i) Define the *luminosity of a star*. *[1]*

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(ii) State **one** factor that determines the luminosity of a star. *[1]*

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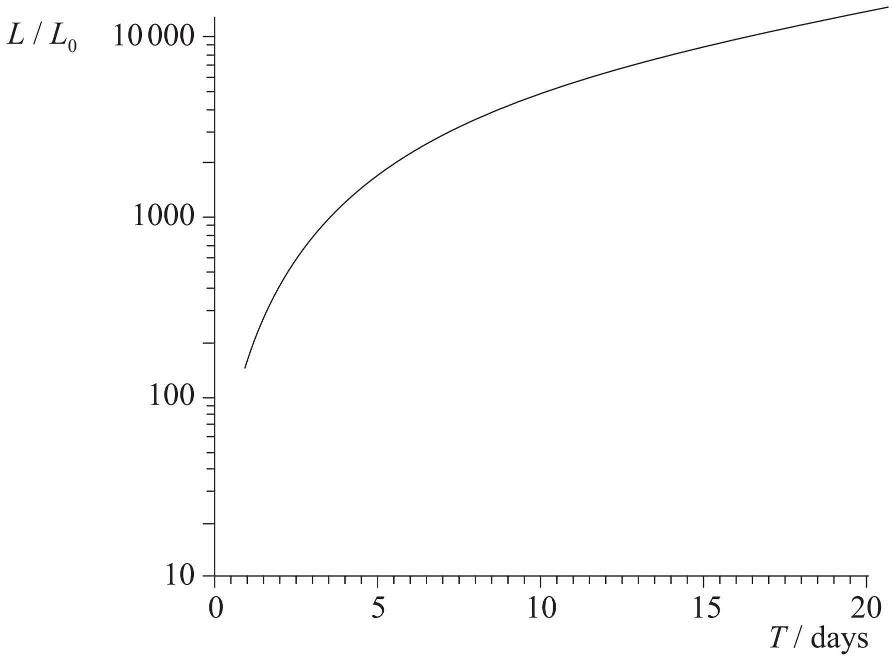
(Question F1 continued)

(b) The graph below shows the variation with period T of the luminosity L of Cepheid variable stars, where the luminosity of the Sun is taken to be L_0.



(i) Outline why the luminosity of a Cepheid star varies periodically. *[2]*

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(ii) Cepheid variable star A has a period of 3.5 d; Cepheid variable star B has a period of 16.5 d. Star A is a distance of 1.6×10^{21} m from Earth and has an apparent brightness at the Earth 1.2×10^{-14} W m^{-2}. The apparent brightness of star B at the Earth is 5.3×10^{-16} W m^{-2}.

Determine the distance of star B from the Earth. *[4]*

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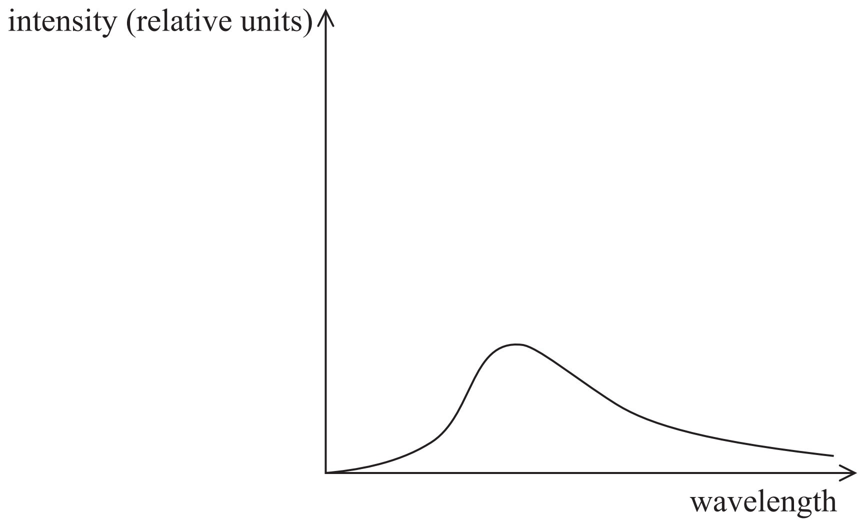
F2. This question is about cosmology.

(a) The diagram below shows the spectrum of the radiation emitted by a black body.



(i) On the diagram above, sketch the spectrum of radiation emitted by the black body at a higher temperature. *[2]*

(ii) State what is meant by *cosmological background radiation*. *[2]*

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(iii) Explain how knowledge of the spectrum of a black body and the existence of cosmological background radiation is consistent with the "Big Bang" model of the universe. *[3]*

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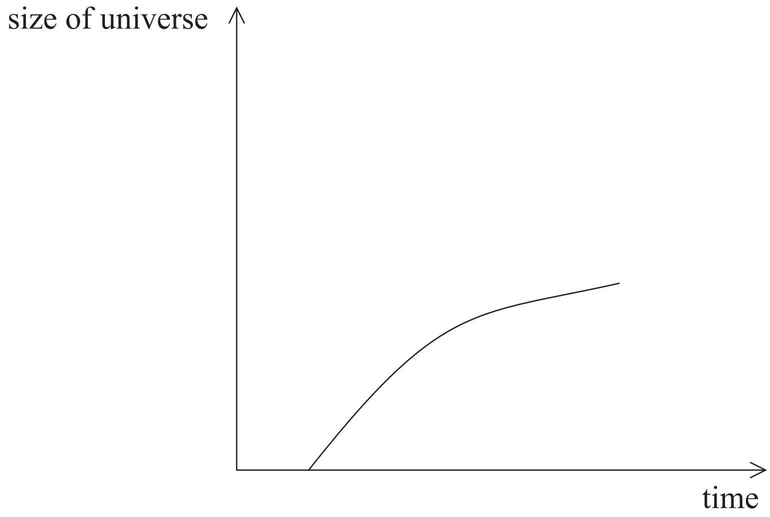
(Question F2 continued)

(b) The diagram below shows one suggestion for the variation with time of the size of the universe. This suggestion is referred to as the "flat" universe.



(i) On the diagram above, draw a line to represent an "open" universe (label this line O) and a line to represent a "closed" universe (label this line C). *[3]*

(ii) State and explain the condition, in terms of critical density of matter in the universe, for the universe to be closed. *[2]*

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Option G — Relativity

G1. This question is about time dilation.

(a) Define the following terms.

(i) *Proper length* *[1]*

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(ii) *Proper time* *[1]*

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(This question continues on the following page)

(Question G1 continued)

(b) A muon is created in the Earth's atmosphere by a cosmic ray striking an oxygen atom. The speed of the muon as measured by an observer on Earth is $0.99c$ where c is the speed of light. The muon decays after a time of 3.1×10^{-6} s as measured in its reference frame.

Calculate,

(i) the distance travelled by the muon as measured in its reference frame. *[2]*

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(ii) for an observer on Earth, the lifetime of the muon and the distance it travels before it decays. *[3]*

Lifetime: . . . .

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Distance: . . . .

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(c) Use your answers to (b) to explain time dilation. *[2]*

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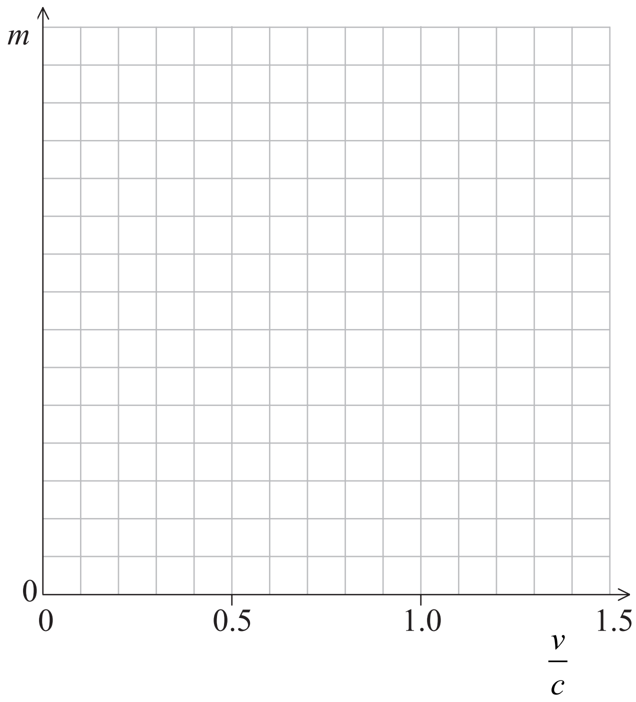
G2. This question is about relativistic mass increase.

(a) Electrons are accelerated from rest through a potential difference. On the axes below, draw a sketch graph to show how the mass m of an electron varies with its speed, $\frac{v}{c}$. (Note: no numerical values are required.) *[3]*



(b) An electron is accelerated through a potential difference of 2.0 MV. The rest mass of the electron is 0.50 MeV c^{-2}.

Determine for the accelerated electron

(i) the final mass in MeV c^{-2}. *[1]*

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(ii) the final speed in terms of c after acceleration. *[3]*

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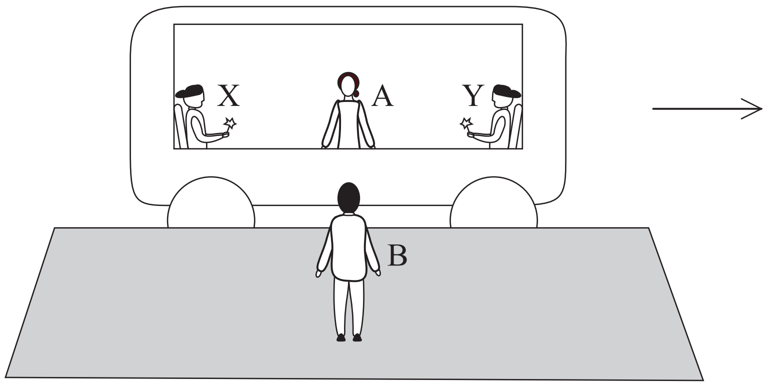
G3. This question is about simultaneity.

Two people, X and Y, are facing each other at opposite ends of a railway carriage. Person A is also in the carriage, midway between them. The carriage is moving in a straight-line with uniform speed relative to person B who is standing at the side of the railway track.

When person A is opposite person B, the two people X and Y each switch on a light. Person A sees the lights at the same time, *i.e.* simultaneously.



Discuss whether person B will describe the switching on of the lights as occurring simultaneously. *[4]*

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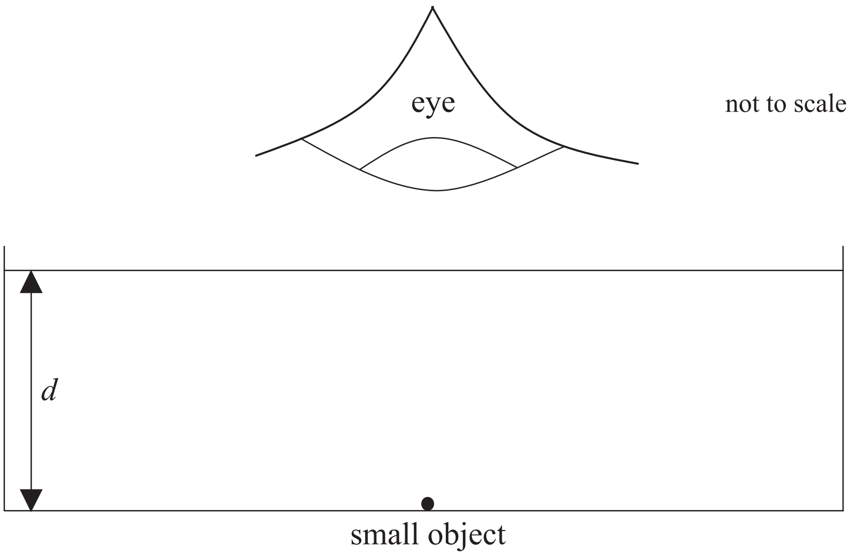
Option H — Optics

H1. This question is about refractive index.

(a) A small object rests at the bottom of a swimming pool of depth d. Viewed from directly above, the object appears to be 5.0 m below the surface of the water.



(i) On the diagram above, draw rays to locate the image of the object as seen from above. *[2]*

(ii) The refractive index of water = 1.3.

Determine the depth d of the swimming pool. *[2]*

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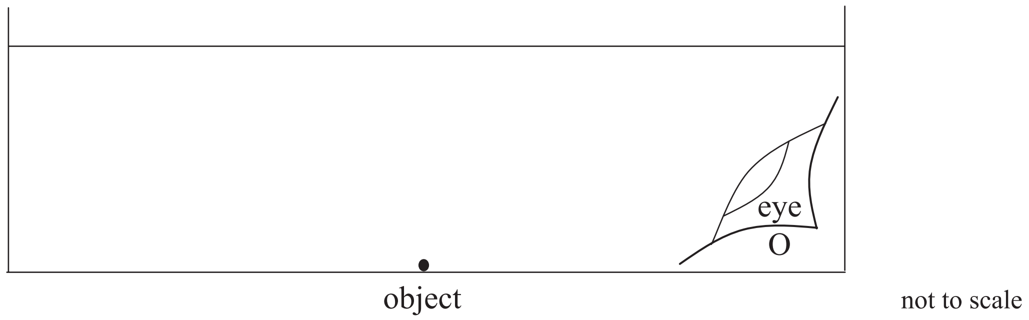
(Question H1 continued)

(b) A diver views the surface of the water from point O as shown in the diagram below.



(i) On the diagram above, draw **two** rays to locate the image of the object as seen by the diver at O. *[3]*

(ii) Explain why the surface of the water needs to be undisturbed for the image to be seen. *[1]*

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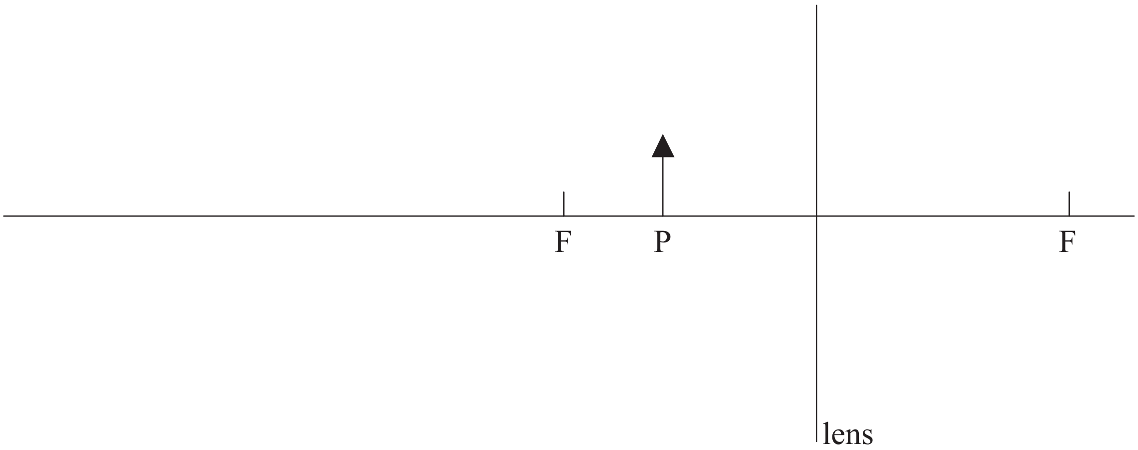
H2. This question is about image formation by a converging lens.

An object P is placed close to a converging lens as shown in the diagram below. The principal foci F of the lens are marked.



(a) On the diagram above, draw rays to locate the position of the image formed by the lens. Label this image with the letter I. *[3]*

(b) The near point of an observer's eye is 25.0 cm from the eye. The lens in the diagram is positioned 4.0 cm from the lens in the observer's eye so as to form an image of the object P at the near point. The focal length of the lens is 8.0 cm.

(i) Define the term *near point*. *[1]*

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(ii) Determine the distance from the object to the lens. *[3]*

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(This question continues on the following page)

(Question H2 continued)

(c) (i) Lenses are subject to chromatic aberration and spherical aberration.

Describe and explain *chromatic aberration* and *spherical aberration*. *[4]*

Chromatic aberration: . . . .

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Spherical aberration: . . . .

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(ii) Suggest how the effects of spherical aberration can be reduced. *[1]*

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