IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M06/4/PHYSI/SP3/ENG/TZ1/XX+

22066512

PHYSICS
STANDARD LEVEL
PAPER 3

Wednesday 10 May 2006 (morning)

1 hour

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

- Write your session number code 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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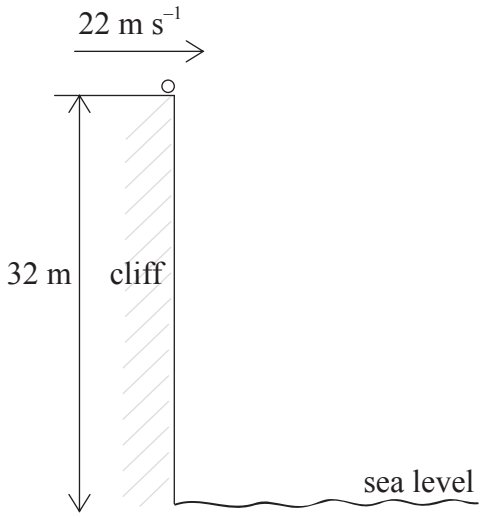
Option A — Mechanics Extension

A1. This question is about projectile motion.

A stone of mass 0.44 kg is thrown horizontally from the top of a cliff with a speed of 22 m s^{-1} as shown below.



The cliff is 32 m high.

(a) Calculate the total kinetic energy of the stone at sea level assuming air resistance is negligible. *[3]*

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(b) In practice, air resistance is not negligible. During the motion of the stone from the top of the cliff to sea level, 34 % of the total energy of the stone is transferred due to air resistance. Determine the speed at which the stone reaches sea level. *[2]*

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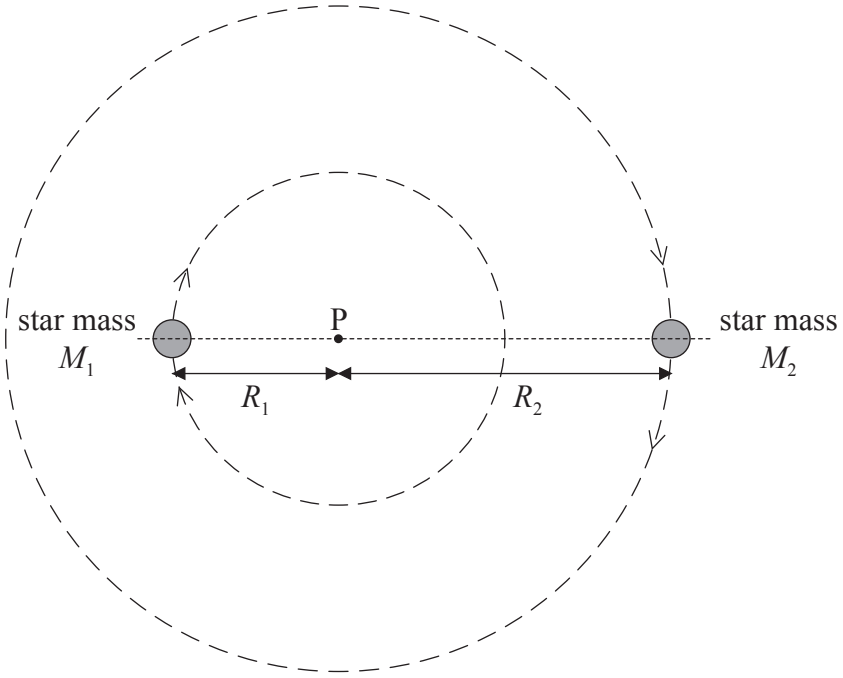
A2. This question is about gravitation.

A binary star consists of two stars that each follow circular orbits about a fixed point P as shown below.



The stars have the same orbital period T. Each star may be considered to act as a point mass with its mass concentrated at its centre. The stars, of masses M_1 and M_2, orbit at distances R_1 and R_2 respectively from point P.

(a) State the name of the force that provides the centripetal force for the motion of the stars. *[1]*

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(b) By considering the force acting on one of the stars, deduce that the orbital period T is given by the expression

$$T^2 = \frac{4\pi^2}{GM_2} R_1 (R_1 + R_2)^2.$$ *[3]*

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(This question continues on the following page)

(Question A2 continued)

(c) The star of mass M_1 is closer to the point P than the star of mass M_2. Using the answer in (b), state and explain which star has the larger mass. *[2]*

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A3. This question is about frictional forces.

(a) State **three** factors that determine the magnitude of the frictional force between two surfaces. *[3]*

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2. . . . . .

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3. . . . . .

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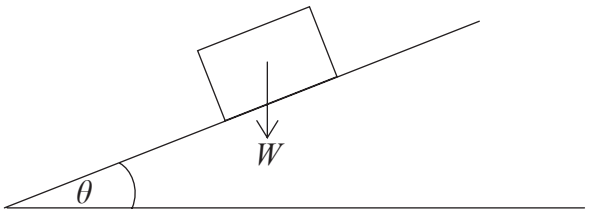
(b) A block of wood of weight W rests on a flat surface inclined at an angle θ to the horizontal, as shown below.



On the diagram above, draw arrows to represent

(i) the reaction force of the slope on the block. Label this arrow R. *[1]*

(ii) the friction force between the block and the slope that acts on the block. Label this arrow F. *[1]*

(This question continues on the following page)

(Question A3 continued)

(c) The coefficient of static friction between the block and the surface in (b) is μ. The angle θ of the slope to the horizontal is gradually increased.

Deduce that

(i) the block will begin to slip when the angle θ is given by

$$\tan\theta = \mu. \qquad \textit{[3]}$$

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(ii) the block will always slip for values of θ equal to, or greater than, 45°. *[1]*

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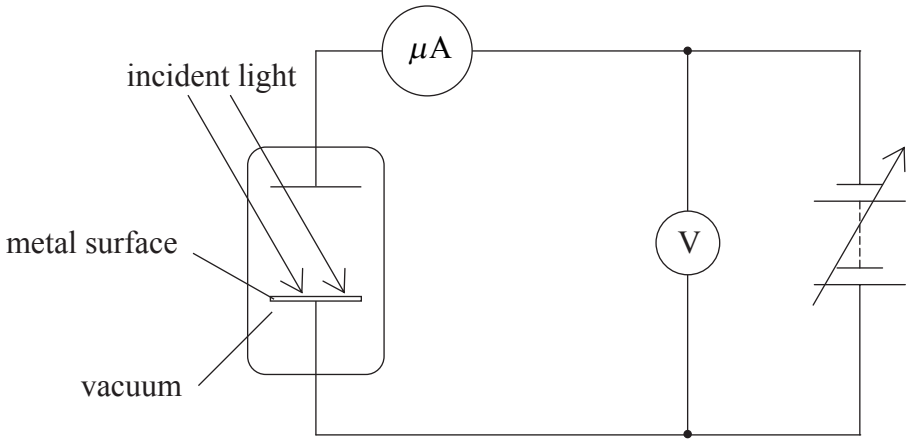
Option B — Quantum Physics and Nuclear Physics

B1. This question is about the photoelectric effect.

A student uses the apparatus shown below to investigate the photoelectric effect.



The minimum potential V_S (the stopping potential) necessary to give zero reading on the microammeter is measured for different values of the wavelength λ of the light incident on the metal surface.

(a) Explain why the intensity of the incident radiation does not affect the value of V_S. *[2]*

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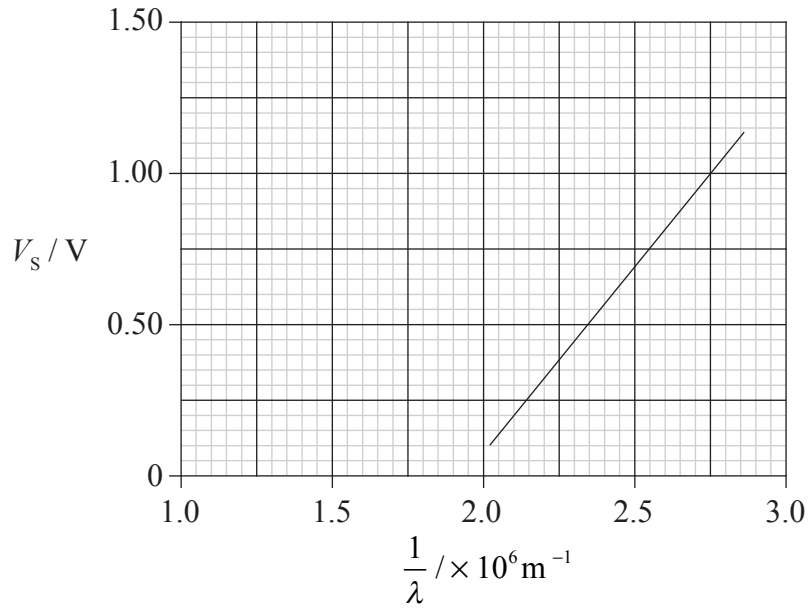
(This question continues on the following page)

(Question B1 continued)

(b) The graph below shows the variation with $\frac{1}{\lambda}$ of the stopping potential V_S.



Use the graph to calculate a value for the Plank constant *h*. Explain your working. *[6]*

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B2. This question is about a mass spectrometer.

(a) State the purpose of a mass spectrometer. *[1]*

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(b) In the space below, draw a schematic labelled diagram of a mass spectrometer. *[4]*

(c) A pure sample of a gaseous element is examined using a mass spectrometer. Atomic masses of 35 *u* and 37 *u* are obtained. Chemical analysis of a similar sample of the gas suggests an atomic mass of 35.5 *u*. Determine the ratio, for this sample,

$$\frac{\text{number of atoms of mass } 35u}{\text{number of atoms of mass } 37u}.$$ *[4]*

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B3. This question is about radioactive decay.

The decay process of a neutron is given by the following equation.

$$n \rightarrow p + e^{-} + \bar{\nu}_e$$

(a) Complete the table below. *[2]*

particle	***n***	***p***	e^{-}	$\bar{\nu}_e$
baryon number				
lepton number				

(b) Baryon number and lepton number are both conserved in this decay process. State **one** other property that is conserved. *[1]*

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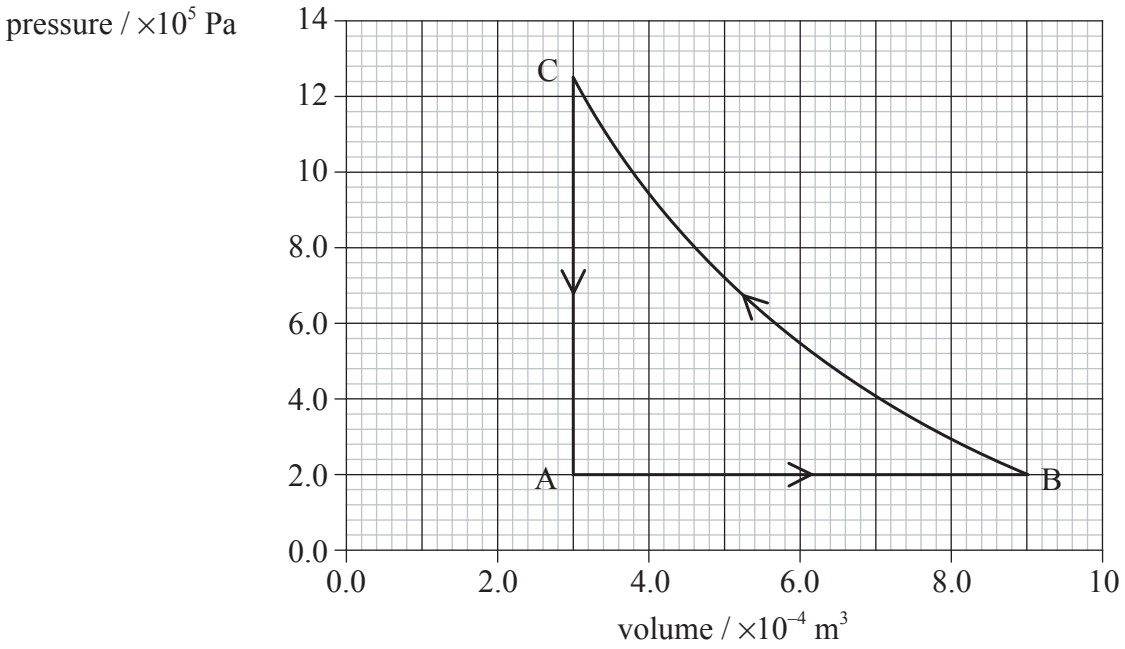
Option C — Energy Extension

C1. This question is about an ideal gas.

A sample of an ideal gas passes through the cycle of ABCA shown on the pressure/volume (p/V) diagram below.



The temperature of the gas at A, the starting point of the cycle, is 17 °C.

(a) (i) State which change, AB, BC or CA, is isochoric. *[1]*

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(ii) Calculate the temperature of the gas at point B. *[2]*

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(iii) Calculate the temperature of the gas at point C. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(b) During the change AB, 300 J of thermal energy is supplied to the gas. Determine the change in internal energy of the gas. *[3]*

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(c) During the change BC, 250 J of thermal energy is transferred. The area ABC on the pressure/volume diagram represents 120 J of energy. Calculate the thermal energy transfer during the stage CA. Explain your working. *[3]*

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C2. This question is about power generation.

(a) Describe the origin of fossil fuels. *[3]*

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(b) An electrical power generating station using fossil fuels as its source of energy has an output of 2 GW. It has been suggested that this station should be replaced by wind turbines, each providing 0.8 MW of electrical power.

(i) State **two** advantages of the use of wind power. *[2]*

1. . . . . .

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2. . . . . .

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(ii) State and explain **two** disadvantages of using wind turbines to replace the fossil-fuel generating station. *[4]*

1. . . . . .

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2. . . . . .

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Option D — Biomedical Physics

D1. This question is about scaling and the form and function of an animal.

(a) State how surface area and mass scale with a linear dimension. *[2]*

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(b) The shape of cold-blooded creatures such as snakes tends to be cylindrical rather than spherical. Explain why the cylindrical shape enables the snake to raise its internal body temperature more rapidly in sunlight than if it were spherical. *[3]*

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D2. This question is about hearing and hearing loss.

(a) Distinguish between the terms *conductive hearing loss* and *sensory hearing loss*. *[2]*

Conductive: . . . . . .

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Sensory: . . . . . .

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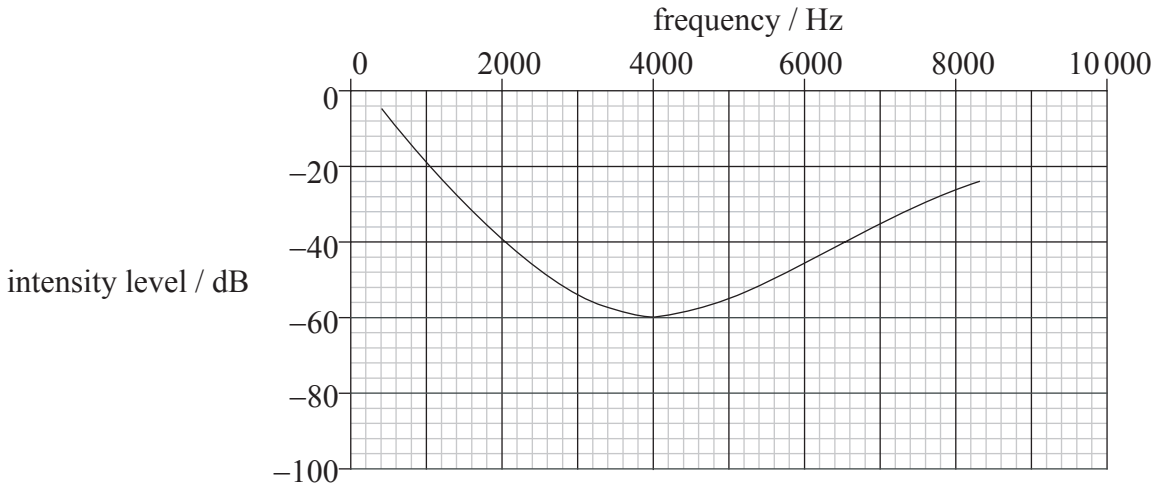
(This question continues on the following page)

(Question D2 continued)

(b) The graph below shows an audiogram for a person with hearing loss.



(i) State why loudness is measured on a logarithmic scale. *[2]*

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(ii) Suggest and explain whether the person suffers from sensory or from conductive hearing loss. *[2]*

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(iii) Use the audiogram to determine the sound intensity required at the ear for the person to just hear sound at the frequency at which the hearing loss is greatest. *[2]*

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D3. This question is about X-rays.

(a) State **two** processes by which X-rays interact with matter. *[2]*

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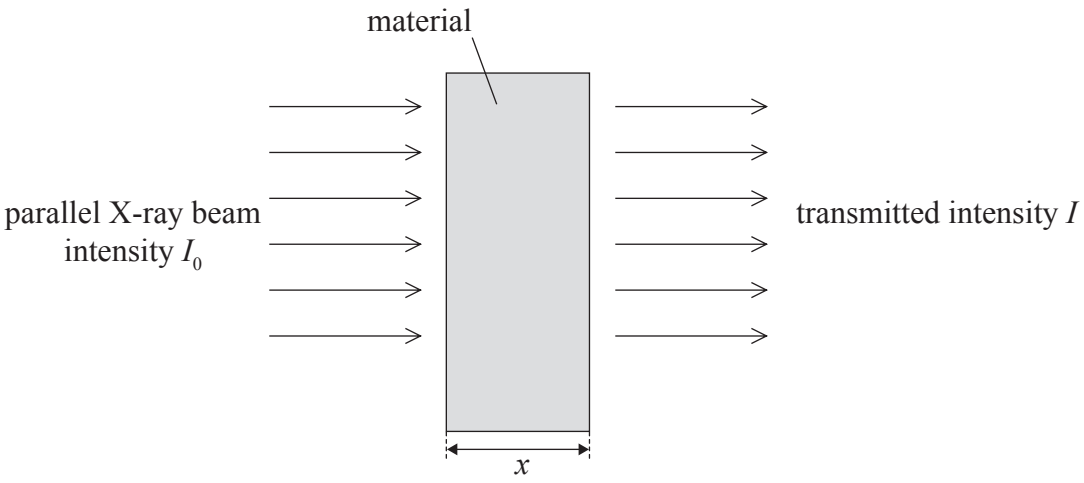
2. . . . . .

(b) A parallel beam of X-rays of intensity I_0 is incident on a material as shown below.



The transmitted intensity is I.

(i) Define the *half-value thickness* $x_{\frac{1}{2}}$ of the material. *[1]*

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(ii) The material is of thickness $8x_{\frac{1}{2}}$. Calculate the ratio $\frac{I}{I_0}$. *[2]*

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(c) State and explain why X-rays, rather than ultrasound, are used in the assessment of bone fractures. *[2]*

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Option E — The History and Development of Physics

E1. This question is about planetary motion.

(a) State the nature of Tycho Brahe's observations that enabled Kepler to formulate his laws of planetary motion. *[1]*

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(b) Explain how Kepler's laws of planetary motion extended the Copernican model of the Solar System. *[2]*

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(c) Outline the contribution of Newton to the explanation of Kepler's laws. *[2]*

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E2. (a) Describe Oersted's discovery of the link between electricity and magnetism. *[2]*

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(b) Outline how Ampère extended Oersted's discovery. *[2]*

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E3. Carnot used the concept of phlogiston (caloric) to explain the behaviour of an ideal heat engine.

(a) Outline the phlogiston (caloric) theory of heat. *[2]*

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(b) Describe **one** phenomenon that the phlogiston theory cannot explain. *[2]*

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E4. This question is about Chadwick's discovery of the neutron.

When alpha particles bombard a boron target, neutrons are produced.

(a) Outline how Chadwick detected the presence of these neutrons. *[3]*

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(b) Outline how Chadwick determined the mass of the neutron. *[4]*

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Option F — Astrophysics

F1. This question is about stars.

Betelgeuse and Rigel are two super giants in the constellation of Orion.

(a) Distinguish between a *constellation* and a *stellar cluster*. *[2]*

Constellation: . . . . . .

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Stellar cluster: . . . . . .

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(b) The star Betelgeuse has a parallax of 0.0077 arc second. Deduce that its distance from Earth is approximately 130 pc. *[1]*

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(c) State why the Hipparcos satellite which orbits Earth is able to measure stellar parallaxes for stars at considerably greater distances than 130 pc. *[1]*

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(This question continues on the following page)

(Question F1 continued)

(d) The table below gives some information about the types and magnitudes of Betelgeuse and Rigel.

Star	Type	Apparent magnitude	Colour	Apparent brightness
Betelgeuse	M	–0.04		$2.0\times10^{-7}\,\mathrm{W\,m^{-2}}$
Rigel	B	0.12		$3.4\times10^{-8}\,\mathrm{W\,m^{-2}}$

(i) Complete the above table for the colours of the stars. *[2]*

(ii) State why Betelgeuse has a lower apparent magnitude than Rigel. *[1]*

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(iii) Given that the distance of Betelgeuse from Earth is 130 pc, calculate the luminosity of Betelgeuse. *[4]*

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(iv) The luminosity of Rigel is 2.3×10^{31} W. Without any further calculation, explain whether Rigel is closer or further than Betelgeuse from Earth. *[3]*

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F2. This question is about Olbers' paradox.

(a) Newton assumed that the universe is static and that the stars are uniformly distributed. State **one** further assumption of the Newtonian universe. *[1]*

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(b) Explain how Newton's assumptions led to Olbers' paradox. *[5]*

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Option G — Relativity

G1. This question is about concepts of time and length in Special Relativity.

(a) Define what is meant by a *frame of reference*. *[1]*

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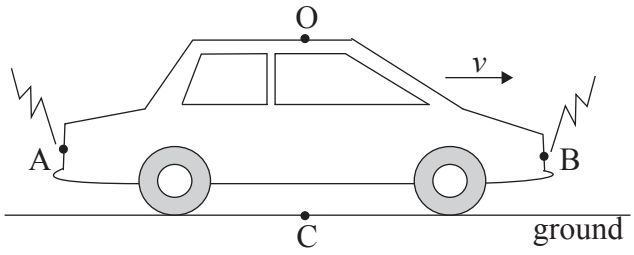
(b) A car moves along a straight level track with velocity v. A and B are points at each end of the car and O is an observer in the car at the mid-point between A and B. When O and C are opposite each other, lightning strikes ends A and B of the car. Observer O receives the light from A and B at the same instant, as measured on his clock.



(i) Discuss whether the lightning strikes appear to be simultaneous to observer O and to observer C. *[4]*

Observer O: . . . . . .

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Observer C: . . . . . .

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(ii) The length of the car, as measured by observer O, is 9.0 m. As measured by C, the length is 7.2 m. Determine the speed, in terms of the speed c of light, of the car as measured by observer C. *[3]*

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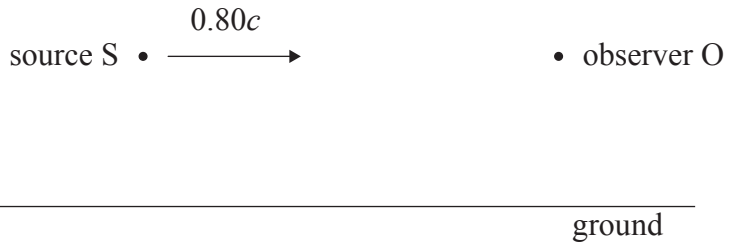
G2. A radar signal is emitted from a source S. The source is moving with speed 0.80*c* relative to the ground in a straight line towards an observer O who is stationary with respect to the ground, as shown below.



The speed of the radar waves is *c* relative to the ground.

(a) Calculate the speed of the radar wave relative to the observer O using

(i) the Galilean transformation equation. *[1]*

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(ii) the principles of Special Relativity. *[3]*

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(b) Explain how your answer to (a) (ii) relates to Maxwell's electromagnetic theory. *[2]*

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G3. (a) Distinguish between *rest mass energy* and *total energy* of a particle. *[2]*

Rest mass energy: . . . . . .

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Total energy: . . . . . .

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(b) Estimate the energy released during the annihilation of an electron-positron pair. Explain why your answer is an estimate. *[2]*

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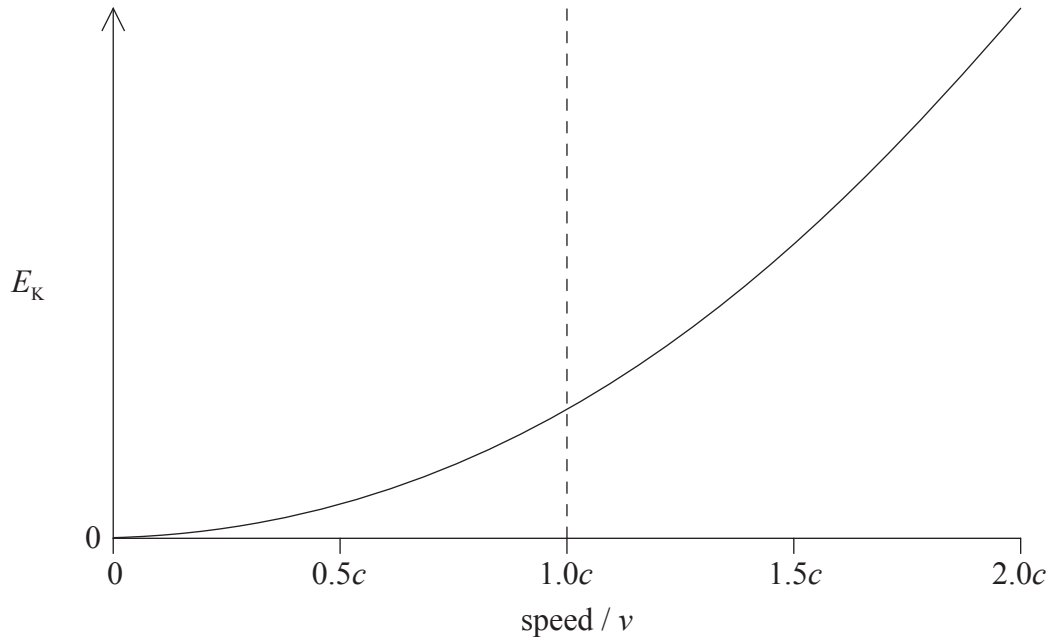
(c) The graph shows the variation with speed v of the kinetic energy E_K of a particle according to Newtonian mechanics.



On the graph above, draw a line to represent the variation with speed v of the kinetic energy according to relativistic mechanics. *[2]*

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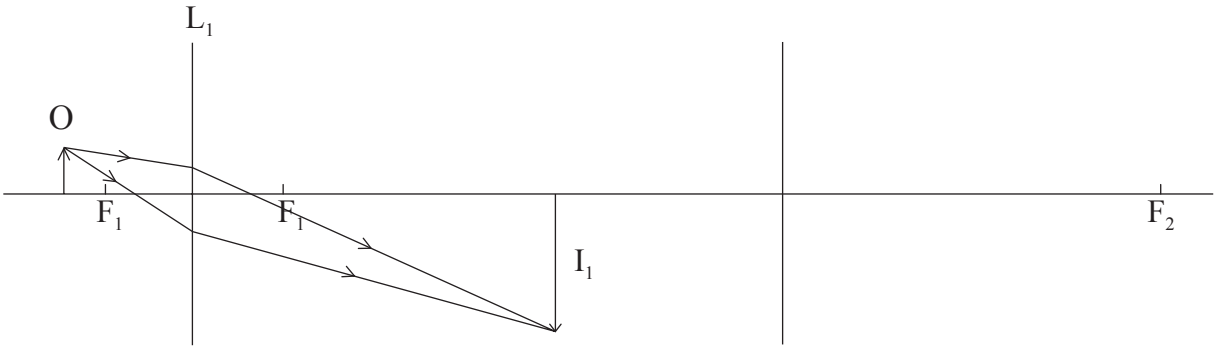
Option H — Optics

H1. This question is about image formation by lenses.

The diagram below shows the positions of two convex lenses L_1 and L_2 used in an optical instrument. F_1 and F_2 are the principal foci of L_1 and L_2 respectively. The object O is viewed through the two lenses.



The diagram also shows two rays from the object O to the position of the image I_1 produced in the lens L_1.

(a) (i) Mark the position of the other principal focus of lens L_2. Label this position F_2. *[1]*

(ii) The image I_1 acts as an object for the lens L_2. Draw **two** construction rays to locate the position of the image I_2 formed by lens L_2. Label this image I_2. *[3]*

(This question continues on the following page)

(Question H1 continued)

(b) State and explain whether the image I_2 is real or virtual. *[1]*

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(c) State the name of this optical instrument. *[1]*

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(d) State

(i) the change, if any, in the positions of the lenses so that the final image in (a) (ii) is formed at infinity. *[2]*

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(ii) why the image, formed at infinity, is magnified. *[1]*

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H2. This question is about refraction and total internal reflection.

(a) Light travels from one optical medium to another. State the conditions necessary for total internal reflection to occur at the boundary between the two media. *[2]*

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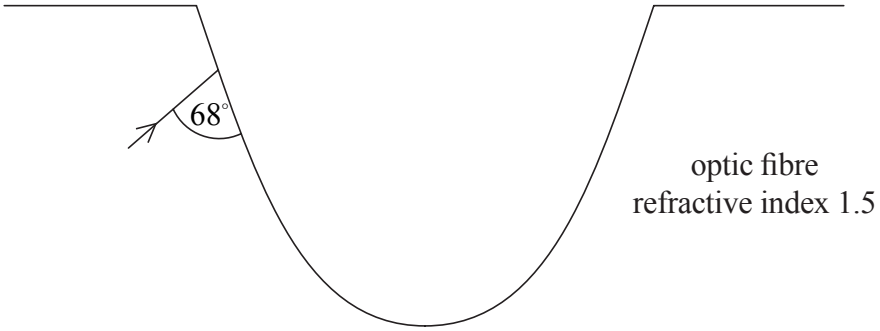
(b) Light is incident on a small scratch in the surface of an optical fibre of refractive index 1.5. The angle between a ray of incident light and the surface of the scratch is 68° as shown below.



(i) Calculate the angle of refraction of the ray at the surface of the scratch. *[2]*

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(ii) On the diagram, draw a sketch of the path of the ray as it emerges from the surface of the scratch. *[1]*

(This question continues on the following page)

(Question H2 continued)

(c) By reference to (b) (ii), suggest and explain **one** reason why, in practice, optical fibres have an outer covering. *[2]*

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(d) State and explain **two** reasons why lasers are used as light sources for optical fibres. *[4]*

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2. . . . . .

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