IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M06/4/PHYSI/HP3/ENG/TZ1/XX+

22066509

PHYSICS
HIGHER LEVEL
PAPER 3

Wednesday 10 May 2006 (morning)

1 hour 15 minutes

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.

0125

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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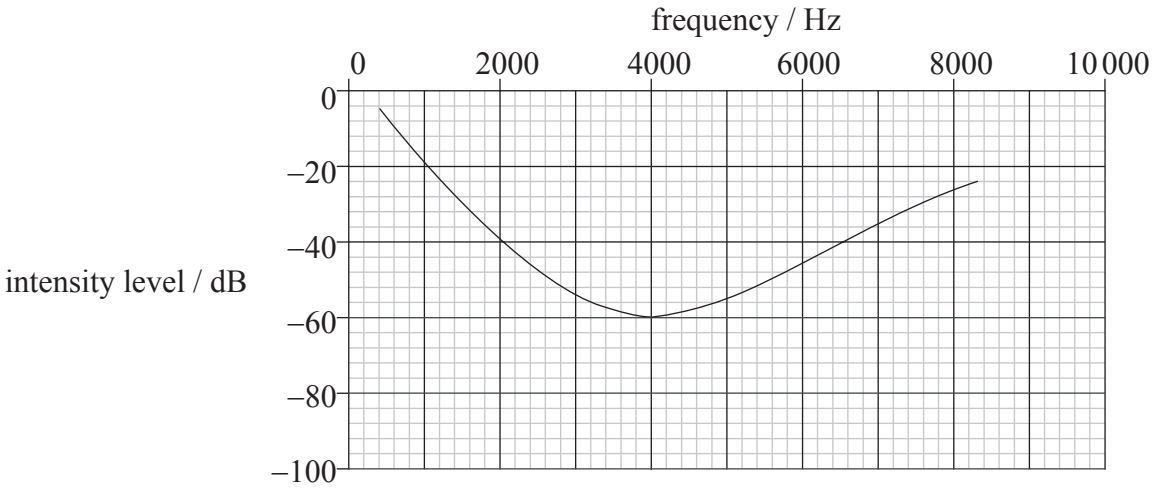
(This question continues on the following page)

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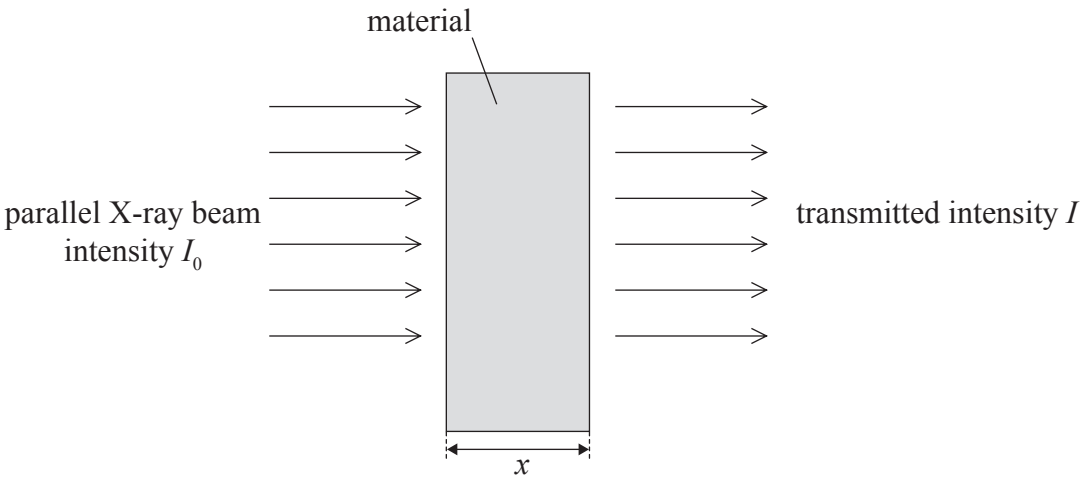
(b) A parallel beam of X-rays of intensity I_0 is incident on a material as shown below.



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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D4. The muscles and bones in the human body provide many examples of lever systems. State and explain why, in general, these lever systems have a mechanical advantage of much less than one. *[4]*

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D5. The effects of ionizing radiation on the human body may become noticeable soon after exposure to the radiation or after many years.

Describe and explain how the interaction of radiation with cells may account for these differences. *[6]*

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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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E5. This question is about a model of the atom.

Niels Bohr developed a model of the hydrogen atom in which an electron of mass m and charge $-e$ orbits a stationary proton. The radius of the orbit is r, as shown below.

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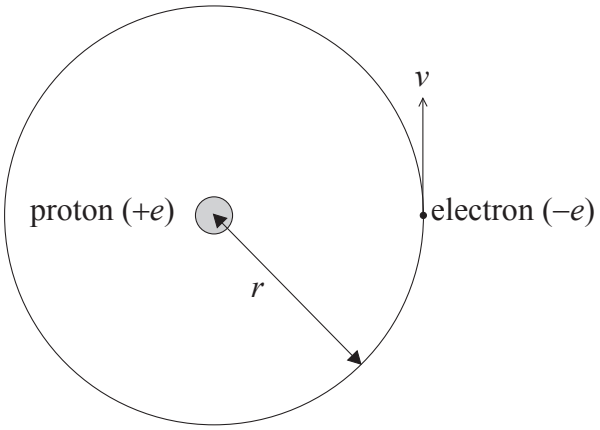

The speed v of the electron may be shown to be given by the expression

$$v^2 = \frac{e^2}{4\pi\varepsilon_0 rm}.$$

(a) Identify the symbol ε_0 in the above equation. *[1]*

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(b) (i) State Bohr's assumption relating to angular momentum. *[2]*

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(ii) Use this assumption to deduce that the radius r is given by

$$r = \frac{\varepsilon_0 h^2}{\pi m e^2} \times n^2$$

where n is a positive integer. *[3]*

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(This question continues on the following page)

(Question E5 continued)

(c) Use the expression in (b) (ii) to calculate, for $n = 1$, a numerical value for r. Comment on your answer. *[3]*

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(d) State **one** reason why the Bohr model can be applied successfully only to the hydrogen-like atom. *[1]*

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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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F3. State and explain **two** conditions that are necessary for nuclear fusion to be initiated in a star. *[4]*

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F4. State **two** characteristics of a quasar. *[2]*

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F5. This question is about the Hubble constant.

(a) State the Hubble equation relating the speed v of recession of galaxies to their separation d. *[1]*

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(b) The distance between Earth and Moon is 5.0×10^{8} m. More precise measurement shows that this distance is increasing at a rate of 0.04 m per year. One estimate for the Hubble constant is 60 km s^{-1} Mpc^{-1}. Using this estimate for the Hubble constant, deduce whether the Moon's recession can be explained on the basis of the expansion of the universe. You may assume $1\,pc = 3.1\times10^{16}$ m. *[3]*

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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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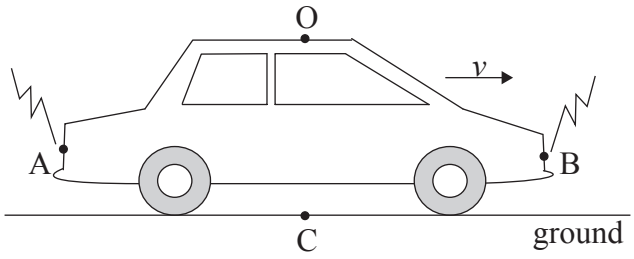
(b) A car moves along a straight level track with velocity v. A and B are points at each end of the car and O is an observer in the car at the mid-point between A and B. When O and C are opposite each other, lightning strikes ends A and B of the car. Observer O receives the light from A and B at the 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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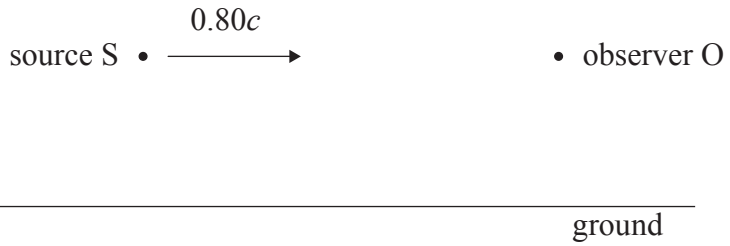
G2. A radar signal is emitted from a source S. The source is moving with speed 0.80*c* relative to the ground in a straight line towards an observer O who is stationary with respect to the ground, as shown below.



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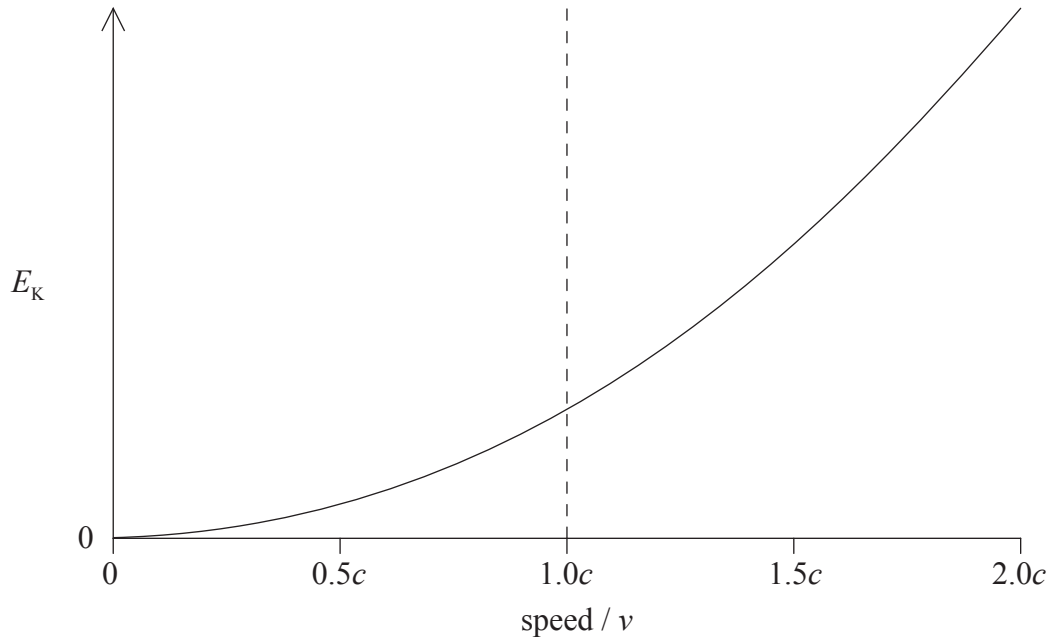
(c) The graph shows the variation with speed v of the kinetic energy E_K of a particle according to Newtonian mechanics.



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

G4. This question is about evidence to support General Relativity.

(a) State the principle of equivalence. *[2]*

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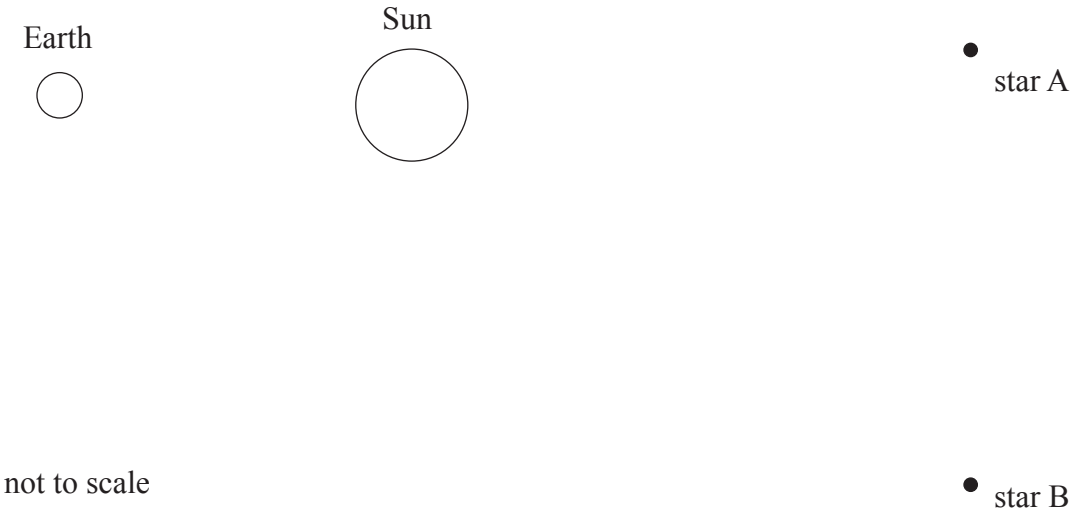
(b) The diagram below shows Earth, Sun and two distant stars A and B.



(i) Add rays to the diagram to show the path of light from star A and star B to Earth. *[2]*

(ii) Describe briefly how Eddington's observations provided evidence for the paths you have drawn in (i). *[2]*

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G5. This question is about black holes.

(a) Describe, by reference to space-time, what is meant by a *black hole*. *[2]*

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(b) After a particular star has become a supernova, its mass is 2×10^{31} kg. Determine the radius of the black hole it subsequently forms. *[2]*

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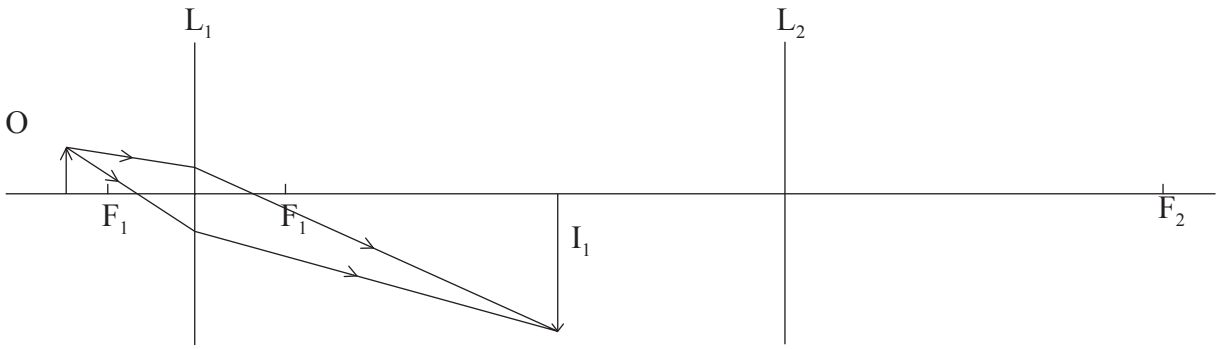
Option H — Optics

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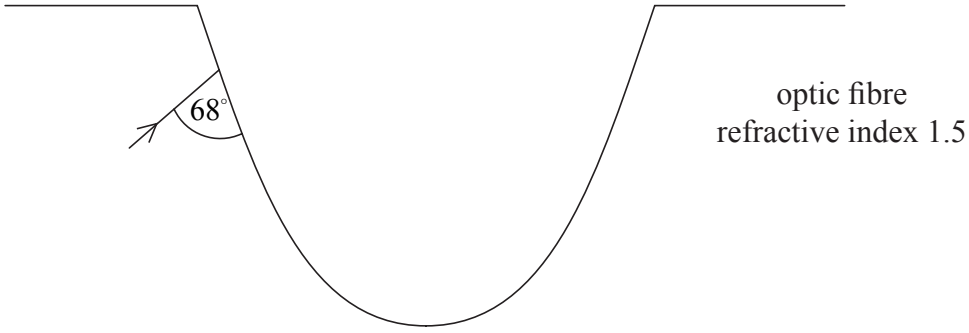
(b) Light is incident on a small scratch in the surface of an optical fibre of refractive index 1.5. The angle between a ray of incident light and the surface of the scratch is 68° as shown below.



(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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H3. This question is about two-source interference.

A double slit is illuminated normally with coherent light. The interference pattern is observed on a screen. The apparatus is shown below.

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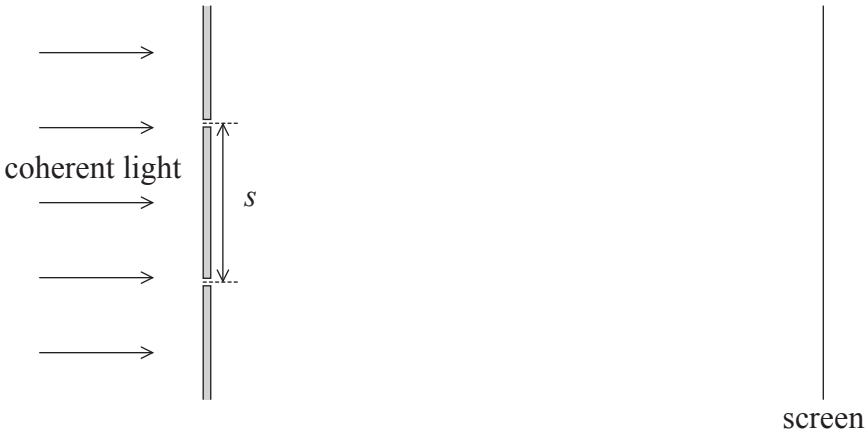

The width of both slits in the double slit arrangement is increased without altering the separation *s*.

Describe and explain the effect, if any, of this change on

(a) the number of fringes observed. *[2]*

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(b) the intensity of the fringes. *[3]*

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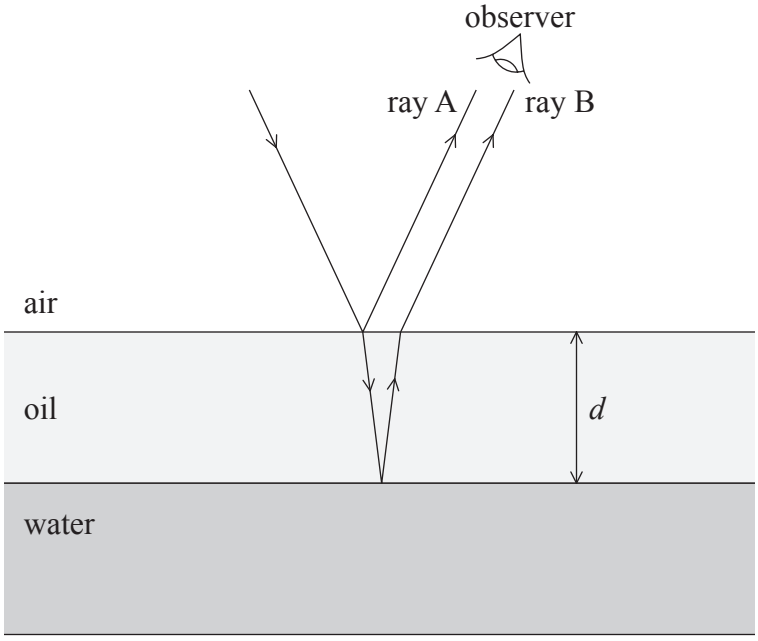
H4. This question is about thin film interference.

A thin film of colourless oil floats on water. Light is reflected from the upper and the lower surfaces of the film as shown below.



The refractive index for light in the oil is **greater** than the refractive index for light in the air. The refractive index for light in the oil is **less** than the refractive index for light in the water.

The light has wavelength λ in the oil.

(a) State, in terms of λ, a value for the thickness d that causes rays A and B to interfere destructively when viewed as shown. Assume that the incident light is approximately normal to the film. Explain your answer. *[3]*

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(b) White light is now incident on the oil film. Explain why, for one thickness d of the oil film, the film appears to have a purple (magenta) colour. *[2]*

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