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

N07/4/PHYSI/HP3/ENG/TZ0/XX+

88076503

PHYSICS
HIGHER LEVEL
PAPER 3

Friday 9 November 2007 (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.

Option D — Biomedical Physics

D1. This question is about scaling.

The length of a human baby is 50 cm and its mass is 3.4 kg.

(a) Estimate, using scaling, the mass of an adult of height 1.8 m. *[2]*

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(b) State **two** assumptions you have made in your estimate in (a). *[2]*

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(c) Explain, by reference to your assumptions, whether your answer in (a) is reasonable. *[3]*

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D2. This question is about hearing.

A sound wave of intensity $3.2 \times 10^{-4}\,\text{W m}^{-2}$ produces a pressure variation on the eardrum.

(a) Calculate the sound intensity level of the sound wave at the eardrum. *[2]*

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(b) Describe how the sound pressure is amplified in the middle ear. *[3]*

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D3. This question is about X-rays and imaging techniques.

(a) State **two** mechanisms by which an X-ray beam is attenuated in matter. *[2]*

1. . . . . .

2. . . . . .

(b) Define the term *half-value thickness*. *[1]*

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(c) When a particular X-ray beam passes through fatty tissue, the intensity of the beam is reduced to a quarter of its initial intensity. Determine the fraction of the incident intensity of this beam when it is transmitted through the same thickness of muscle. The half-value thickness of muscle is 4.0 mm and that of fatty tissue is 6.0 mm. *[3]*

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(d) State the difference between an X-ray image and a CT image. *[2]*

X-ray image: . . . . . .

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CT image: . . . . . .

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D4. This question is about metabolic rate.

(a) Distinguish between *metabolic rate* and *basal metabolic rate*. *[2]*

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(b) Whilst asleep, Esmeralda breathes in oxygen at the rate $4.0 \times 10^{-6}\,m^3\,s^{-1}$. Whilst running, her metabolic rate is 620 W and her rate of oxygen intake is $3.1 \times 10^{-5}\,m^3\,s^{-1}$. Assuming that the power generated by the body is proportional to the rate of oxygen intake, determine Esmeralda's basic metabolic rate and the extra power she needs for running. *[3]*

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D5. This question is about the radioactive isotope iodine-131.

A nucleus of the radioactive isotope iodine-131 decays with the emission of a β^--particle and a γ-photon. The average biological half-life of iodine-131 is 20 days and its physical half-life is 8.0 days.

(a) Distinguish between *biological half-life* and *physical half-life*. *[2]*

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(b) Iodine is readily absorbed by the thyroid. Using the data above, suggest **two** reasons why iodine-131 is used to treat cancer of the thyroid. *[3]*

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Option E — The History and Development of Physics

E1. This question is about the work of Galileo and Newton.

(a) State the difference between the Copernican model and the Ptolemaic model of the universe. *[1]*

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(b) State **one** advantage of the Copernican model of the solar system. *[1]*

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(c) Galileo discovered four moons orbiting Jupiter. Outline how this discovery supports the Copernican model of the solar system. *[3]*

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(d) Galileo is said to have dropped objects of different masses from the top of the Leaning Tower of Pisa.

(i) Describe how the results of his observations were inconsistent with the Aristotelian view of falling objects. *[2]*

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(ii) Outline how Newtonian mechanics accounts for the result of Galileo's observations. *[2]*

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E2. This question is about the relation between magnetism and electricity.

Oersted observed that an electric current in a wire causes a compass needle to deflect.

(a) State the reason for the deflection of the compass needle. *[1]*

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(b) Ampere extended Oersted's work by experimenting with two current-carrying wires. Outline the results of his experiments. *[3]*

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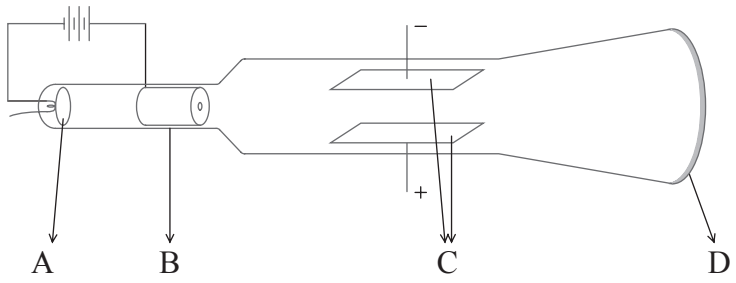
E3. This question is about the discovery of the electron.

(a) In 1897, J J Thomson measured the charge to mass ratio $\left(\frac{e}{m}\right)$ for electrons.

The diagram below illustrates a modern version of part of the apparatus he used.



State the name, and explain the purpose, of the parts of the apparatus labelled above.

(i) Part A: name: . . . . . *[1]*

purpose: . . . . . .

(ii) Part B: name: . . . . . *[1]*

purpose: . . . . . .

(iii) Part C: name: . . . . . *[1]*

purpose: . . . . . .

(iv) Part D: name: . . . . . *[1]*

purpose: . . . . . .

(b) Discuss the significance of this experiment in respect of the nature of electrons. *[3]*

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E4. This question is about the hydrogen atom.

In 1890, Johannes Rydberg discovered an empirical wavelength relation for series of spectral lines of various elements. For the spectrum of atomic hydrogen, the relation is

$$\frac{1}{\lambda} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$$

Where λ is wavelength, R is the Rydberg constant and m and n are integers

(a) Explain how this equation is used to determine, for example, the wavelengths in the **visible** line spectrum of atomic hydrogen. *[2]*

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(b) Determine the ionization energy of the hydrogen atom ($R = 1.1 \times 10^7\ \text{m}^{-1}$). *[3]*

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(c) In 1913, Niels Bohr proposed a model of the hydrogen atom in which the electron could only occupy certain stationary (stable) orbits.

State

(i) what is meant by a stationary (stable) orbit. *[1]*

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(ii) the Bohr postulate that determines the allowed stationary orbits. *[1]*

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(This question continues on the following page)

(Question E4 continued)

(d) Outline how the model of the hydrogen atom proposed in 1926 by Erwin Schrödinger, accounts for the existence of stationary electron orbits. *[3]*

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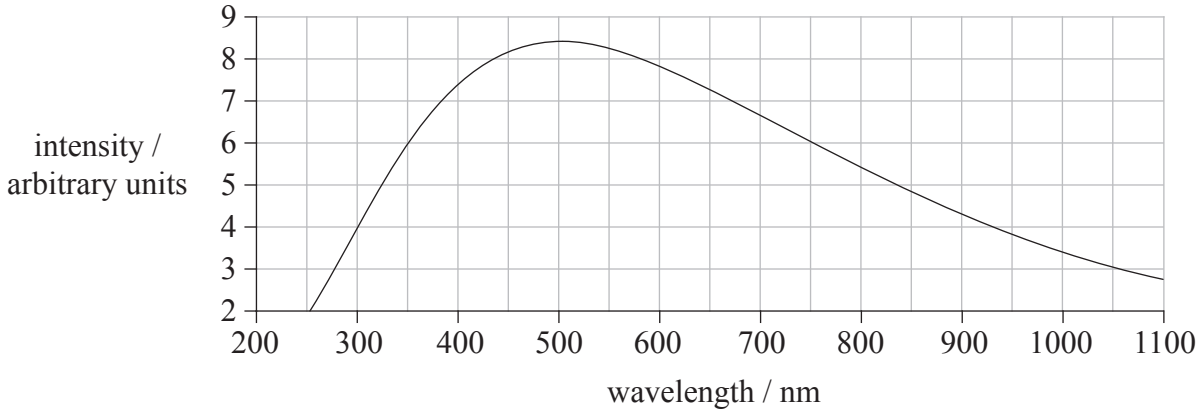
Option F — Astrophysics

F1. This question is about the Sun.

The black body spectrum of the Sun is shown below.



(a) Deduce that the surface temperature of the Sun is approximately 5800 K. *[2]*

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(b) The emission spectrum of the Sun is crossed by dark lines. Outline how these lines are used to determine the chemical composition of the Sun's atmosphere. *[3]*

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F2. This question is about the luminosity of stars.

(a) Define *luminosity*. *[1]*

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(b) Data for the surface temperature T and the radius R of two stars A and B are given in the table below.

	T / K	R / km
Star A	3.0×10^{3}	8.7×10^{11}
Star B	2.0×10^{4}	6.8×10^{7}

Using **only** data from the table, determine the ratio $\frac{\text{luminosity of A}}{\text{luminosity of B}}$. *[3]*

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F3. This question is about the Sun and the star Sirius A.

The table below gives data for the Sun and the star Sirius A.

Star	**Apparent brightness / W m^{-2}**	**Luminosity (relative units)**
Sun	1.4×10^{3}	1.0
Sirius A	1.1×10^{-7}	23

(a) Explain which star will have the greatest apparent magnitude. *[2]*

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(b) Using the data from the table, deduce that the distance of Sirius from Earth is 5.4×10^{5} AU. *[3]*

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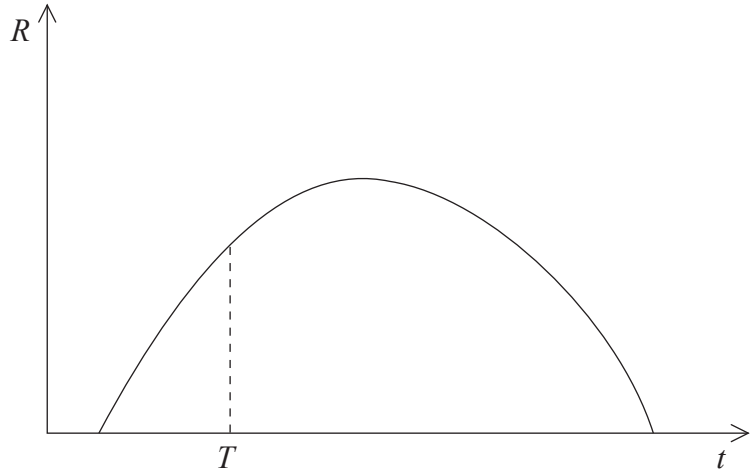
F4. This question is about the development of the universe.

The diagram below shows the variation with time t of the radius R of the observable universe, based on a closed model of the universe. The point $t = T$ is the present time.



(a) State what is meant by a closed universe. *[1]*

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(b) On the diagram above, draw the variation with time t of the radius R of the observable universe, based upon an open model of the universe. *[3]*

(c) Explain, by reference to your answer to (b), why the predicted age of the universe depends upon the model of the universe chosen. *[2]*

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F5. This question is about nuclear synthesis in stars.

(a) Under certain circumstances, the gravitational collapse of a gas may initiate nuclear fusion and hence form a star. State the **two** conditions necessary for nuclear fusion to be initiated. *[2]*

1. . . . . .

2. . . . . .

(b) The nuclear fusion process of a main sequence star essentially involves the fusion of hydrogen to helium. When all the hydrogen is fused, it will develop into either a red giant or a red supergiant.

(i) State what property of the star determines whether it will become a red giant **or** red supergiant. *[1]*

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(ii) Compare the changes in nuclear synthesis that take place in a red giant to those that take place in a red supergiant. *[3]*

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F6. This question is about Hubble's law.

(a) Two galaxies are separated by a distance d. Use Hubble's law to derive an expression for the time T it has taken for the galaxies to reach this separation. *[2]*

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(b) Assuming a value of the Hubble constant $H = 80\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$, and using your answer to (a), estimate that the age of the universe is about 10^{10} years. (1 year $= 3.2 \times 10^{7}$ s) *[2]*

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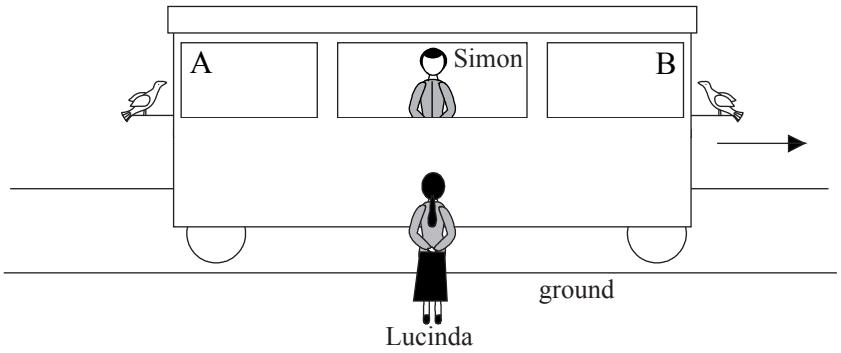
Option G — Relativity

G1. This question is about simultaneity.

In the diagram below, Simon is in a railway carriage that is travelling in a straight-line with uniform speed relative to Lucinda who is standing on the ground by the track. There is a window at each end A and B of the railway carriage. Simon determines his position to be at the midpoint of the railway carriage.

At the instant that Simon and Lucinda are opposite each other, a bird lands at end A of the carriage and another one lands at end B of the carriage. Lucinda determines that the two birds land simultaneously.



State, and explain, whether Simon will observe the landings of the birds to be simultaneous. *[4]*

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G2. This question is about time dilation.

The distance between a star and Earth is 5.0×10^{16} m as measured by an observer on Earth. An astronaut in a spaceship is moving from the Earth towards the star at a speed of 0.60c as measured by the observer on Earth.

(a) Calculate the time taken to travel from the Earth to the star as measured by

(i) the observer on Earth. *[2]*

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(ii) the astronaut. *[2]*

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(b) State, and explain, which of your answers in (a) is the proper time. *[2]*

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(c) At the time when the astronaut leaves the Earth, the astronaut and the observer on Earth are the same age. After reaching the star the astronaut returns to Earth. Explain any age difference between the astronaut and the observer on the astronaut's return to Earth. *[3]*

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G3. This question is about relativistic mass and energy.

(a) Outline why it is not possible for an object with rest mass to attain the speed of light. *[3]*

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(b) An electron is accelerated from rest through a potential difference of 6.00×10^6 V.

After acceleration,

(i) state the total energy of the electron in MeV. *[1]*

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(ii) deduce that the speed of the electron is 0.997c. *[3]*

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G4. This question is about relativistic momentum.

An electron is accelerated from rest through a potential difference of 2.00×10^6 V. Determine the momentum in MeV c^{-1} of the electron after acceleration. (Rest mass of electron = 0.511 MeV c^{-2}.) *[4]*

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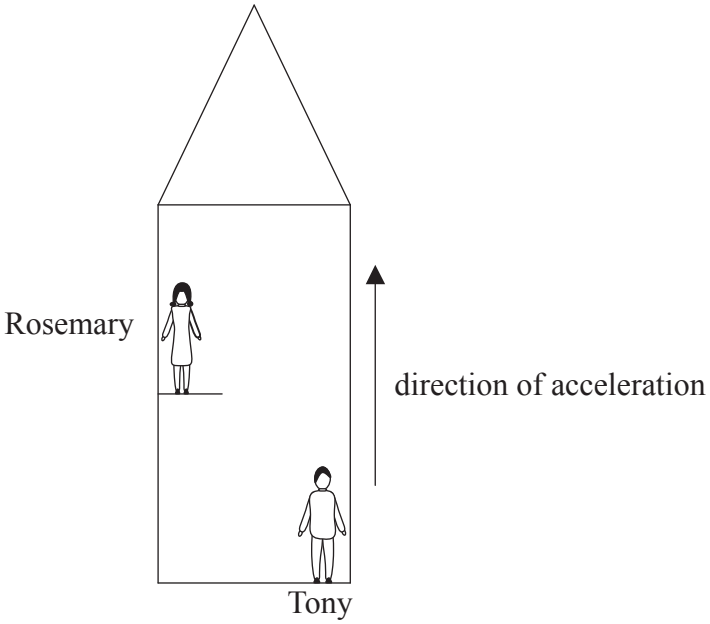
G5. Tony and Rosemary are in an accelerating spaceship as shown below.



Rosemary throws a ball in a direction horizontal to the floor that Tony is standing on.

(a) On the diagram above, draw the path of the ball as seen by Tony. *[1]*

(b) Describe how this situation relates to Einstein's principle of equivalence. *[3]*

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(c) Both Tony and Rosemary have a light source. When the acceleration of the spaceship is zero the frequency of the light emitted, as measured by Tony and Rosemary, is the same.

State

(i) how the frequency of the sources compare to Rosemary when the spaceship is accelerating in the direction shown. *[1]*

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(ii) the name of the phenomenon you have used in your answer to (c)(i). *[1]*

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Option H — Optics

H1. This question is about refraction.

(a) Define *refractive index*. *[1]*

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(b) In a certain medium, the speed of light of a particular frequency is $2.1 \times 10^8 \, m \, s^{-1}$. Calculate the refractive index of the medium for this frequency. *[2]*

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(c) With reference to your answer in (b), describe what is meant by optical dispersion. *[3]*

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H2. This question is about image formation by a plane mirror.

(a) State the **two** laws of reflection of light. *[2]*

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2. . . . . .

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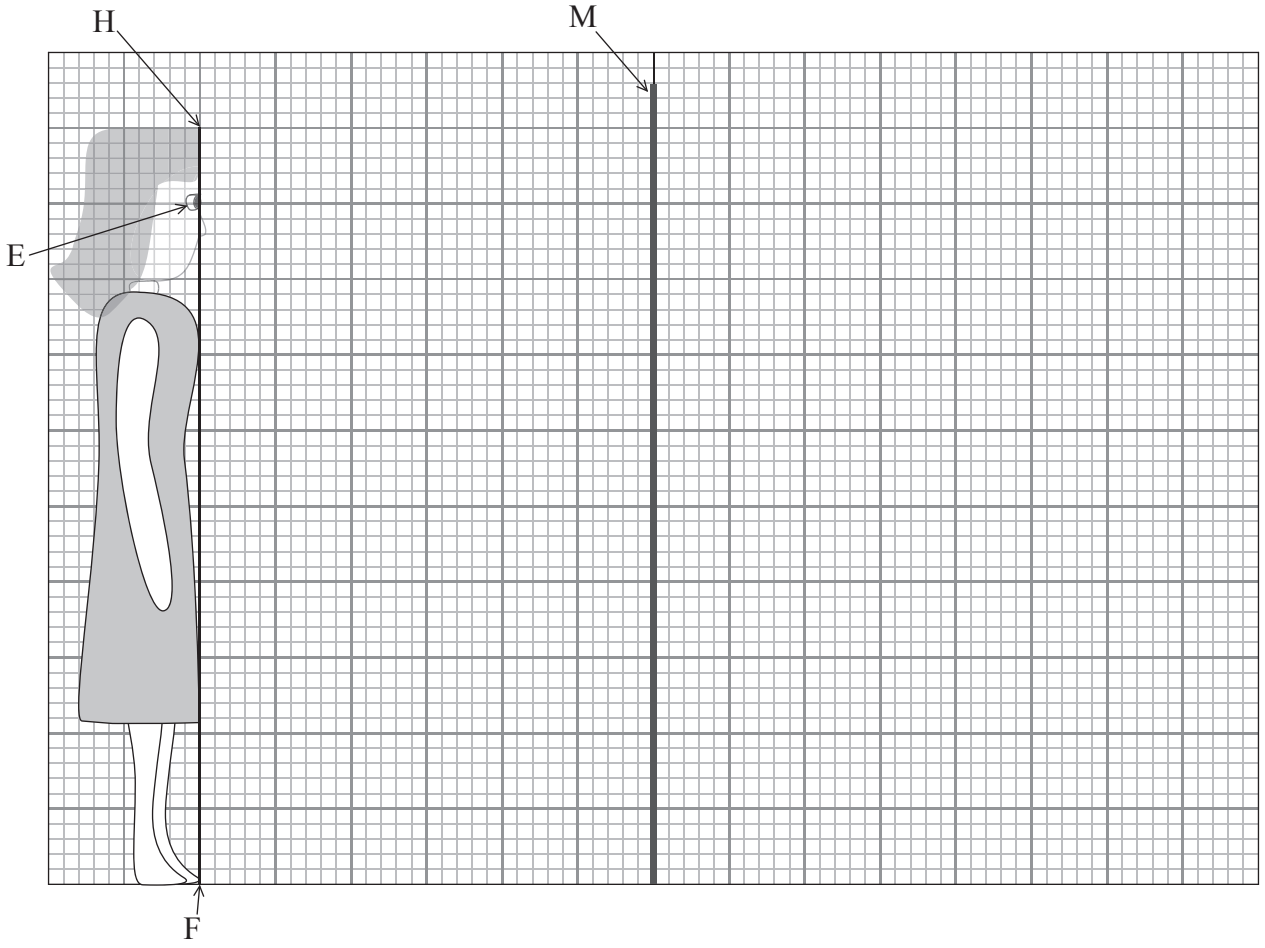
(b) In the diagram below, the line labelled HF represents a person standing in front of a vertical mirror labelled *M*. The position of the person's eye is labelled E.



On the diagram above draw

(i) the position of the image of the person, formed by the mirror. *[2]*

(ii) a ray from the foot F, and a ray from the top of the head H, to show the reflection of these rays into the eye E. *[2]*

(This question continues on the following page)

(Question H2 continued)

(c) The height of the person is 1.50 m and her eye is 1.35 m above the floor. The length and height of the mirror above the floor are adjusted so that she can just see the whole of her image in the mirror.

By reference to your ray diagram in (b)(ii), deduce

(i) the minimum length of the mirror. *[1]*

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(ii) the height of the lower edge of the mirror above the floor. *[1]*

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(d) The person now stands further away from the mirror. State the effect, if any, that this has to your answers in (c)(i) and (ii). *[1]*

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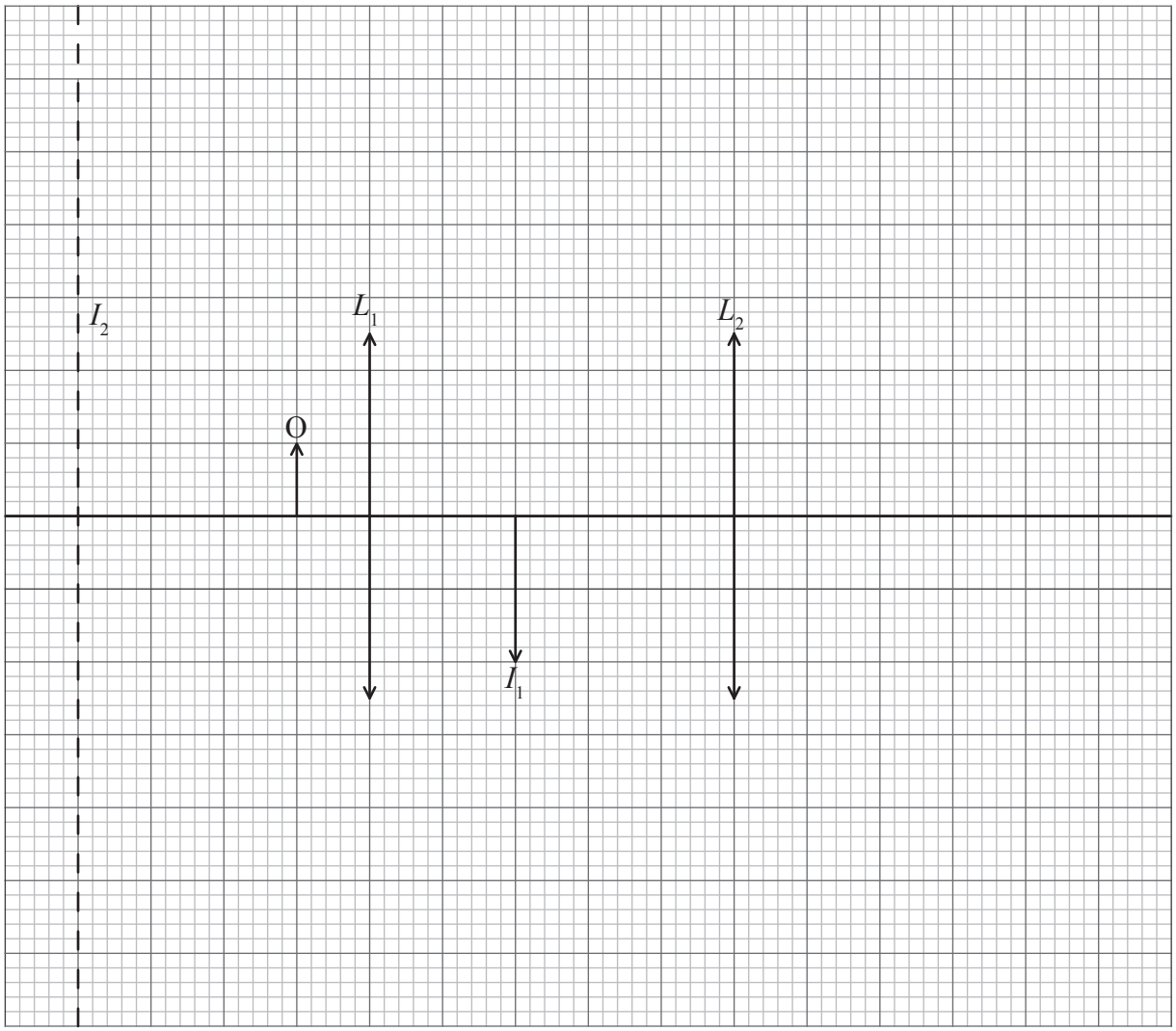
H3. This question is about a compound microscope.

The diagram below shows two lenses of a compound microscope. L_1 is the objective lens and L_2 is the eyepiece lens.



I_1 is the image of the object O formed by the objective lens L_1. The final image formed is in the plane shown by the dotted line labelled I_2.

(a) On the diagram above, construct a ray **or** rays to determine the position of the principal focus of the eyepiece. Label this position with the letter F. *[2]*

(This question continues on the following page)

(Question H3 continued)

(b) By using the grid, take measurements to determine the linear magnification of

(i) the objective lens. *[1]*

. . . . . .
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(ii) the eyepiece. *[1]*

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(c) Use your answer to (b) to determine the total linear magnification of the microscope. *[1]*

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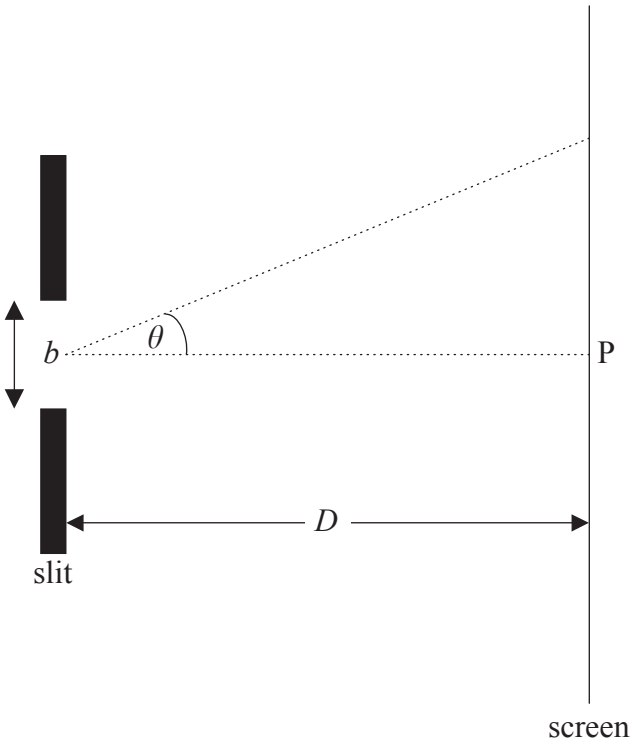
H4. This question is about diffraction.

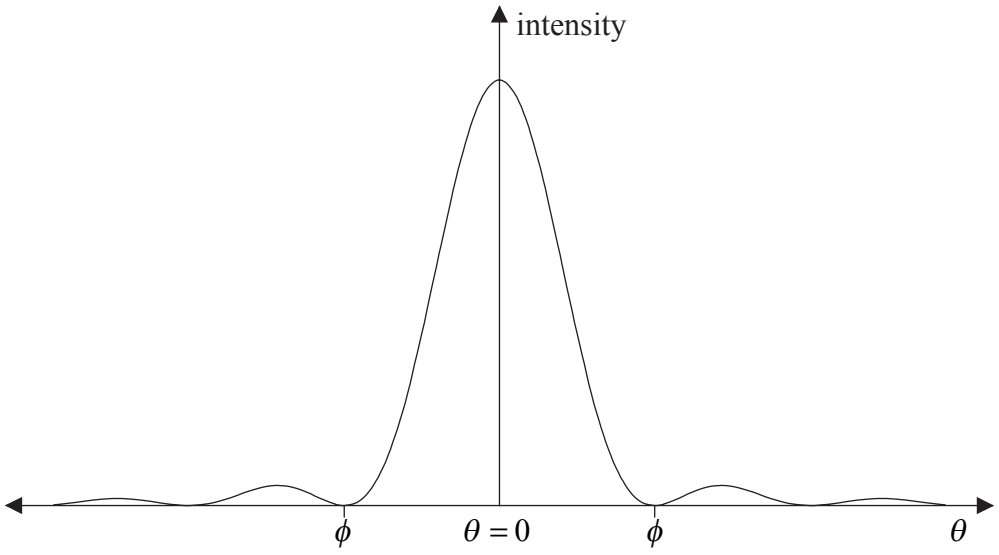
Plane wavefronts of monochromatic light of wavelength λ are incident on a rectangular slit of width b. After passing through the slit, the light is brought to a focus on a screen distance D from the slit as shown below. The width of the slit is comparable to the wavelength of the incident light and $b \ll D$. The point P on the screen is opposite the centre of the slit.



(This question continues on the following page)

(Question H4 continued)

The sketch graph below shows that the variation with angle θ of the intensity of the light on the screen.



(a) Explain qualitatively, this intensity distribution. *[3]*

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(b) The angle $\theta = \phi$ is the angular half-width of the central maximum of the intensity distribution and is given by the expression $\phi = \frac{\lambda}{b}$. Derive an expression in terms of D, λ and b for the half-width d of the central maximum. *[2]*

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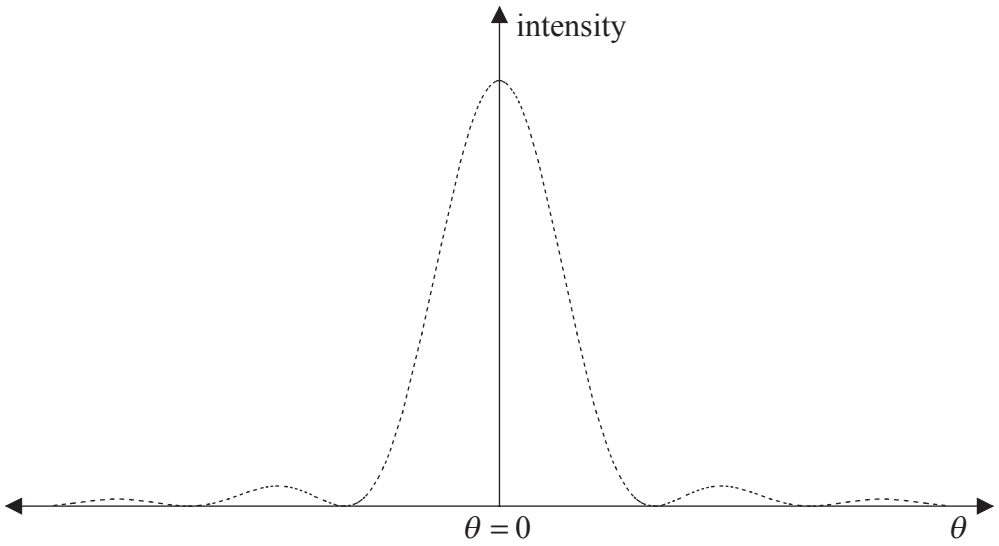
(This question continues on the following page)

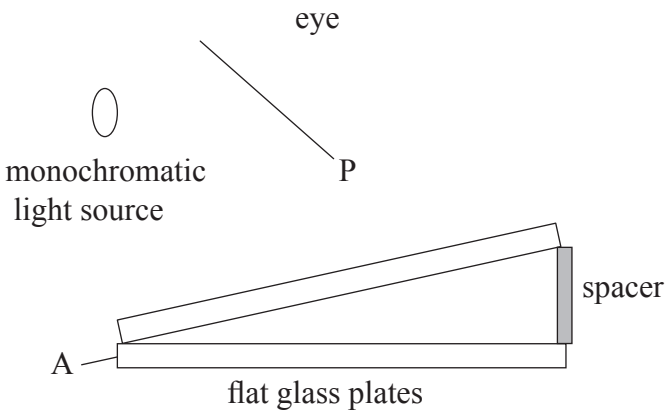
(Question H4 continued)

(c) The single slit is replaced by two rectangular slits of width b. The distance between the centre of the slits is equal to $2b$.

On the axes below, draw a sketch of the of the intensity distribution on the screen. (The intensity distribution of a single slit is shown by the dotted line.) *[2]*



H5. A wedge shaped film of air is made by separating two thin, flat glass plates by a spacer.



It is arranged for light from a monochromatic source to be incident on the plates by reflection from another glass plate P. The light reflected from the wedge is viewed from above as shown in the diagram. A system of equally spaced, parallel fringes is observed. (The diagram is not to scale.)

(a) State what happens to the phase of the light waves reflected from the upper surface of the plate labelled A in the diagram. *[1]*

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(b) The wavelength of the light is 560 nm. Calculate by how much the width of the wedge changes between one bright fringe and the next bright fringe. *[2]*

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