INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

PHYSICS
HIGHER LEVEL
PAPER 3

Wednesday 16 May 2001 (morning)

1 hour 15 minutes

Name

Number

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and 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 boxes below.

OPTIONS ANSWERED	EXAMINER	TEAM LEADER	IBCA
	/30	/30	/30
	/30	/30	/30
	TOTAL /60	TOTAL /60	TOTAL /60

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OPTION D — BIOMEDICAL PHYSICS

D1. *This question is about blood pressure.*

When a nurse takes the blood pressure of a particular patient the systolic reading is 140 mm of mercury and the diastolic reading is 80 mm of mercury.

(a) Explain the meaning of the terms *systolic* and *diastolic*. *[2]*

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(b) Show that a blood pressure reading of 80 mm of mercury is equivalent to 11 kPa.
(Density of mercury $= 1.36 \times 10^4 \text{ kg m}^{-3}$*, acceleration due to gravity* $= 10 \text{ m s}^{-2}$*.)* *[2]*

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(c) Explain why blood pressure readings are usually taken at the upper arm. *[2]*

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(d) If the height of the patient is 1.8 m and his systolic blood pressure reading at the upper arm is 140 mm, estimate the blood pressure reading if it were to be taken at the patient's ankle while he was standing upright.

State **one** assumption that you have made in your calculation. *[4]*

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D2. *This question is about scaling.*

Toby has a mass of 70 kg and Susie has a mass of 50 kg.

(a) Estimate the ratio of thermal energy loss from Toby to that from Susie. *[4]*

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(b) State **one** assumption that you have made in your estimate. *[1]*

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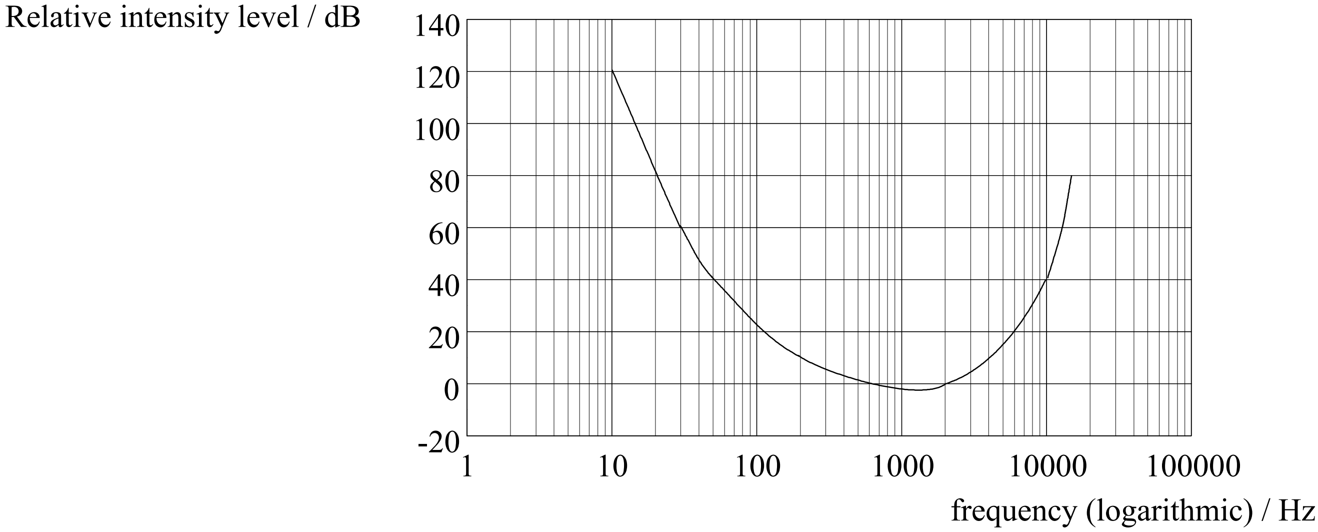
D3. *This question is about hearing.*

The graph below shows how the minimum intensity of sound that is required to be just heard (threshold of hearing) varies with frequency for the average human ear.



Use the graph to find

(a) the frequency range over which a sound of intensity 10^{-8} W m^{-2} can just be heard. *[2]*

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(b) the frequency at which the ear is most sensitive. *[1]*

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(c) how much less intense a sound of 200 Hz must be than a sound of intensity 10 000 Hz if it is to be just heard. *[2]*

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D4. *This question is about X-rays.*

(a) State **two** mechanisms responsible for the attenuation of X-rays by matter. *[2]*

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(b) Define the term *linear attenuation coefficient.* *[2]*

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(c) State the **two** factors upon which the value of the linear attenuation coefficient depends. *[2]*

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(d) (i) X-rays of a specific energy are used to image a suspected leg bone fracture. The patient's leg is 15 cm thick and the bone is 5 cm thick. At this particular energy the linear attenuation coefficient for tissue is $5\ m^{-1}$ and the linear attenuation coefficient for bone is $60\ m^{-1}$.

Show that after the X-rays pass through the leg their intensity will have been reduced about ten times more by the bone than by the tissue. *[3]*

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(ii) Explain why an X-ray beam of this particular energy is suitable for detecting a leg fracture. *[1]*

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OPTION E — HISTORICAL PHYSICS

E1. *This question is about different views on the nature of motion.*

Here are two simple observations.

Observation 1. If you are holding a book in your hand and release it, it falls to the ground.

Observation 2. In order to make a book move along a flat surface you have to exert a force on the book continuously.

(a) Complete the table below in respect of the different views that Aristotle and Galileo had about aspects of these observations.

Aspect of the observations	Aristotle's view	Galileo's view
The time for books of different mass to reach the ground when dropped from the same height.	. . . .	. . . .
The relationship between a constant force applied to a book and the velocity of the book.	. . . .	. . . .

[4]

(b) How did the methods by which Galileo and Aristotle reached their conclusions differ? *[1]*

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(c) In what way did Newton extend Galileo's view of the effect of the force on the motion of the book? *[1]*

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E2. *This question is about the physics of Kepler and Newton.*

Kepler's third law states that the square of the orbital period of rotation of a planet around the Sun is proportional to the cube of the average radius of orbit.

(a) Upon whose precise observations did Kepler base his law? *[1]*

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(b) Why did Kepler refer to the **average** radius of orbit? *[1]*

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(c) The asteroid called Ceres is on average three times further away from the Sun than the Earth. What is the orbital period, in years, of Ceres about the Sun? *[3]*

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(This question continues on the following page)

(Question E2 continued)

(d) Newton was able to explain Kepler's third law by proposing that there exists, between a planet and the Sun, a central force of attraction that varies as the inverse square of the planet's distance from the Sun.

(i) What did Newton mean by a *central force*? *[1]*

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(ii) In applying his law of gravitation to extended objects such as the Sun and planets, Newton made an assumption which he later proved mathematically. What was this assumption? *[2]*

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(iii) A consequence of Newton's ideas on mechanics and gravity is that the mass of the Sun can be found by observing the effect that the Sun has on the planets that orbit it. Use the following data to estimate the mass of the Sun.

Universal gravitational constant	$\approx 6 \times 10^{-11}$ N m^2 kg^{-2}
Average orbital radius of the Earth about the Sun	$\approx 1.5 \times 10^{11}$ m
One year	$\approx 3 \times 10^{7}$ s

[4]

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(iv) Newton's theory of mechanics and gravity is said to be *deterministic*. Explain what deterministic means. *[2]*

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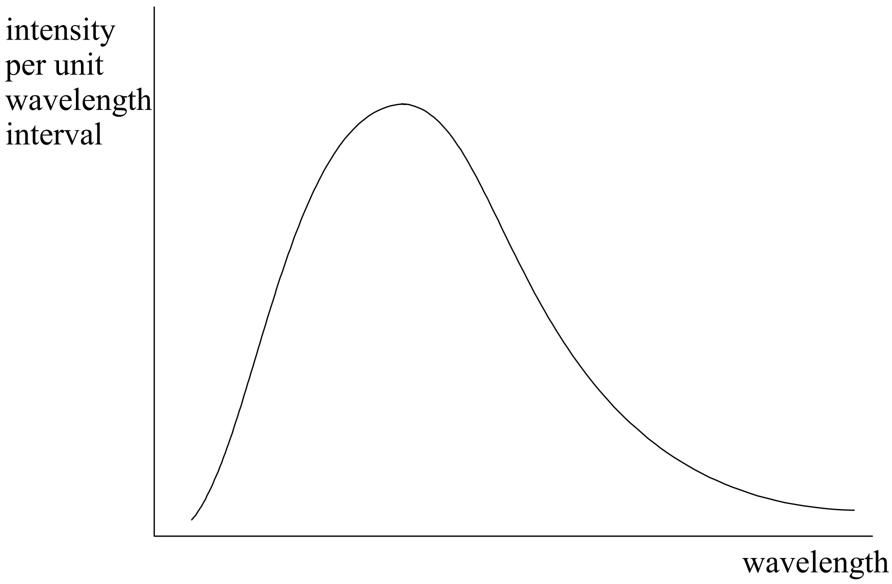
E3. *This question is about models proposed to explain how radiation is emitted and absorbed.*

The sketch graph below shows how the measured intensity of radiation from a black body at a certain temperature varies with wavelength.



Rayleigh and Jeans attempted to derive a theoretical relationship between intensity and wavelength based on the laws of classical physics. Their result did not fit the above curve.

(a) Sketch on the above diagram the result that Rayleigh and Jeans obtained. *[1]*

(b) This failure to fit theory with experiment was called the ‘ultra-violet catastrophe’. Explain why it was called this. *[2]*

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(Question E3 continued)

(c) In 1900 Max Planck proposed a different model for the emission and absorption of radiation by an oscillator. In what ways did Planck's model differ from that used by Rayleigh and Jeans? *[5]*

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(d) Why is Planck's model regarded as being the 'correct' model? *[1]*

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(e) In what way did Einstein extend the Planck model? *[1]*

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OPTION F — ASTROPHYSICS

Note that there is only ***one*** *question in this Option*

F1. *This question is about various aspects of the stars Sirius A and Sirius B.*

(a) Sirius A is at a distance of 2.64 pc from the Earth. With the aid of a diagram describe how the distance of Sirius A from the Earth can be determined. *[6]*

Diagram

Description

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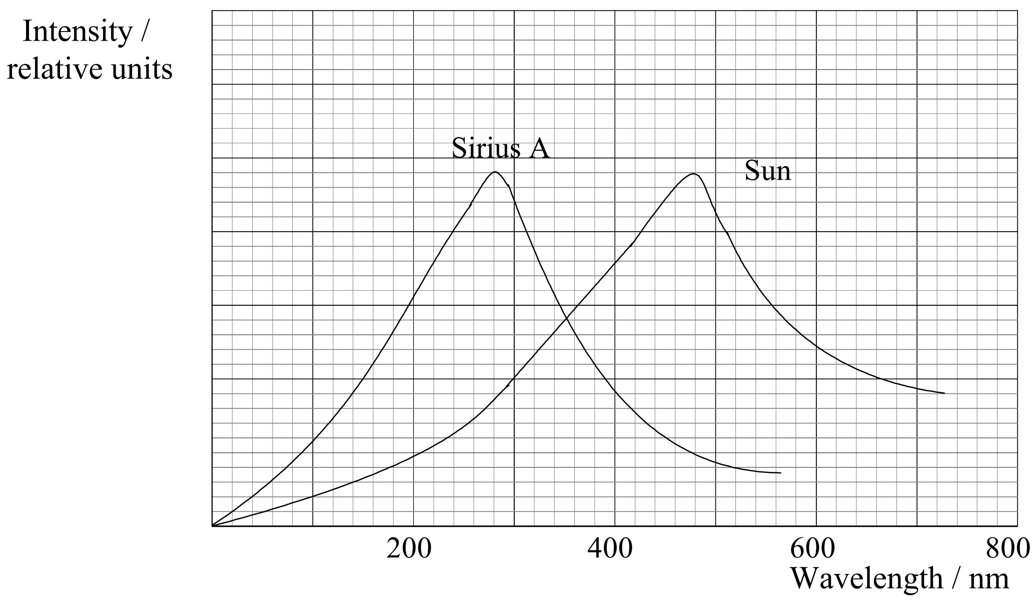
(Question F1 continued)

In answering questions (b), (c), and (d) you will need the following data:

Distance of Sirius A from Earth	= 2.64 pc
Apparent brightness of Sirius A	= 1.42×10^{-5} W m^{-2}
Temperature of the Sun	= 6000 K
Apparent brightness of the Sun	= 1370 W m^{-2}
1 parsec	= 2.1×10^{5} AU

(b) The graph below shows the spectra of the Sun and the star Sirius A. *(The intensities have been 'normalised' such that both curves fit on the same graph.)*



Use the information from the graph to

(i) explain whether or not the temperature of Sirius A is higher than that of the Sun. *[2]*

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(ii) find the surface temperature of Sirius A. *[2]*

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(Question F1 continued)

(c) Show that the distance from Earth to Sirius A is equivalent to 5.5×10^5 AU. *[1]*

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(d) Show that the luminosity of Sirius A is about 3.1×10^3 times that of the Sun. *[4]*

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(e) What factor other than temperature determines the luminosity of a star? *[1]*

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(f) Sirius A has a companion star Sirius B. Sirius A is a main sequence star whilst Sirius B is a white dwarf.

(i) State **two** characteristics of a white dwarf that are different to the characteristics of a main sequence star. *[2]*

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(ii) Outline the main processes by which a main sequence star of a mass similar to that of the Sun becomes a white dwarf. *[6]*

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(Question F1 continued)

(g) Sirius A has a mass about twice that of the Sun. In what ways would the evolution of a main sequence star of a mass about ten times that of the Sun differ from the evolution of Sirius A? *[4]*

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(h) Sirius A and Sirius B form a system known as a visual binary.

(i) Explain the term *visual binary*. *[1]*

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(ii) What property of a visual binary system, other than separation of the stars, is measured in order to find the mass of the system? *[1]*

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OPTION G — SPECIAL AND GENERAL RELATIVITY

G1. *This question is about time dilation.*

(a) One of the two postulates of the Special Theory of Relativity can be stated as *'the laws of physics are the same for observers in different inertial reference frames.'*

(i) What does the term *inertial reference frame* mean? *[1]*

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(ii) State the other postulate of Special Relativity. *[2]*

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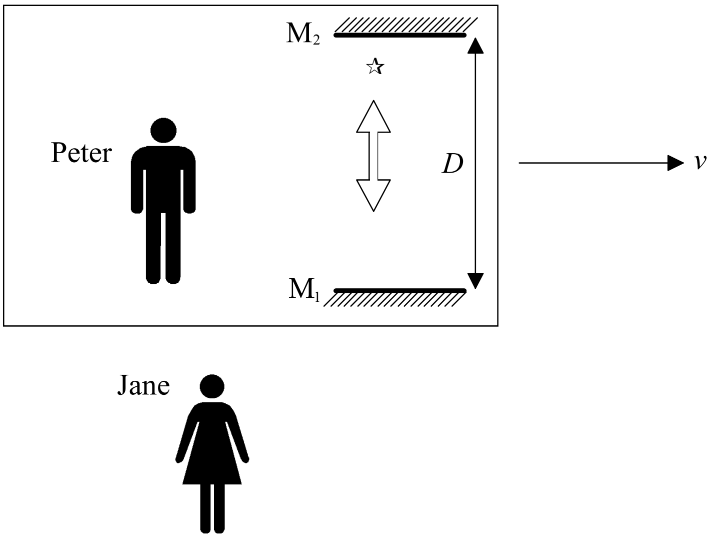
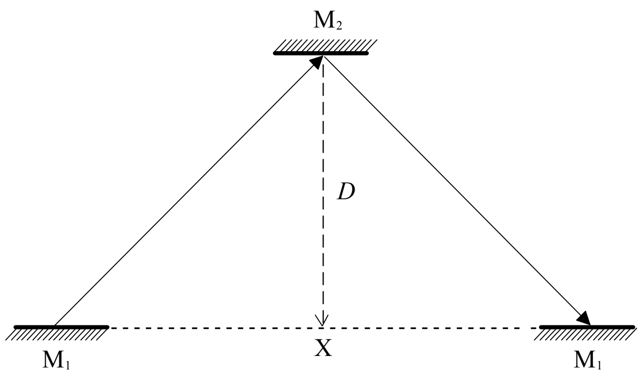
(This question continues on the following page)

(Question G1 continued)

(b) In the diagram below Peter is moving with uniform velocity relative to Jane. A light pulse reflects between the two plane mirrors separated by a distance D as shown in the diagram. To Peter the pulse is seen to traverse a perpendicular path between the mirrors.



The diagram below shows how the path of the light pulse appears to Jane as it leaves mirror M_1, reaches M_2 and returns to M_1.



The time for the pulse to move from M_1 to M_2 and back as measured by Jane is Δt and the speed of Peter as measured by Jane is v.

If the speed of the pulse is c write down expressions for the distances M_1X and M_1M_2 in terms of c, v and Δt.

(i) M_1X *[1]*

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(ii) M_1M_2 *[1]*

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(This question continues on the following page)

(Question G1 continued)

(c) The time for the pulse to move from M_1 to M_2 and back as measured by observer Peter is $\Delta t'$.

(i) Write down an expression for the distance *D* between the mirrors in terms of *c* and $\Delta t'$. *[1]*

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(ii) Show that

$$\Delta t = \frac{\Delta t'}{\sqrt{1 - \frac{v^2}{c^2}}}$$

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(d) Peter and Jane are each wearing a wristwatch with a second hand that takes one minute to make one complete revolution and Peter is moving at a speed of 0.9c with respect to Jane.

When Peter observes the second hand on his watch to have made one complete revolution, how many revolutions will Jane observe the second hand of her watch to have made? *[2]*

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(This question continues on the following page)

(Question G1 continued)

(e) An experiment that demonstrates *time dilation* involves the decay of particles called *muons.*

(i) Outline how the observation of the decay of muons created in the upper atmosphere supports the phenomenon of time dilation. *[4]*

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(ii) Muons have a half-life of 3.1×10^{-6} s as measured in a reference frame in which the muons are at rest.

Suppose an accelerator creates a pulse of muons moving with a speed of 0.9c.

How far will the pulse have travelled as measured by a laboratory observer when half the muons in the pulse will have decayed? *[3]*

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G2. *This question is about the relativistic dynamics of muons.*

After acceleration from rest through a potential difference of 50 MV, muons attain a speed of 0.75c as measured by a laboratory observer.

(a) What is the gain in kinetic energy of the muons measured in electron-volts? *[1]*

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(b) Show that the rest mass of the muons is about 100 MeV/c^2. *[4]*

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(c) Show that the momentum of the muons after acceleration is about 113 MeV/c. *[2]*

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G3. *This question is about gravitational and inertial mass.*

One of the cornerstones of Einstein's General Theory of Relativity is that gravitational mass and inertial mass are equivalent.

In 1969 Neil Armstrong was the first man to stand on the surface of the Moon. In what has become a classic film, he is shown holding a hammer in one hand and a feather in the other. He released them at the same time and both reached the surface of the moon at the same time.

Explain how this demonstrates the equivalence of gravitational mass and inertial mass. *[4]*

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OPTION H — OPTICS

H1. *This question is about the refraction of light.*

The diagrams below show two different situations in which a monochromatic ray of light is incident on the boundary between two surfaces. In **Diagram 1** the boundary is between air and glass and in **Diagram 2** the boundary is between water and glass.

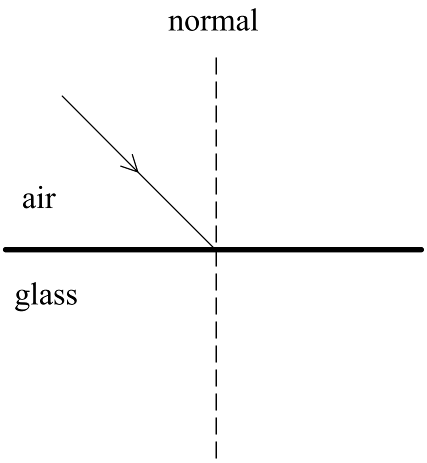

Diagram 1

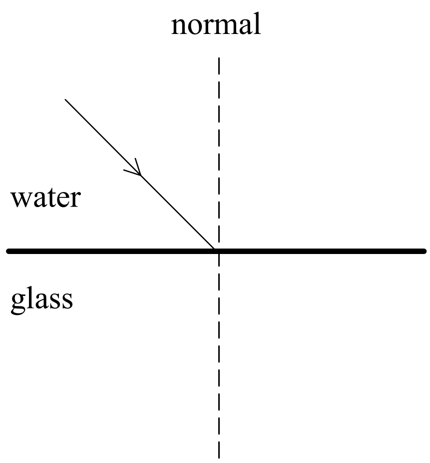

Diagram 2

The refractive index of glass is greater than that of water.

(a) On each diagram sketch the reflected and refracted rays. *[3]*

(b) The refractive index for glass is 1.5 and for water 1.3. Calculate the critical angle for the glass-water boundary. *[1]*

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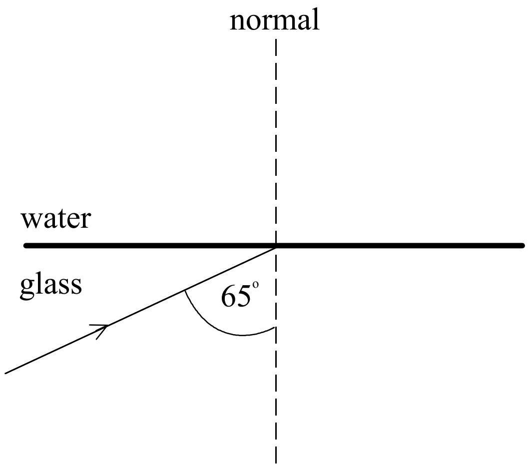
(Question H1 continued)

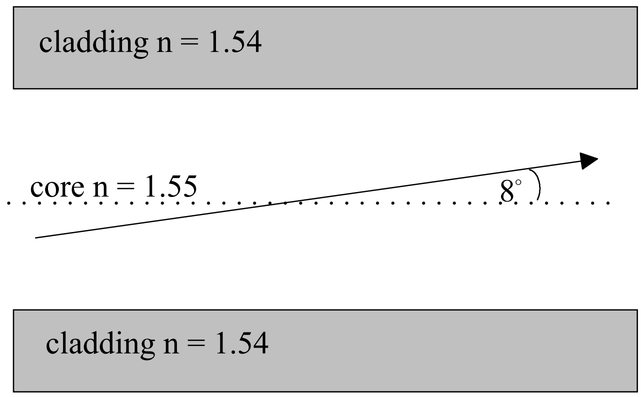
(c) A ray is incident at the glass-water boundary as shown on the diagram below. Sketch the subsequent path(s) of the ray. *[2]*



(d) The core of an optical fibre is made of material of refractive index 1.55. Cladding made of material of refractive index 1.54 surrounds the core.

Show that rays that cross the axis of the core at an angle greater that 8° will **not** be internally reflected at the core-cladding boundary.

The situation is shown in the diagram below. *[2]*



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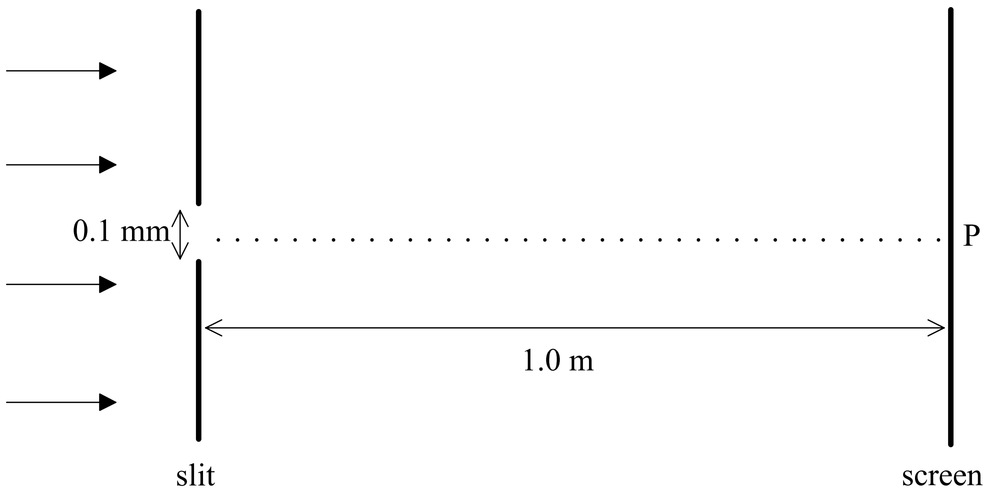
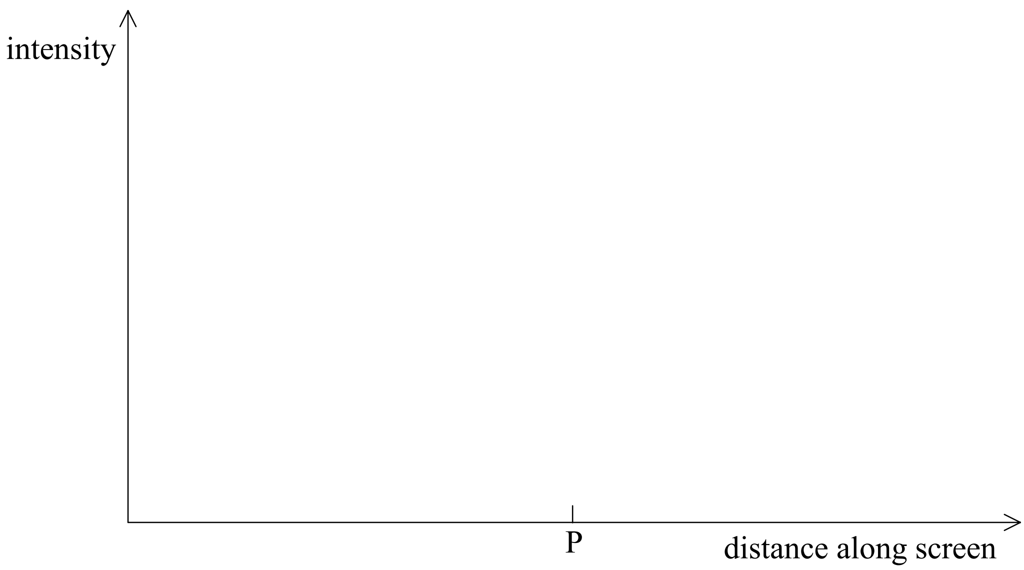
H2. *This question is about diffraction.*

In the diagram below (not to scale) a monochromatic beam of light of wavelength 500 nm is incident on a single slit of width 0.1 mm. After passing through the slit the light is brought to a focus (the focusing lens is not shown) on a screen placed at a distance of 1.0 m from the slit.



(a) On the axes below sketch a diagram showing how the intensity of the light varies at different points along the screen. *(Note that this is a sketch graph; no values are required).* *[3]*



(b) Calculate the width of the central maxima. *[3]*

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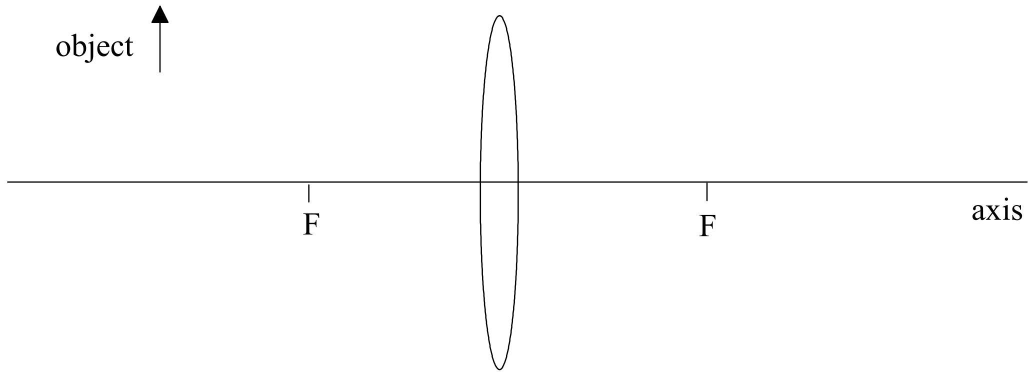
H3. *This question is about the compound microscope.*

(a) The diagram below shows a convex lens, the position of the principal foci (focal points), F, of the lens, and an object which is to be viewed by the lens.



(i) Redraw the object at an appropriate location on the principal axis such that the lens will form a **magnified, virtual image** of the object. *[1]*

(ii) Construct a ray diagram that enables the position of the image to be located. *[2]*

(iii) Mark on the diagram a position where the eye could be placed in order to view the image. *[1]*

(b) The lens above is to be used as the eyepiece of a compound microscope. The diagram below shows the **objective** lens, its two principal foci (focal points), F_o, and the object that is to be viewed.

Mark the following on the axis:

(i) the approximate position, X, of the image formed by the objective lens; *[1]*

(ii) the approximate position, C, of the **eyepiece** lens; *[1]*

(iii) the principal foci (focal points), F, of the eyepiece lens; *[1]*

(iv) the approximate position, Y, of the final image. *[1]*

H4. *This question is about optical resolution*

Abigail looks at a particular star with her naked eye and she sees the star as a point of light. When she looks at the star through a telescope she sees that there are two points of light. The star Abigail is looking at is actually two stars close together.

(a) Explain, assuming that Abigail's eyes are functioning normally,

(i) why she is unable to distinguish the two stars with her naked eye. *[3]*

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(ii) how the telescope enables her to distinguish the two stars. *[2]*

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(b) The system that Abigail is observing is 4.2×10^{16} m from the Earth and the two stars are separated by a distance of 2.6×10^{11} m. Assuming that the average wavelength of the light emitted by the stars is 500 nm, estimate the minimum diameter of the objective lens of a telescope that will just enable the two stars to be distinguished. *[3]*

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