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

N05/4/PHYSI/HP3/ENG/TZ0/XX+

88056503

PHYSICS
HIGHER LEVEL
PAPER 3

Friday 18 November 2005 (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.

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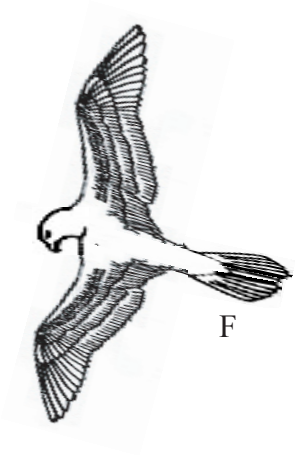
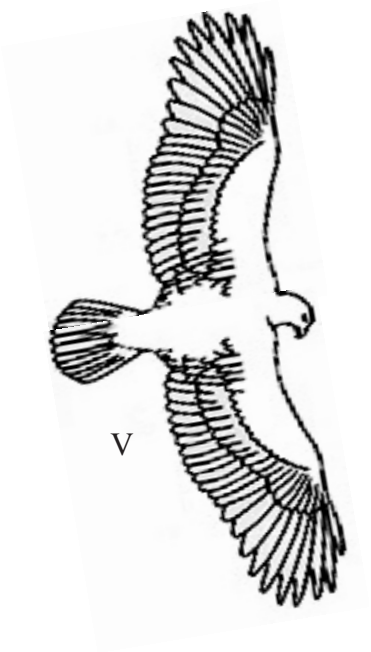
Option D — Biomedical Physics

D1. This question is about shape and form.

The diagrams below show the outline of two birds F and V.





State and explain, with reference to shape and form, which bird is more suited to

(a) slow guided flight. *[2]*

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(b) fast straight-line flight. *[2]*

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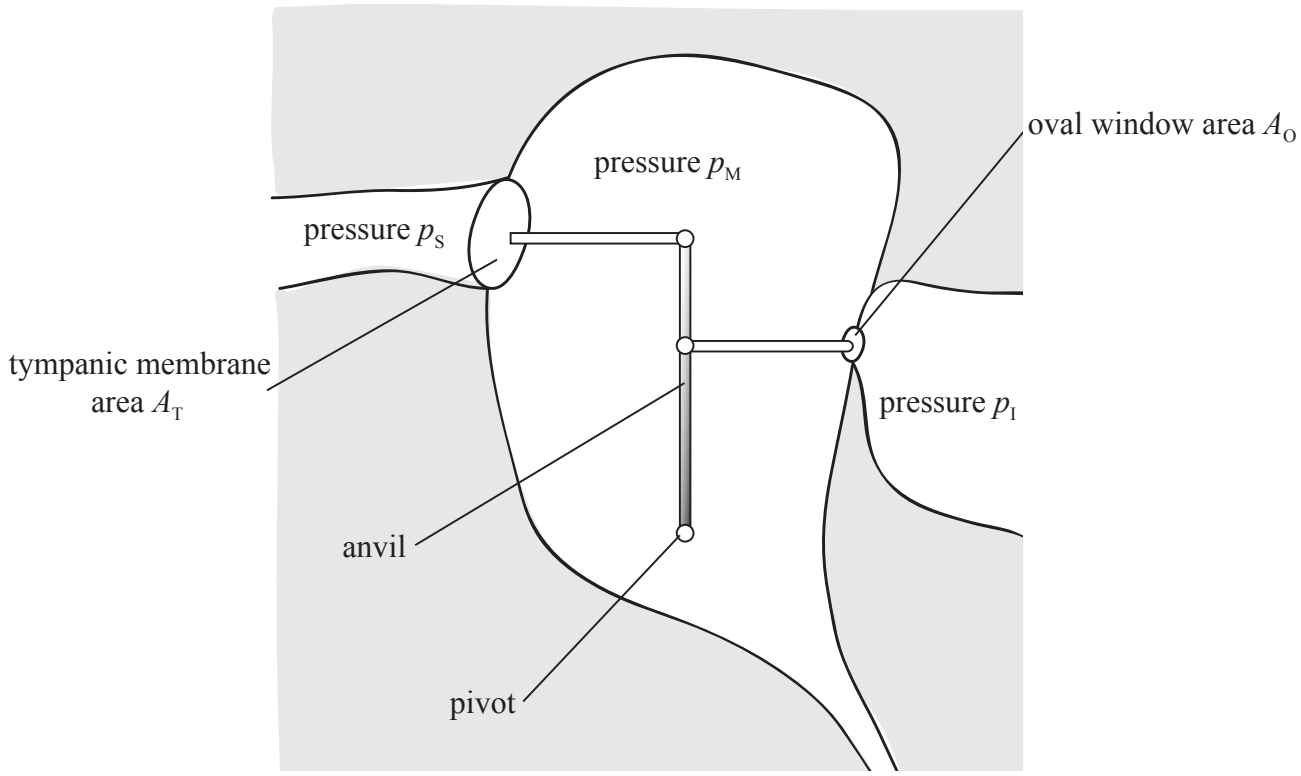
D2. This question is about the ear.

The diagram illustrates the lever system of the ossicles in the middle ear.



The tympanic membrane (eardrum) has area A_T and the oval window has area A_O. At one particular time, a sound wave produces a total pressure p_S on the tympanic membrane. The pressure in the middle ear is p_M and in the inner ear p_I.

(a) Determine, in terms of p_S, p_M and A_T, the force applied to the anvil by the tympanic membrane. *[3]*

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(This question continues on the following page)

(Question D2 continued)

The force F applied by the ossicles to the oval window is given by the expression

$$F = \frac{3}{2}(p_S - p_M) \times A_T .$$

(b) (i) State why the force F is greater than the force determined in (a). *[1]*

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(ii) Deduce that the pressure difference $(p_M - p_I)$ across the oval window is given by

$$(p_M - p_I) = \frac{3}{2}(p_S - p_M) \times \frac{A_T}{A_O} .$$ *[1]*

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(c) For humans, the ratio $\frac{A_T}{A_O}$ is about 20. Use this information to outline the function of the ossicles. *[2]*

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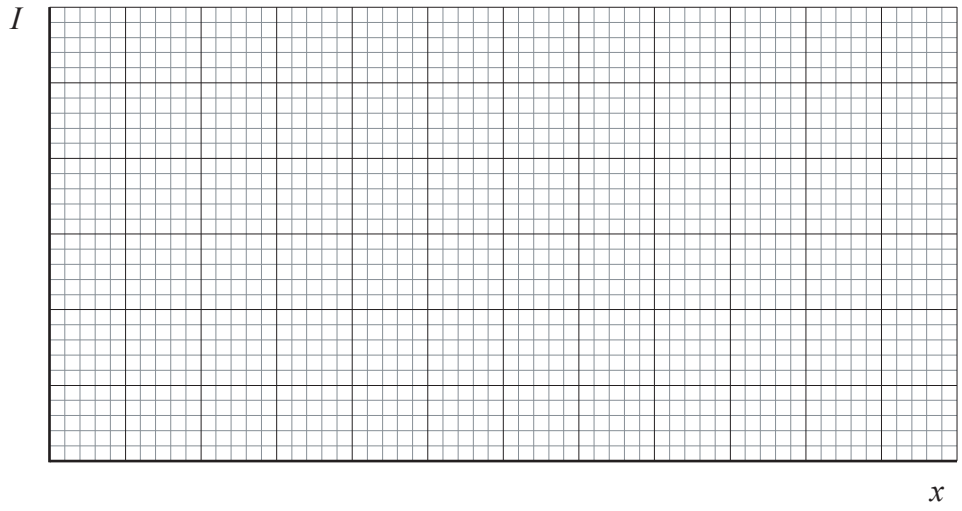
D3. This question is about X-rays.

A parallel beam of monochromatic X-rays is incident normally on a block of aluminium.

(a) (i) On the axes below, draw a sketch graph to show the variation with thickness x of aluminium of the intensity I of the X-ray beam. *[2]*



(ii) Write down an equation for the line on the graph that you have sketched. State the name of any other symbols used in the equation. *[2]*

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(iii) Define *half-value thickness*. *[1]*

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(b) Explain, by reference to attenuation coefficients, why a "barium meal" may be used for X-ray diagnosis of the stomach. *[4]*

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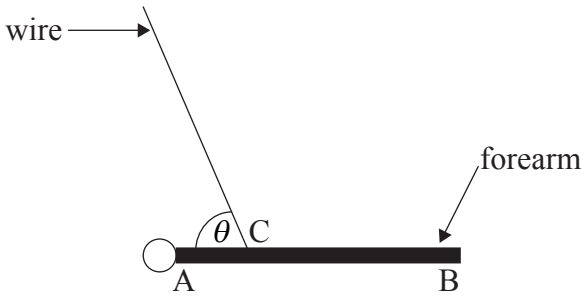
D4. This question is about modelling the human arm.

The forearm (lower arm) may be modelled to be a uniform rod AB hinged at end A. The rod AB is supported by means of a wire connected to the rod at point C, as shown below.



not drawn to scale

(a) Define *centre of gravity*. *[1]*

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(b) On the diagram, draw in the position of the centre of gravity of the rod AB. Label this point G. *[1]*

(c) Suggest why the wire is needed to hold the rod AB horizontally. *[1]*

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A 45 N weight is suspended from end B of the rod. The wire makes an angle θ of 60° with the rod when the rod is horizontal. The rod AB is of length 42.0 cm and has a weight of 25 N. The distance AC is 3.0 cm.

(d) Calculate the tension in the wire. *[3]*

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(e) The tension in the wire is larger than the weight held at B. Suggest an advantage of this arrangement in a human forearm. *[1]*

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D5. State **two** mechanisms by which radiation causes damage to cells in the body. For **one** of these mechanisms, briefly outline how the damage is caused. *[3]*

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2. . . . . .

Outline: . . . . . .

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Option E — The History and Development of Physics

E1. This question is about the motion of the planets.

In general, planets are observed from Earth to make apparently slow progress across the night sky from west to east against the background of the fixed stars. At certain times, the planets undergo retrograde motion.

(a) Explain what is meant by *retrograde motion*. *[2]*

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(This question continues on the following page)

(Question E1 continued)

(b) Outline how retrograde motion was explained by

(i) Ptolemy. *[1]*

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(ii) Copernicus. *[2]*

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(This question continues on the following page)

(Question E1 continued)

(c) State **two** observations made by Galileo that indicated that Earth is not the centre of the universe. *[2]*

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2. . . . . .

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E2. This question is about the caloric theory.

(a) State and explain how, on the basis of the caloric theory, the following phenomena were explained.

(i) Transfer of energy from a body at high temperature to one at low temperature *[2]*

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(ii) Latent heat of fusion *[2]*

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(b) It was discovered that work done is related to change in thermal energy.

(i) Outline how this was discovered. *[1]*

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(ii) State and explain **two** reasons why this discovery led to doubt about the caloric theory. *[2]*

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2. . . . . .

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E3. This question is about electricity and magnetism.

(a) Outline briefly the discovery made in 1819 by Oersted in connection with electric current. *[2]*

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(b) Shortly after Oersted's discovery, Ampère announced a further discovery in connection with electric current. Briefly discuss Ampère's discovery and its significance. *[2]*

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(c) In 1831, Henry and Faraday separately announced a link between electric current and magnetic fields. State the nature of this link and suggest why their discovery was so important to the development of industrial society. *[2]*

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E4. This question is about quantum concepts and atomic models.

(a) Outline the Bohr model of the atom. *[3]*

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(b) Describe how this model may be used to explain the line spectrum of atomic hydrogen. No mathematical detail is required. *[3]*

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(c) The ionization energy of atomic hydrogen is 2.2×10^{-18} J. Calculate a value for the constant in the Rydberg formula. *[4]*

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Option F — Astrophysics

F1. This question is about the solar system.

(a) State the name of the planet in the solar system that has

(i) the greatest mass. *[1]*

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(ii) an orbit around the Sun between that of Saturn and of Neptune. *[1]*

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(b) State where, in the solar system, the asteroid belt is found. *[1]*

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(c) State **two** features of the orbits of comets. *[2]*

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2. . . . . .

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F2. This question is about stellar spectra.

Stars may be described in terms of their spectral classes.

(a) (i) Describe the colour of a B star. *[1]*

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(ii) Identify the class of the Sun. *[1]*

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(b) Discuss **two** different ways in which atomic spectra can be used to deduce physical data for stars. *[4]*

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F3. This question is about stellar magnitude and brightness.

(a) State what is meant by *apparent magnitude*. *[1]*

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(b) Define *absolute magnitude*. *[2]*

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(c) Explain why a star with an apparent magnitude of 6 radiates approximately 2.5 times more light power than a star with an apparent magnitude of 7. *[3]*

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(d) The star Capella has an apparent magnitude of +0.05 and its distance from Earth is 14 pc. Estimate its absolute magnitude. *[3]*

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F4. This question is about stars.

Describe the final nuclear reaction in the core, and the final evolutionary state, of

(a) a low-mass star (of the order of 1 solar mass). *[2]*

nuclear reaction: . . . . . .

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evolutionary state: . . . . . .

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(b) a high-mass star (of approximately 15 solar masses). *[2]*

nuclear reaction: . . . . . .

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evolutionary state: . . . . . .

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F5. This question is about extragalactic astrophysics.

(a) In an observation of a distant galaxy, spectral lines are recorded. Spectral lines at these wavelengths cannot be produced in the laboratory. Explain this phenomenon. *[2]*

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(b) Describe how Hubble's law is used to determine the distance from the Earth to distant galaxies. *[2]*

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(c) Explain why Hubble's law is not used to measure distances to nearby stars or nearby galaxies (such as Andromeda). *[2]*

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Option G — Relativity

G1. This question is about Special Relativity.

(a) Explain what is meant by an *inertial frame of reference*. *[1]*

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(b) State the **two** postulates of the Special Theory of Relativity. *[2]*

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An observer in a frame of reference A measures the relativistic mass and the length of an object that is at rest in his frame of reference. He also measures the time interval between two events that take place at one point in his reference frame. The relativistic mass and length of the object, and time interval between the two events, are also measured by a second observer in reference frame B that is moving at constant velocity relative to the observer in frame A.

(c) (i) By crossing out the inappropriate words in the table below, state whether the observer in frame B will measure the quantities as being larger, the same size or smaller than when measured by the observer in frame A. *[3]*

Quantity	Measured by observer in frame B
mass	larger / the same / smaller
length	larger / the same / smaller
time interval	larger / the same / smaller

(ii) Use your answers in (c) (i) to suggest how the observer in frame B will consider the density of the object in frame A to be affected. *[3]*

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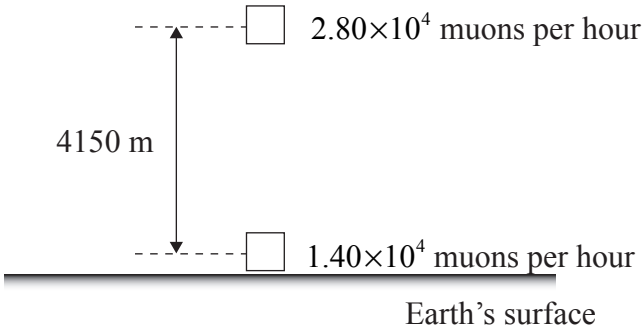
G2. This question is about muon decay.

Muons, created in the upper atmosphere, travel towards the Earth's surface at a speed of $0.994\,c$ relative to an observer at rest on the Earth's surface.

A muon detector at a height above the Earth's surface of 4150 m, as measured by the observer, detects 2.80×10^4 muons per hour. A similar detector on the Earth's surface detects 1.40×10^4 muons per hour, as illustrated below.



The half-life of muons as measured in a reference frame in which the muons are at rest is $1.52\,\mu$s.

(a) Calculate the half-life of the muons, as observed by the observer on the Earth's surface. *[2]*

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(b) Calculate, as measured in the reference frame in which the muons are at rest,

(i) the distance between the detectors. *[1]*

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(ii) the time it takes for the detectors to pass an undecayed muon. *[1]*

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(This question continues on the following page)

(Question G2 continued)

(c) Use your answers to (a) and (b) to explain the concepts of

(i) time dilation. *[2]*

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(ii) length contraction. *[2]*

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G3. Two electrons are travelling directly towards one another. Each has a speed of 0.80 *c* relative to a stationary observer. Calculate the relative velocity of approach, as measured in the frame of reference of one of the electrons. *[3]*

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G4. This question is about General Relativity.

(a) State Einstein's *principle of equivalence*. *[1]*

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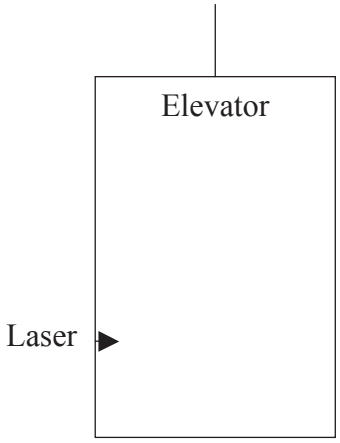
In a thought experiment, a laser is attached to the wall of a high-speed elevator (lift) as shown in the diagram below. The laser is set to emit a beam parallel to the floor of the stationary elevator.



The elevator is set in motion from the top of a tall building. While it is still accelerating downward the laser beam is fired (*shot 1*), it is fired again (*shot 2*) once the elevator is moving with constant velocity, and again (*shot 3*) as the elevator slows down.

(b) On the diagram, draw the path of the laser beam as seen by an observer in the elevator for

(i) constant speed, label this line C.

(ii) constant downward acceleration, label this line D.

(iii) constant upward acceleration, label this line U. *[3]*

(c) Explain how the paths you have drawn in (b) are consistent with the principle of equivalence. *[3]*

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G5. This question is about relativistic momentum and energy.

A proton is accelerated from rest through a potential difference of $2.0\times10^{9}\,\text{V}$. Calculate the final momentum of the proton in units of $\text{MeV}\,\text{c}^{-1}$. *[3]*

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Option H — Optics

H1. This question is about electromagnetic waves.

(a) Outline the electromagnetic nature of light. *[3]*

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(b) Suggest why it is better to specify the regions of the electromagnetic spectrum in terms of a frequency range rather than a wavelength range. *[2]*

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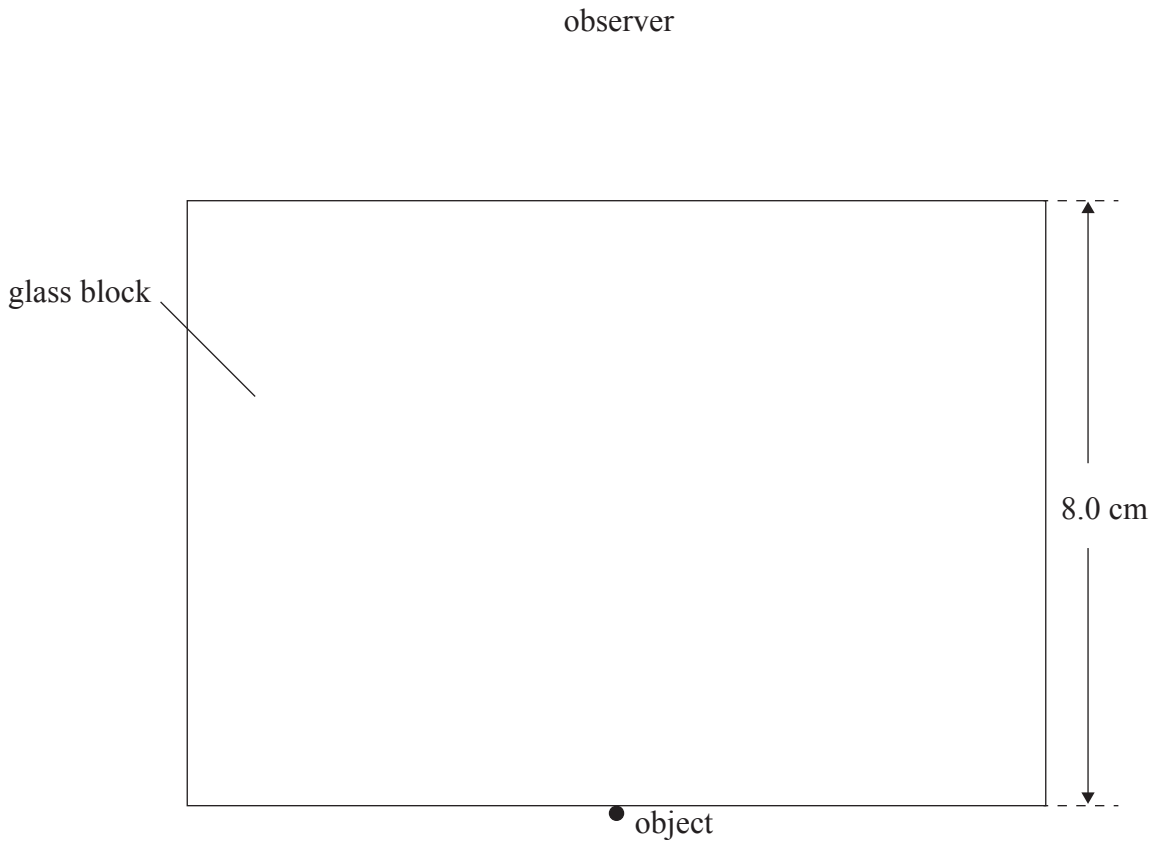
H2. This question is about refractive index.

An observer looks vertically downward on to a small object. A rectangular glass block is placed on the object, as shown below.



(a) On the diagram, draw two rays to show the apparent position of the object. *[2]*

The refractive index of the glass of the block is 1.48 and the thickness of the block is 8.0 cm.

(b) Determine the apparent position of the object. *[3]*

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(c) Suggest why your answer in (b) is correct **only** when the object is viewed from vertically above it. *[1]*

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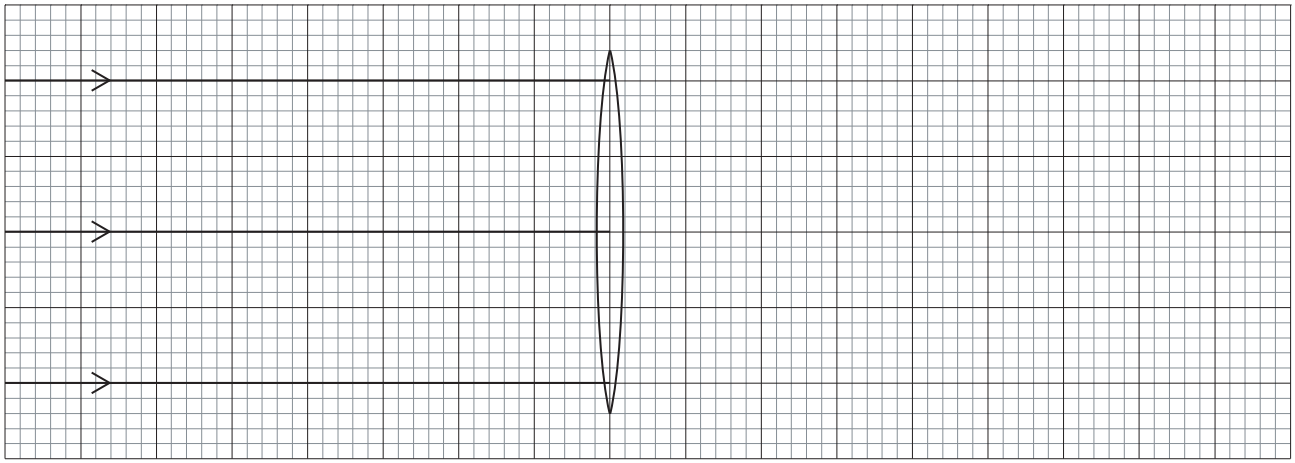
H3. This question is about a combination of lenses.

The diagram below shows rays of light incident on a thin converging (convex) lens of focal length 25 cm. The rays are parallel to the principal axis of the lens.



scale: 1 cm represents 5 cm

(a) Using a scale of 1 cm to represent 5 cm, draw the rays on the diagram above, after passing through the lens. *[1]*

A thin diverging (concave) lens of focal length 30 cm is placed 10 cm from the converging lens on the opposite side to the light incident on the converging lens (to the right of the converging lens). The principal axes of the two lenses coincide.

(b) (i) On the diagram above, draw the position of the diverging lens as a straight-line. Label this line with the letter D. *[1]*

(ii) Calculate the position where the rays cross the principal axis after passing through the diverging lens. On the diagram above, mark this position with the letter I. *[2]*

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(iii) On the diagram above, draw the rays of light emerging from the diverging lens to the point where they cross the principal axis at I. *[1]*

(This question continues on the following page)

(Question H3 continued)

(c) Extend the rays drawn in (b) (iii) until they meet the incident parallel rays. Estimate the effective focal length of the lens combination. *[2]*

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(d) Suggest how the effective focal length of the lens combination may be made longer. *[2]*

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H4. This question is about resolution.

(a) State the Rayleigh criterion for the images of two point sources to be just resolved. *[2]*

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A man is walking along a straight path at night towards two light sources as shown below.

not drawn to scale

When the man is 150 m from the sources, the images of the two sources are just resolved by his eye. The wavelength of the light from each source is 590 nm and the diameter of the aperture of his eye is 5.0 mm.

(b) Estimate the distance between the two sources. *[3]*

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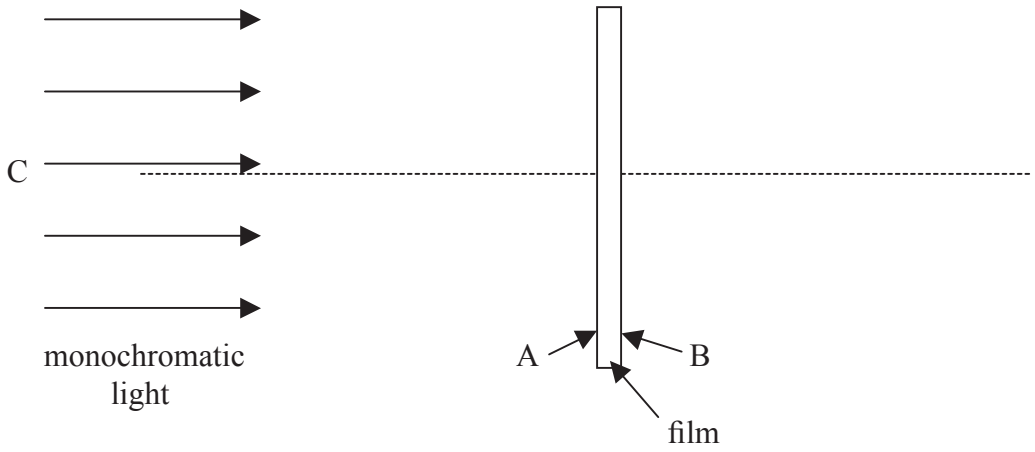
H5. This question is about thin film interference.

Monochromatic light is incident on a thin film of transparent plastic as shown below.



The plastic film is in air.

Light is partially reflected at both surface A and surface B of the film.

(a) State the phase change that occurs when light is reflected from

(i) surface A. *[1]*

. . . . . .

(ii) surface B. *[1]*

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The light incident on the plastic has a wavelength of 620 nm. The refractive index of the plastic is 1.4.

(b) Calculate the minimum thickness of the film for the light reflected from surface A and surface B to undergo destructive interference. *[3]*

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