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

M06/4/PHYSI/HP3/ENG/TZ2/XX+

22066515

PHYSICS
HIGHER LEVEL
PAPER 3

Wednesday 10 May 2006 (morning)

1 hour 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

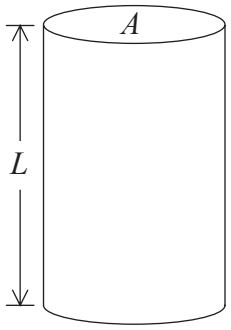
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet.

0131

Option D — Biomedical Physics

D1. This question is about stress in bones.

A section of bone has a length L and a uniform cross section A as shown below.



Weights are placed on the bone until it breaks. The maximum weight that could be supported is W. Determine the maximum weight that can be supported when all the linear dimensions of the bone are doubled. *[4]*

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D2. This question is about sound intensity.

(a) Define *sound intensity level*. *[2]*

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(b) The earphone of a personal radio produces 2.8×10^{-7} W of sound power. This power may be assumed to be incident uniformly on the eardrum of area 1.9×10^{-5} m^2. Calculate the sound intensity level at the eardrum. *[3]*

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(c) Comment on your answer to (b). *[1]*

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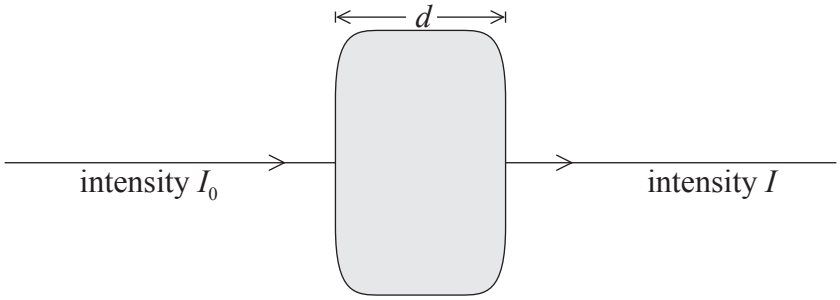
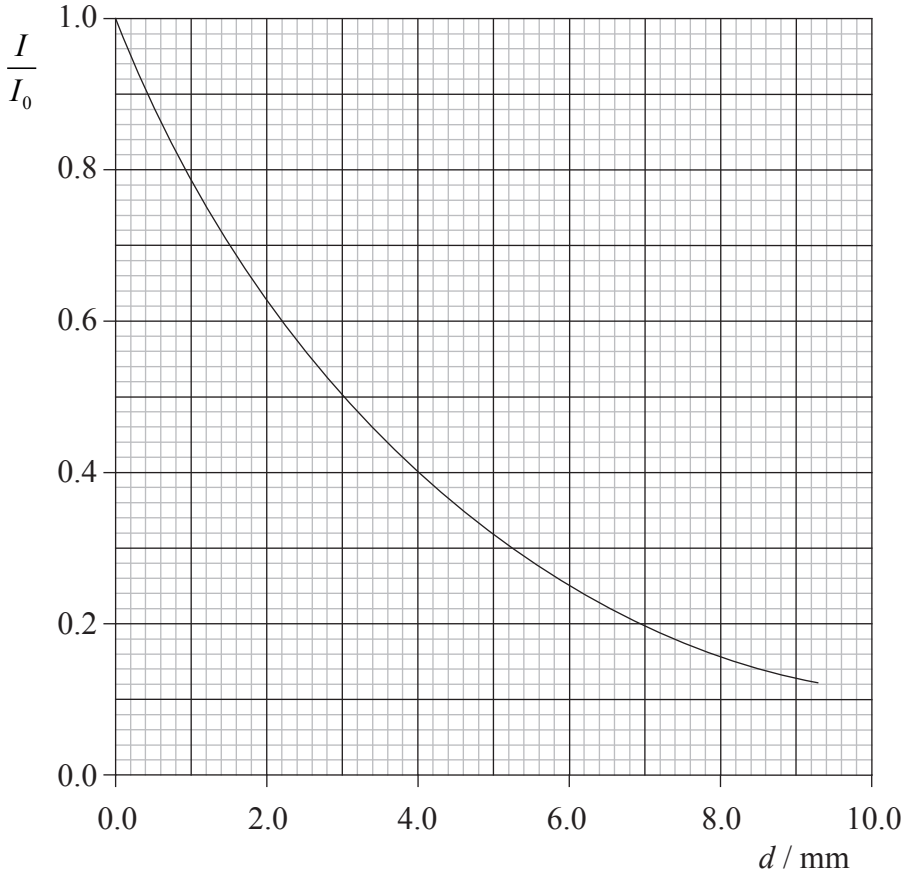
D3. This question is about X-ray absorption.

The diagram below shows a parallel beam of X-rays incident on a section of bone of thickness d.



The incident intensity is I_0 and the transmitted intensity is I. The graph below shows the variation with bone thickness d of the ratio $\frac{I}{I_0}$. The incident intensity I_0 is constant.



(This question continues on the following page)

(Question D3 continued)

(a) (i) Estimate the half-value thickness of the bone. *[1]*

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(ii) Use your answer in (i) to calculate the attenuation coefficient of X-rays of this sample of bone. *[2]*

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(b) For X-rays of different frequency, the fraction $\frac{I}{I_0}$ for a given thickness of bone is greater than shown on the graph. Explain the effect of this change on the attenuation coefficient and on the half-value thickness calculated in (a). *[3]*

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(c) Explain by reference to attenuation coefficients why barium meals may be used to assist in the X-ray imaging of the stomach. *[4]*

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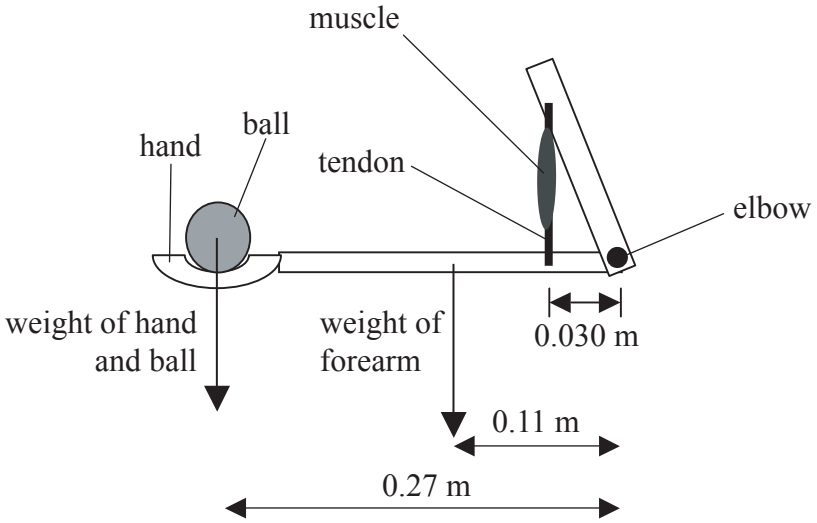
D4. This question is about biomechanics.

The diagram below illustrates a child's forearm and hand including some of the bones and one tendon and muscle. The child is holding a ball whilst keeping the forearm horizontal.



The forearm is pivoted at the elbow.

(a) Explain why this system acts with a mechanical advantage of less than one. *[3]*

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(b) Explain the benefit of having a small mechanical advantage for the arm-hand system. *[2]*

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D5. This question is about the effects of ionizing radiation on the body.

(a) The term "absorbed dose" is used in radiation dosimetry.

State **three** factors that affect the absorbed dose. *[3]*

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2. . . . . .

3. . . . . .

(b) State and explain **two** possible precautions that can be taken to reduce the exposure of a radiation worker given that the time of exposure cannot be changed. *[2]*

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Option E — The History and Development of Physics

E1. This question is about orbital motion.

(a) State **two** differences between the Copernican model of the solar system and that of Kepler. *[2]*

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(b) Discuss the contribution of Newton to the explanation of Kepler's laws. *[3]*

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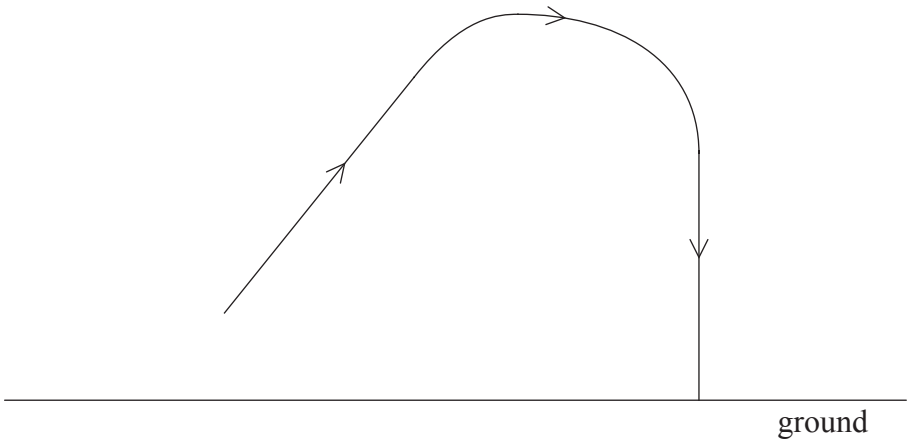
E2. This question is about Aristotelian view of motion.

Aristotle considered that a ball thrown into the air followed the path shown below.



Use the Aristotelian view of motion to explain the shape of this path. *[4]*

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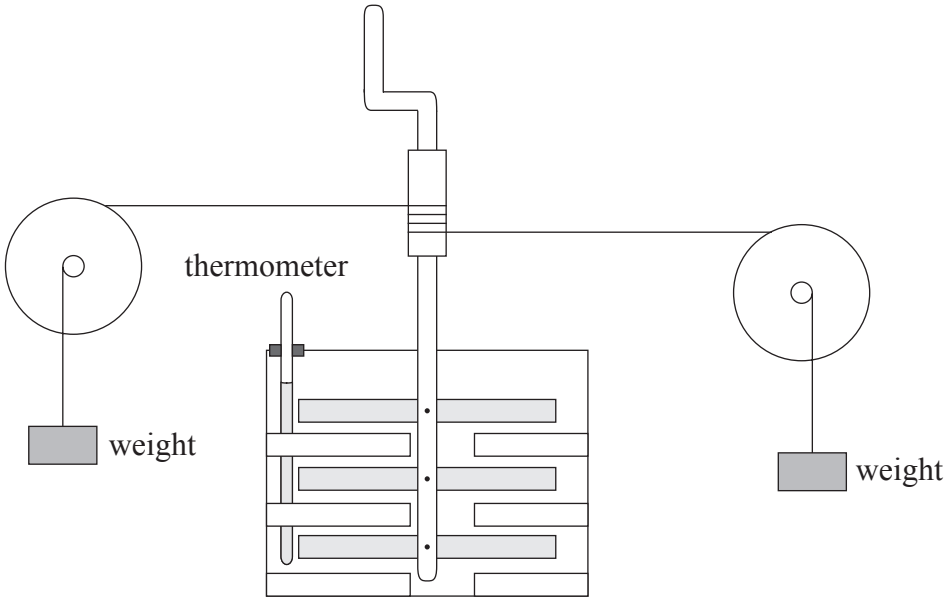
E3. This question is about Joule's experiment.

In 1843, Joule began a series of experiments involving the agitation of water by a rotating paddle. A diagram of his apparatus is shown below.



(a) State the aim of Joule's experiment. *[1]*

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(b) Outline the experimental procedure and the measurements taken. *[5]*

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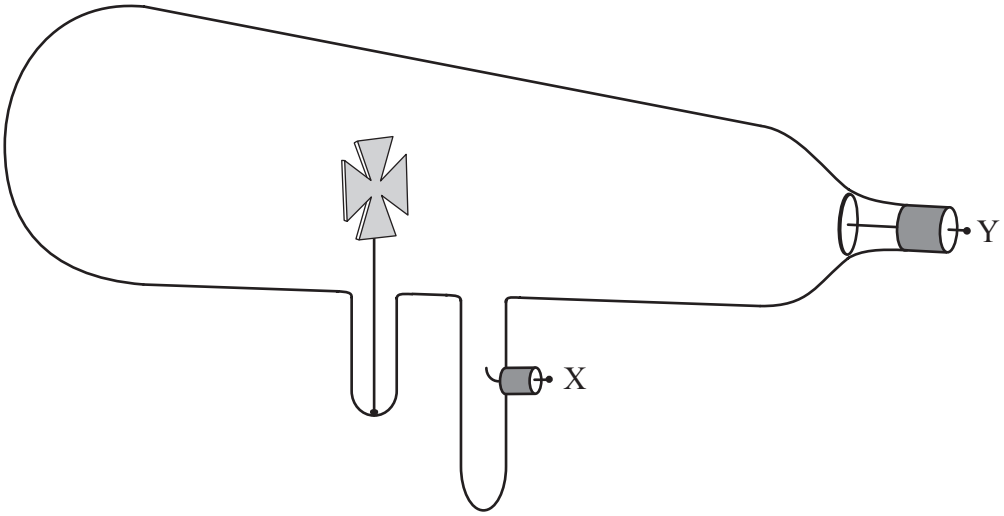
E4. This question is about cathode rays.

To study the nature of cathode rays, Crookes used a vacuum tube as shown in the diagram below.



(a) State what was seen when

(i) a high voltage was applied between X and Y to produce cathode rays. *[2]*

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(ii) subsequently a magnet was moved close to the tube. *[1]*

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(b) Some physicists thought that the rays produced could be a form of light. Comment on this suggestion. *[2]*

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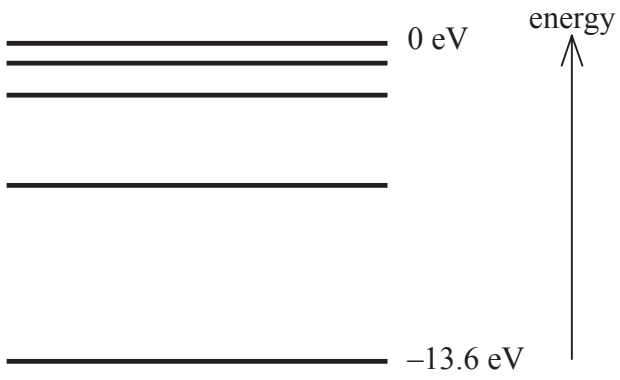
E5. This question is about the Rydberg formula and atomic models.

The diagram represents the four lowest electron energy levels in the hydrogen atom and also shows the position of 0 eV. Transitions between these energy levels correspond to part of one of the spectral series used by Rydberg in developing his formula.



(a) Draw an arrow on the diagram to represent the transition that corresponds to values in the Rydberg formula of $m = 2$ and $n = 4$. *[2]*

(b) This transition corresponds to a spectral line that has a frequency of 6.18×10^{14} Hz. Determine a value for the Rydberg constant. *[3]*

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(c) State **two** limitations of the Bohr model. *[2]*

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(This question continues on the following page)

(Question E5 continued)

(d) Outline **three** features of the Schrödinger model. *[3]*

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Option F — Astrophysics

F1. This question is about stars.

(a) Stars are very massive. State why stable stars are not crushed inwards under gravitational pressure. *[2]*

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(b) State the difference between a visual binary star and a spectroscopic binary star. *[2]*

Visual binary: . . . . . .

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Spectroscopic binary: . . . . . .

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F2. This question is about the star Antares.

The following are some data concerning the star Antares. The parallax angle is measured from an ideal position where no atmospheric turbulence affects measurements.

Spectral class	M
Parallax angle	5.0×10^{-3} arcsecond
Apparent brightness	1.6×10^{-8} Wm^{-2}
Wavelength of the maximum intensity of light emitted λ_{max}	935 nm

(a) State the colour of Antares. *[1]*

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(This question continues on the following page)

(Question F2 continued)

(b) Deduce that the distance of Antares from Earth is 6.2×10^{18} m. *[2]*

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(c) Calculate

(i) the luminosity of Antares. *[3]*

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(ii) the surface temperature of Antares. *[2]*

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(d) The radius R of the Sun is 7.0×10^{8} m. Use your answers in (c) to deduce that the radius of Antares is about 500 R. *[3]*

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F3. This question is about Olbers' paradox.

(a) Newton proposed a model of the universe that is infinite in extent and in which the stars are uniformly distributed. Olbers suggested that, if this model were correct, then the sky would never be dark. Explain how Olbers reached this conclusion. *[3]*

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(b) Suggest **two** reasons how the Big Bang model of the universe accounts for the night sky being dark. *[2]*

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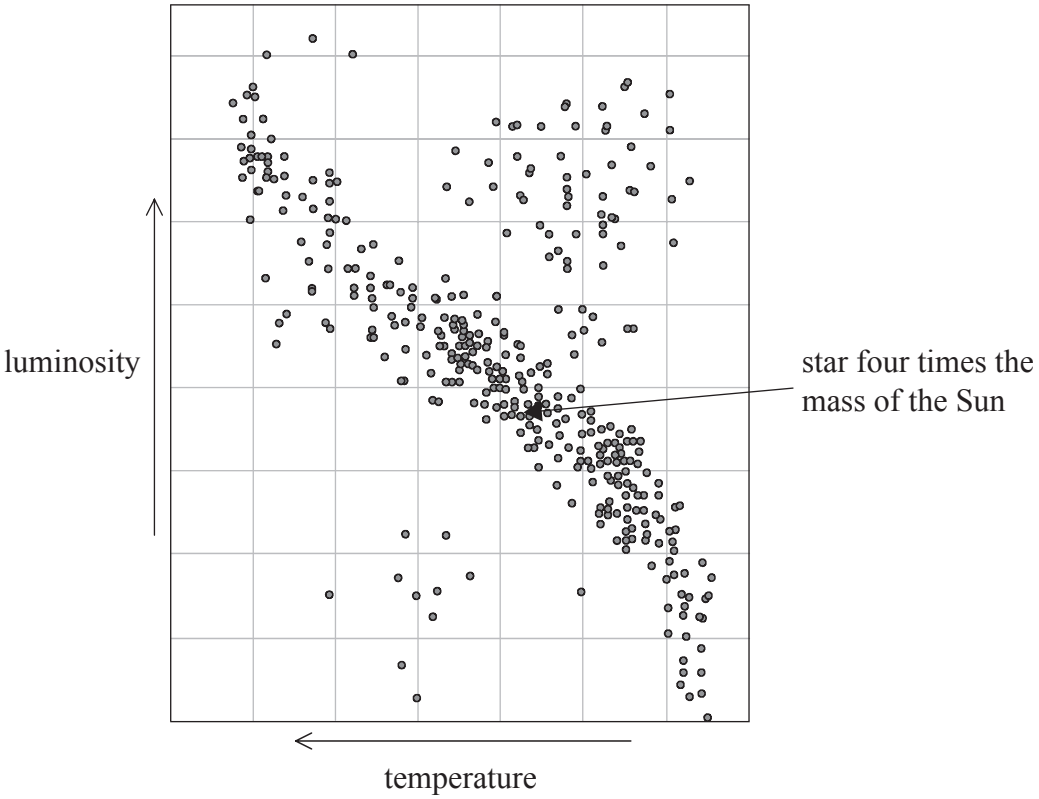
F4. This question is about star evolution.

The Hertzsprung-Russell diagram below shows the position of a star on the main sequence. The star has four times the mass of the Sun.



(a) (i) On the Hertzsprung-Russell diagram, draw the evolutionary path followed by this star as it leaves the main sequence. *[2]*

(ii) State the name of the object into which the star finally develops. *[1]*

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(b) The star will eventually fuse most of its hydrogen.

State

(i) the subsequent fusion process that occurs. *[1]*

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(ii) the final fusion product that will occur in this star. *[1]*

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F5. This question is about Hubble's law.

(a) Hubble's law may be expressed as $v = H_0 d$. Explain what is meant by the symbol v. *[2]*

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(b) Determine the age of the universe assuming a value for the Hubble constant of $65\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$. *[3]*

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Option G — Relativity

G1. This question is about proper time.

A muon at the top of the atmosphere is moving toward the ground with speed v. In the frame of reference of a person at rest with respect to the ground, the muon takes a time T_g to reach the ground. In the frame of reference of the muon, the ground takes a time T_m to reach the muon.

(a) Explain why the *proper time* is measured by a clock in the muon frame of reference. *[2]*

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(b) The time T_g was measured to be 10.2 μs. The speed v is 0.98 c. Calculate T_m. *[2]*

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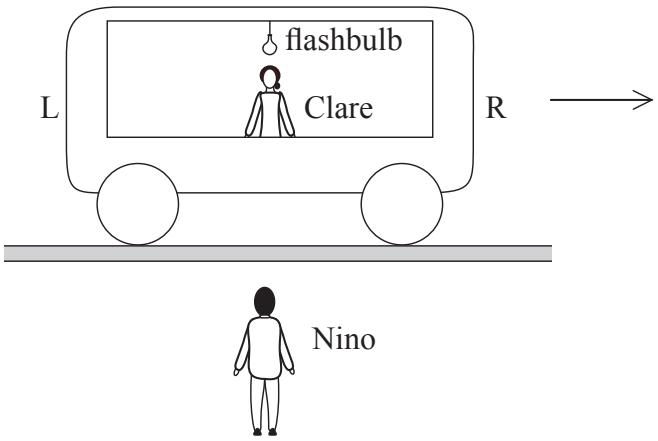
G2. This question is about simultaneity.

The diagram below shows a railway carriage travelling to the right at constant velocity. A flashbulb is hanging from a point midway between the ends L and R of the carriage. Each flash produces single pulses sent in opposite directions.



Clare is at rest at the centre of the carriage. Light pulses from the flashbulb are observed by Clare to strike the opposite walls L and R of the carriage simultaneously. Nino is at rest on the ground. He is opposite Clare at the moment when the bulb flashes.

State and explain whether Nino observes the pulses striking L and R simultaneously. *[3]*

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G3. This question is about relative velocities.

(a) Describe what is meant by a *Galilean transformation*. *[1]*

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(b) Two electrons travel along the same straight line towards each other. The speed of each electron with respect to an observer in the laboratory frame of reference is 0.9800 *c*.

Calculate the relative speed of the electrons using

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

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(ii) the relativistic transformation equation. *[2]*

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(c) Comment on your answers in (b). *[2]*

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G4. This question is about mass-energy.

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

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(b) The rest mass of a proton is 938 MeV c^{-2}. State the value of its rest mass-energy. *[1]*

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(c) A proton is accelerated from rest through a potential difference V until it reaches a speed of 0.980 c. Determine the potential difference V as measured by an observer at rest in the laboratory frame of reference. *[4]*

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G5. This question is about space-time, gravitational lensing and black holes.

(a) State **two** conditions for the path of a particle to be represented as a straight-line on a space-time diagram. *[2]*

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2. . . . . .

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(b) (i) Explain, with the aid of a diagram, what is meant by *gravitational lensing*. *[3]*

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(ii) Outline **one** piece of experimental evidence for gravitational lensing. *[3]*

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(This question continues on the following page)

(Question G5 continued)

(c) Suggest **two** reasons why the planet Jupiter cannot become a black hole. *[2]*

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Option H — Optics

H1. This question is about the nature of light.

(a) State the means by which the energy of an oscillating electric charge is propagated. *[1]*

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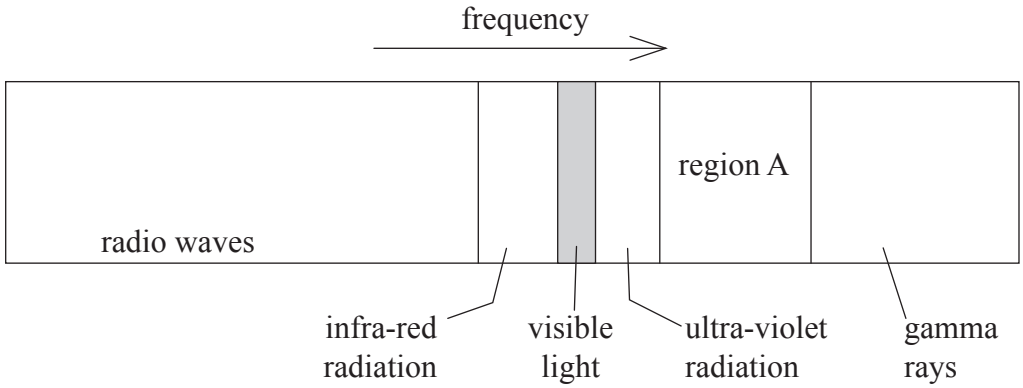
(b) The diagram below represents the electromagnetic spectrum.



State

(i) the name of the region A. *[1]*

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(ii) the order of magnitude of the frequency of visible light. *[1]*

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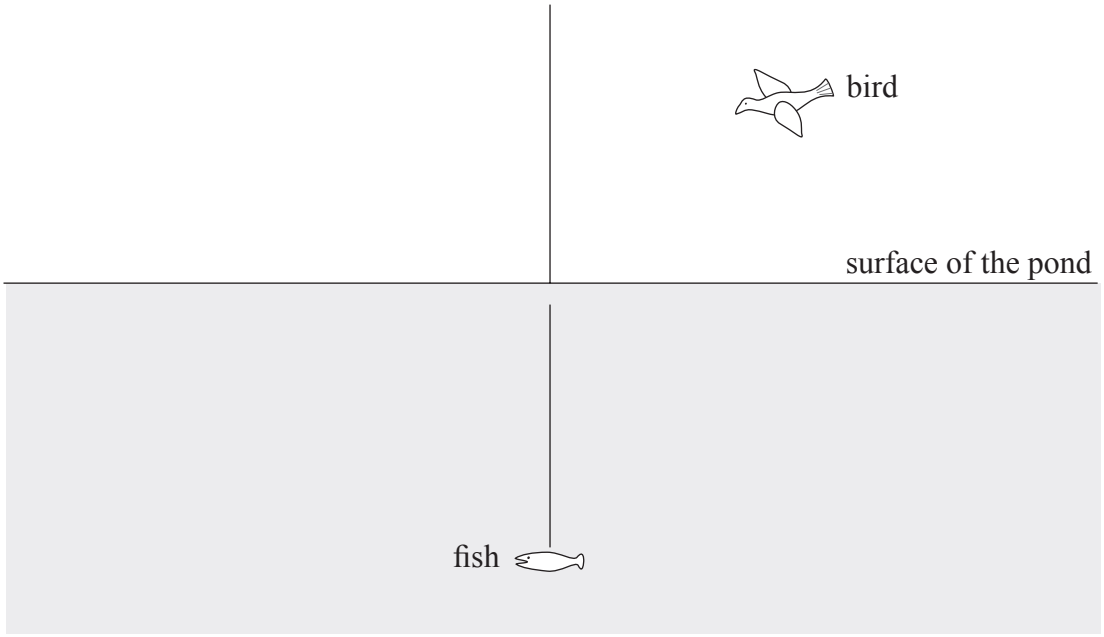
H2. This question is about refraction.

A bird is hovering above a pond. A fish is in the pond at the position shown in the diagram below.



(a) Draw rays on the diagram above to locate the position of the image of the fish as seen by the bird. *[3]*

(b) Explain whether the image of the fish is real or virtual. *[1]*

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(c) The fish is 48 cm below the surface of the pond. The bird hovers vertically above the fish. Calculate the apparent depth of the fish. The refractive index of water is 1.3. *[2]*

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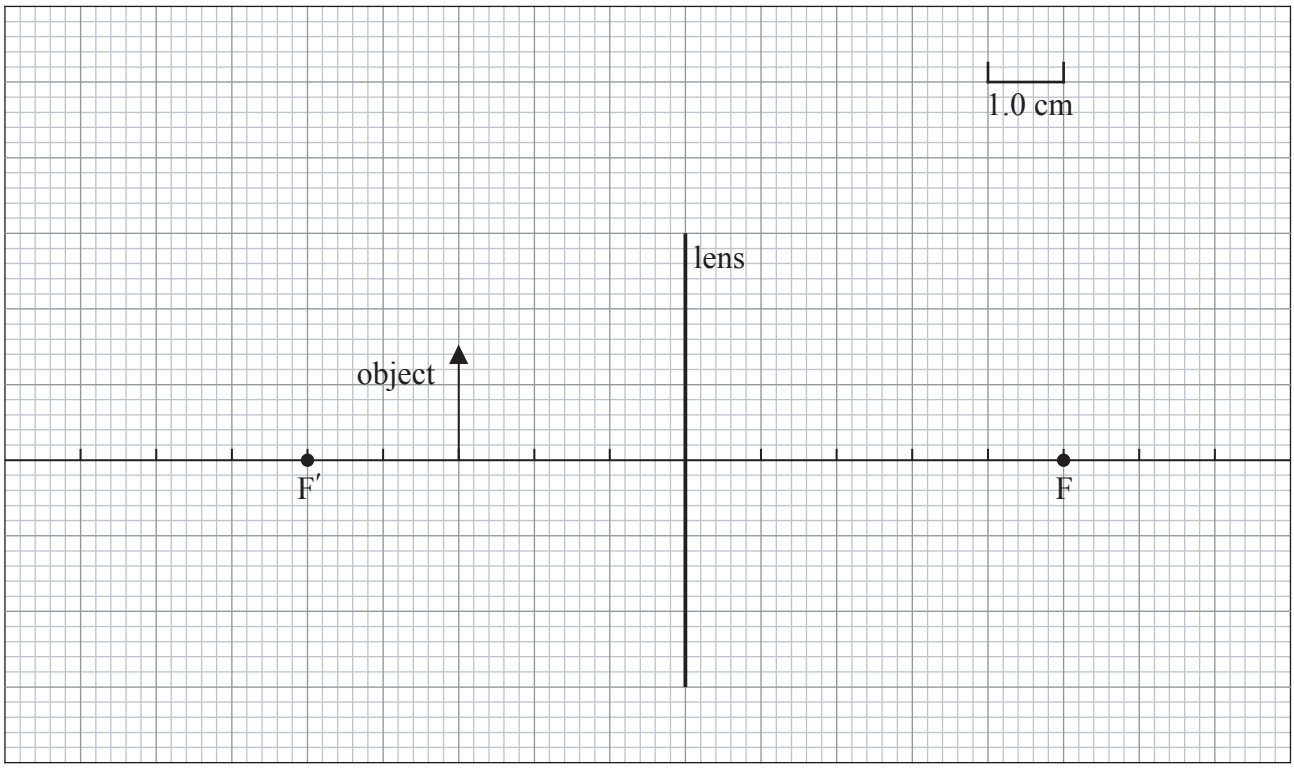
H3. This question is about magnification.

An object is placed 3.0 cm from a converging (convex) lens of focal length 5.0 cm.

(a) On the diagram below, draw rays to locate the position of the image produced by the lens. *[3]*



(b) On the diagram above, mark with the letter E, the position from which the image should be viewed. *[1]*

(c) Use your ray diagram above to calculate the magnification of the image. *[2]*

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(This question continues on the following page)

(Question H3 continued)

(d) For high magnification, a compound microscope may be used. This microscope consists of an objective lens and an eyepiece lens.

(i) State the type of lens used as **both** the objective lens and the eyepiece lens. *[1]*

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(ii) The magnification produced by the objective lens is 24. The image of the object produced by this lens is formed 3.4 cm from the eyepiece lens of focal length 4.0 cm. Determine the magnification of the final image produced by the microscope. *[4]*

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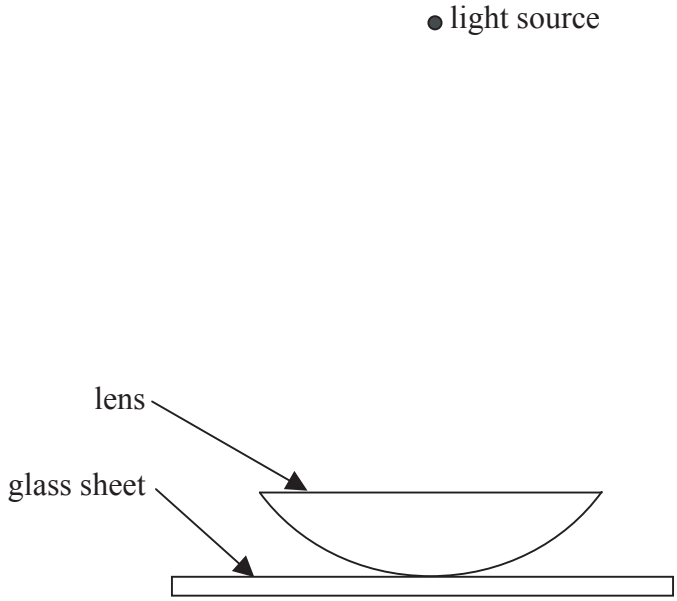
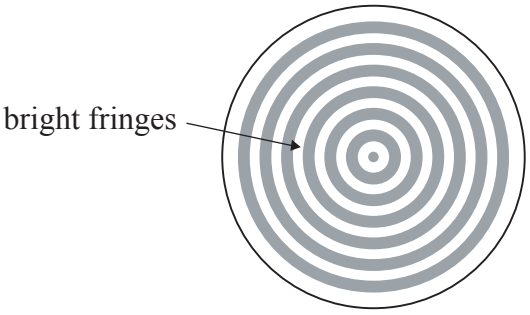
H4. This question is about a wedge film.

A lensmaker will sometimes check the shape of a lens surface by resting the lens on a flat sheet of glass and then viewing the arrangement in monochromatic light at near-normal incidence, as shown in the diagram below.



This produces a circular interference pattern with a dark centre, as shown below.



Explain how **one** of the bright fringes arises. You may draw on the diagram if you wish. *[4]*

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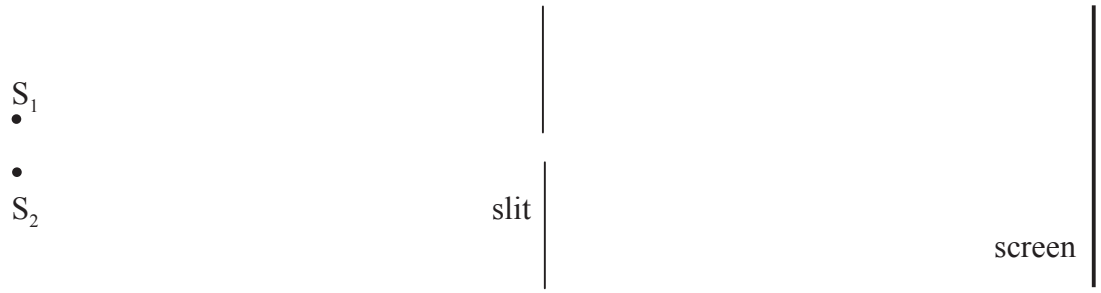
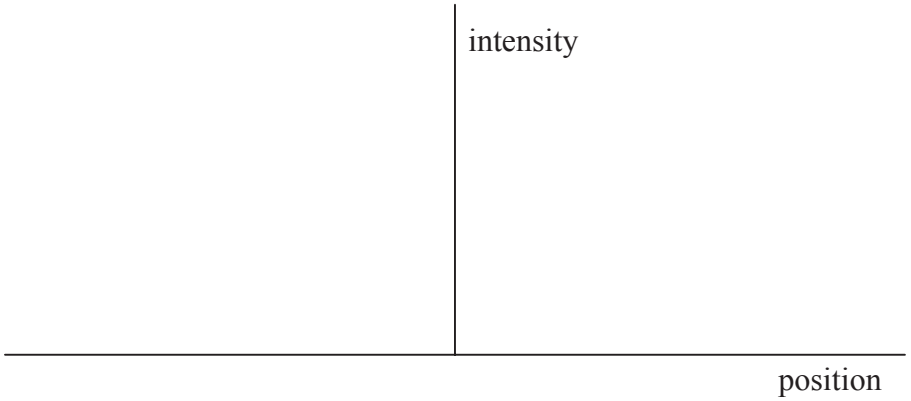
H5. This question is about the Rayleigh criterion.

(a) Light from two monochromatic distant point sources, S_1 and S_2, is incident on a narrow slit. After passing through the slit, the light is incident on a screen.



On the axes below, draw the intensity distribution of the diffracted light on the screen from each source when the images of S_1 and S_2 are just resolved according to the Rayleigh criterion. *[3]*



(b) A woman views an approaching car at night. The apertures of her eyes are each of diameter 3.0 mm. The headlamps of the car are separated by a distance of 1.2 m and emit light of wavelength 400 nm.

Calculate the distance of the car from the woman at which the images of the two headlamps are just resolved. *[3]*

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