IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M06/4/PHYSI/SP3/ENG/TZ2/XX+

22066518

PHYSICS
STANDARD LEVEL
PAPER 3

Wednesday 10 May 2006 (morning)

1 hour

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

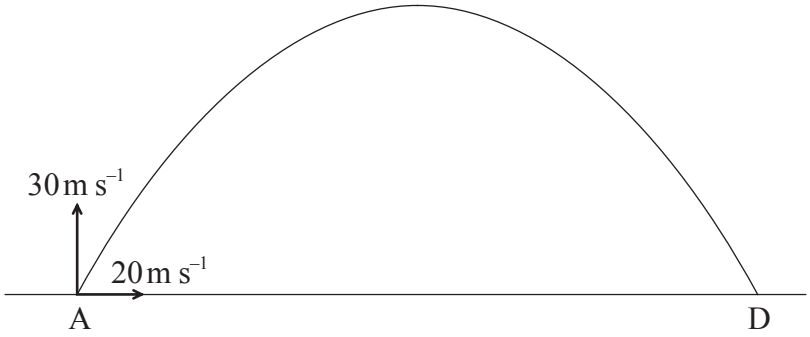
- Write your session number code in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your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

0133

Option A — Mechanics Extension

A1. This question is about the trajectory of a golf ball.

A golfer hits a golf ball at point A on a golf course. The ball lands at point D as shown on the diagram. Points A and D are on the same horizontal level.



The initial horizontal component of the velocity of the ball is 20 m s^{-1} and the initial vertical component is 30 m s^{-1}. The time of flight of the golf ball between point A and point D is 6.0 s. Air resistance is negligible and the acceleration of free fall g = 10 m s^{-2}.

Calculate

(a) the maximum height reached by the golf ball. *[3]*

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(b) the range of the golf ball. *[2]*

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A2. This question is about a spacecraft.

A spacecraft above Earth's atmosphere is moving away from the Earth. The diagram below shows two positions of the spacecraft. Position A and position B are well above Earth's atmosphere.

At position A, the rocket engine is switched off and the spacecraft begins coasting freely. At position A, the speed of the spacecraft is $5.37 \times 10^3\,\text{m s}^{-1}$ and at position B, $5.10 \times 10^3\,\text{m s}^{-1}$. The time to travel from position A to position B is 6.00×10^2 s.

(a) (i) Explain why the speed is changing between positions A and B. *[1]*

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(ii) Calculate the average acceleration of the spacecraft between positions A and B. *[2]*

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(iii) Estimate the average gravitational field strength between positions A and B. Explain your working. *[3]*

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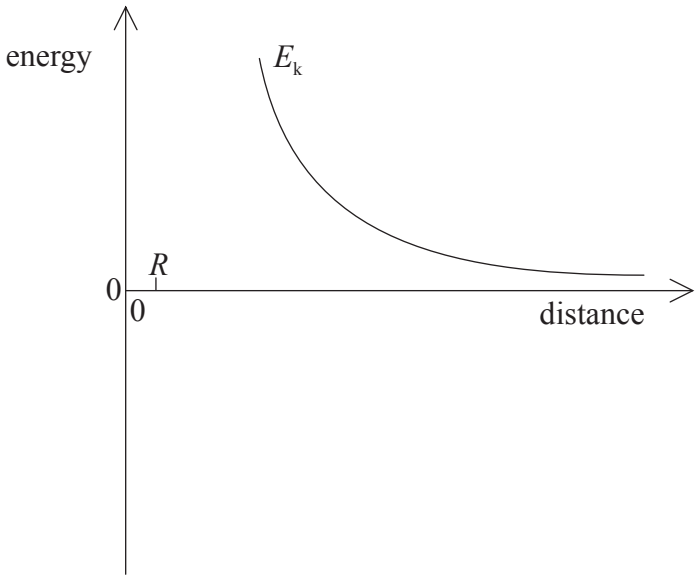
(This question continues on the following page)

(Question A2 continued)

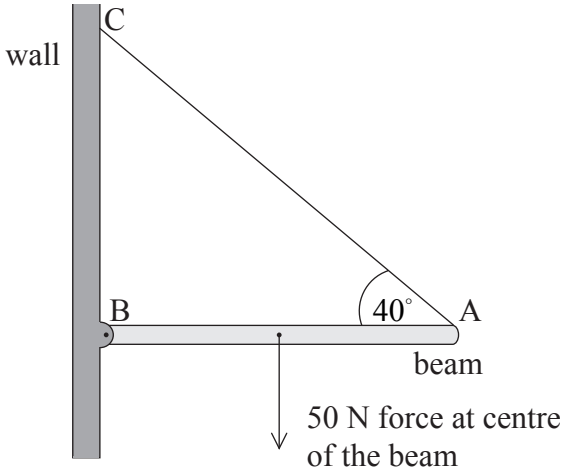
(b) The diagram below shows the variation with distance from Earth of the kinetic energy E_k of the spacecraft. The radius of Earth is R.



On the diagram above, draw the variation with distance from the surface of Earth of the gravitational potential energy E_p of the spacecraft. *[2]*

A3. This question is about equilibrium.

The diagram below shows a uniform beam of weight 50 N. The beam is attached to a wall at B by a hinge. The beam is held horizontally by a wire attached to the end A of the beam and the wall at C. The angle between the wire and the beam is 40°.



(a) On the diagram above, draw an arrow to represent the force *R* acting on the beam at the hinge. *[2]*

(b) The tension in the wire is 39 N. Determine the magnitude and direction of the force *R*. *[5]*

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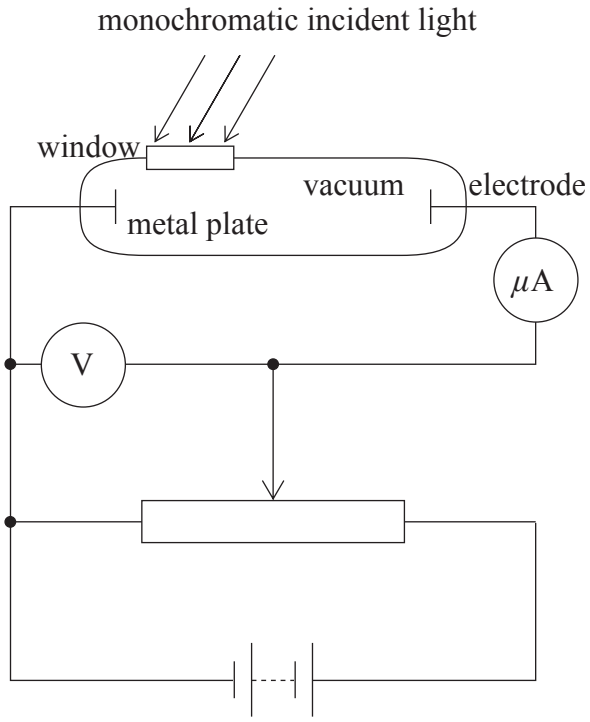
Option B — Quantum Physics and Nuclear Physics

B1. This question is about the photoelectric effect.

The apparatus shown below may be used to investigate the photoelectric effect.

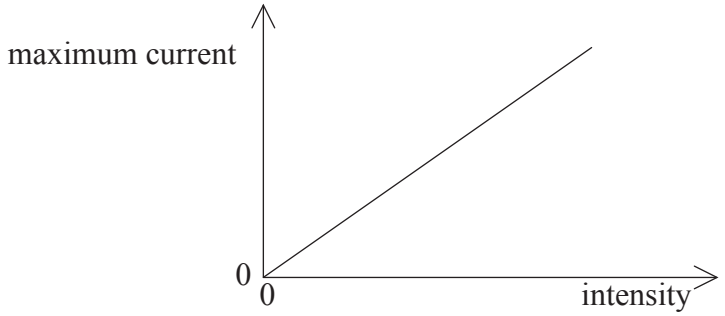


The potential difference V applied between the metal plate and electrode may be varied in magnitude and in direction. This is repeated for different values of intensity for the same frequency of light.

(This question continues on the following page)

(Question B1 continued)

(a) Monochromatic light is incident on the metal plate. The potential difference between the plate and the electrode is adjusted so that the reading on the microammeter is a maximum. The graph below shows the variation with intensity of the monochromatic light of the maximum current.



Explain the features of this graph. *[4]*

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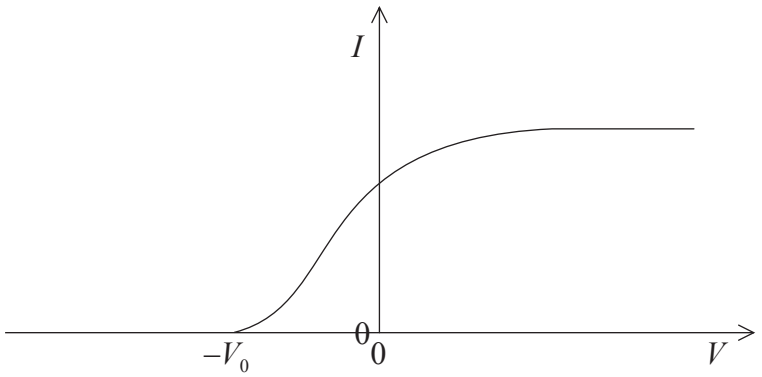
(b) The frequency and the intensity of the light are held constant. The graph below shows the variation with the potential difference V of the current I measured on the microammeter.



The frequency of the light is doubled at a constant intensity. On the graph above, draw a second line to show the variation with potential difference of the current in the microammeter. *[3]*

B2. This question is about atomic spectra.

An electron undergoes a transition from an atomic energy level of 3.20×10^{-15} J to an energy level of 0.32×10^{-15} J. Determine the wavelength of the emitted photon. *[3]*

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B3. This question is about radioactivity.

(a) A sample of radioactive material is found by chemical analysis to contain 8.90×10^{19} atoms of uranium-235. The activity of the sample is 4.25×10^{2} Bq.

Calculate, for the uranium-235

(i) the decay constant. *[2]*

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(ii) the half-life in years. *[2]*

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(b) An isotope has a half-life of approximately four hours. Suggest why measurement of the number of atoms and the activity of a sample of this isotope cannot be used to determine its half-life. *[1]*

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B4. This question is about α-particle scattering.

In 1913, Geiger and Marsden carried out an experiment in which α-particles were fired at a piece of gold foil. The diagram below shows two such α-particles A and B moving toward a gold nucleus in the directions shown.

(a) On the diagram above, draw possible paths followed by A and B. *[2]*

(b) Explain how a knowledge of the initial KE of α-particles such as A enables an upper limit for the diameter of a nucleus to be estimated. *[3]*

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Option C — Energy Extension

C1. This question is about thermodynamic processes.

(a) State what is meant by the concept of *internal energy* of an ideal gas. *[1]*

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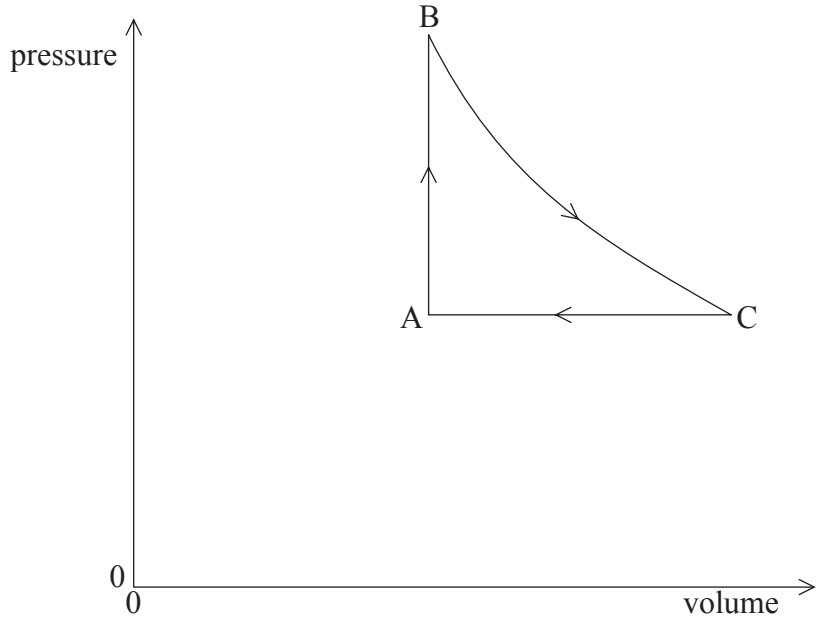
(b) The diagram below shows the variation with volume of the pressure of a fixed mass of an ideal gas.



The change from B to C is an isothermal change at 546 K. At point A, the pressure of the gas is 1.01×10^5 Pa, the volume of the gas is 22.0 m^3 and the temperature of the gas is 273 K.

(i) State the temperature of the gas at point C. *[1]*

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(ii) Calculate the volume of the gas at point C. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(c) For the change from B to C, 31.5×10^5 J of thermal energy is transferred to the gas.

(i) State the work done in the change from A to B. *[1]*

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(ii) Determine the work done during the change C to A. *[2]*

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(iii) Explain whether the work in (ii) is done **by** the gas or **on** the gas. *[2]*

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(iv) Determine the work done by the gas during one cycle ABCA. *[2]*

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C2. This question is about wind power.

The maximum theoretical wind power P for air of speed v moving normally through area A where ρ is the density of air is given by

$$P = \frac{\rho A v^3}{2}.$$

(a) (i) Air of density $1.3\,\text{kg m}^{-3}$ and speed of $9.0\,\text{m s}^{-1}$ is incident on a wind turbine having blades of diameter 15 m. Calculate the maximum wind power incident on the turbine. *[2]*

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(ii) State why it is impossible in practice to extract all of the power P in (i) from the air. *[1]*

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(iii) State **two** reasons why wind turbines are not placed close to one another. *[2]*

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2. . . . . .

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(b) A nuclear power station has an output power of 200 MW. It is proposed to replace the power station with a series of wind turbines each with an energy output of 750 kW. State and discuss **one** advantage and **one** disadvantage such a change might bring if this proposal was to take place. *[4]*

Advantage: . . . . . .

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Disadvantage: . . . . . .

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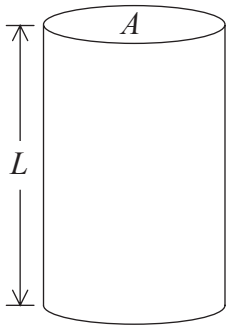
Option D — Biomedical Physics

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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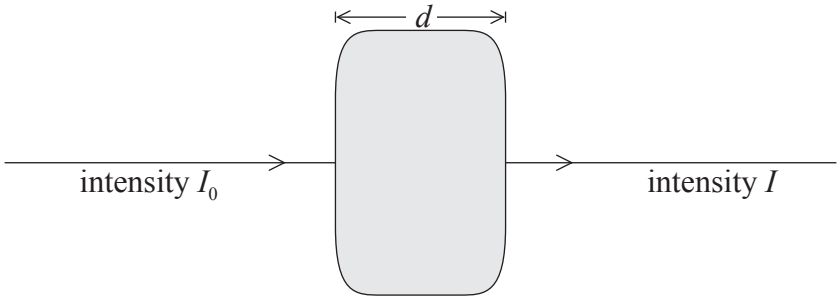
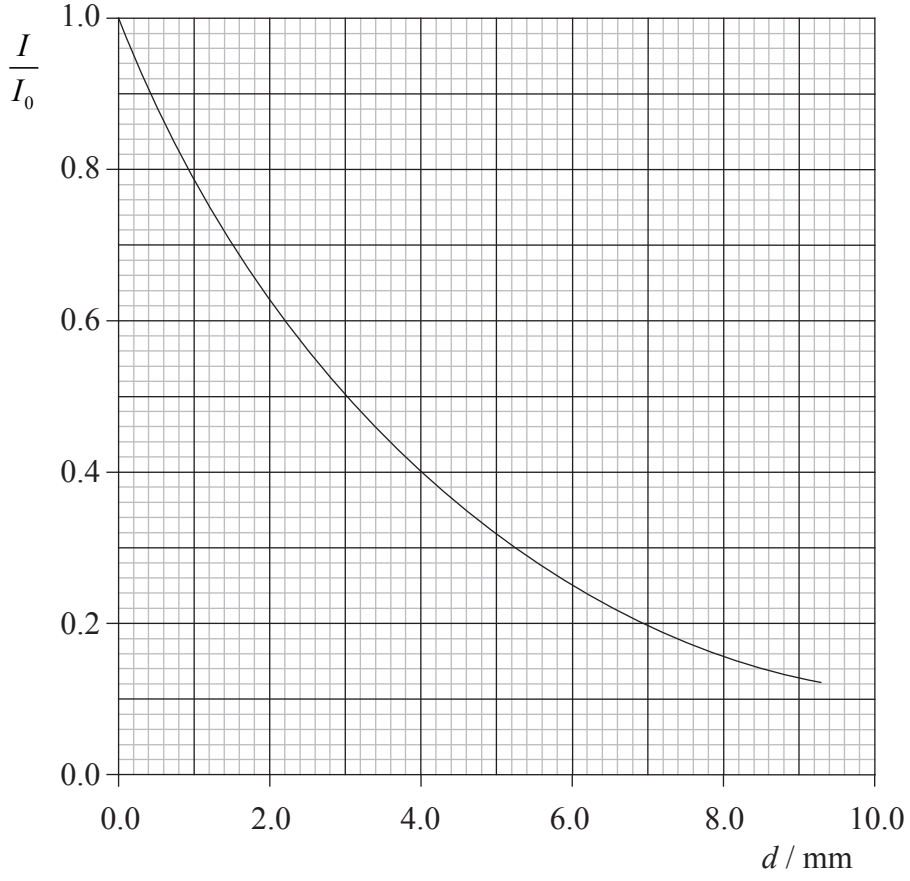
D3. This question is about X-ray absorption.

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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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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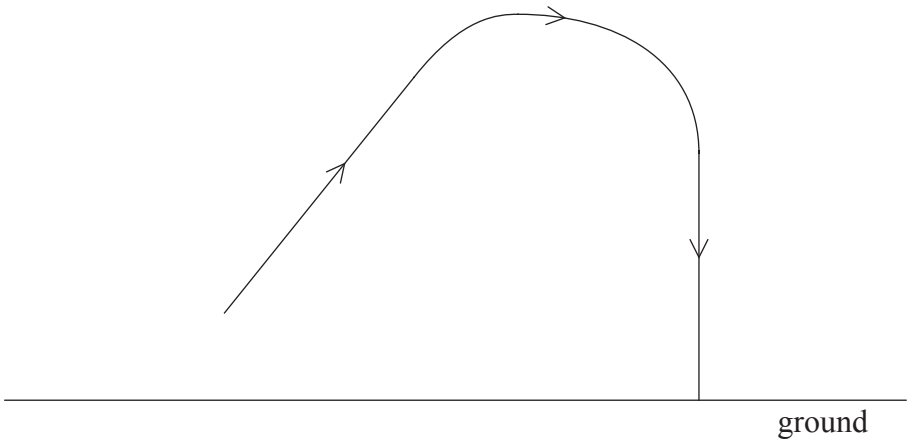
E2. This question is about Aristotelian view of motion.

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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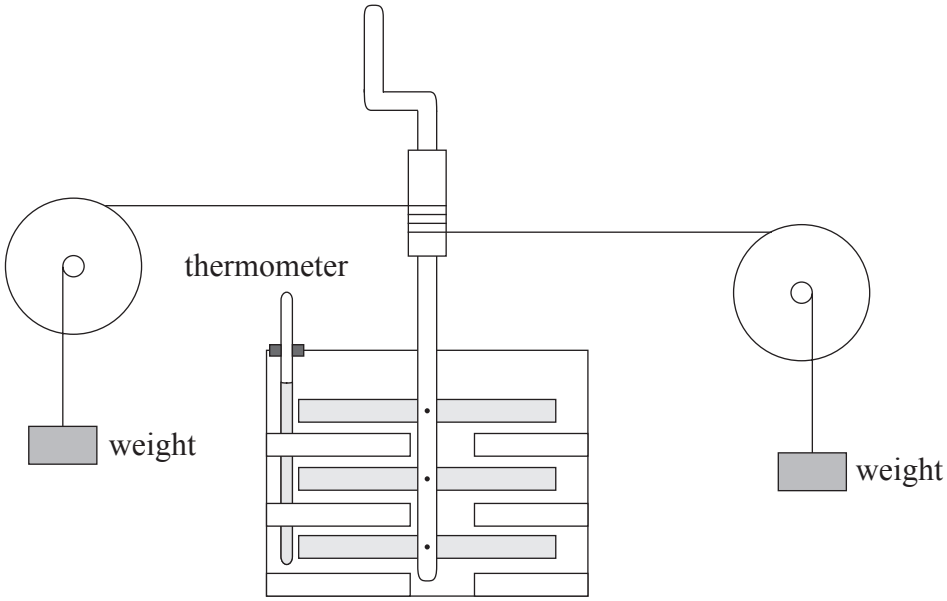
E3. This question is about Joule's experiment.

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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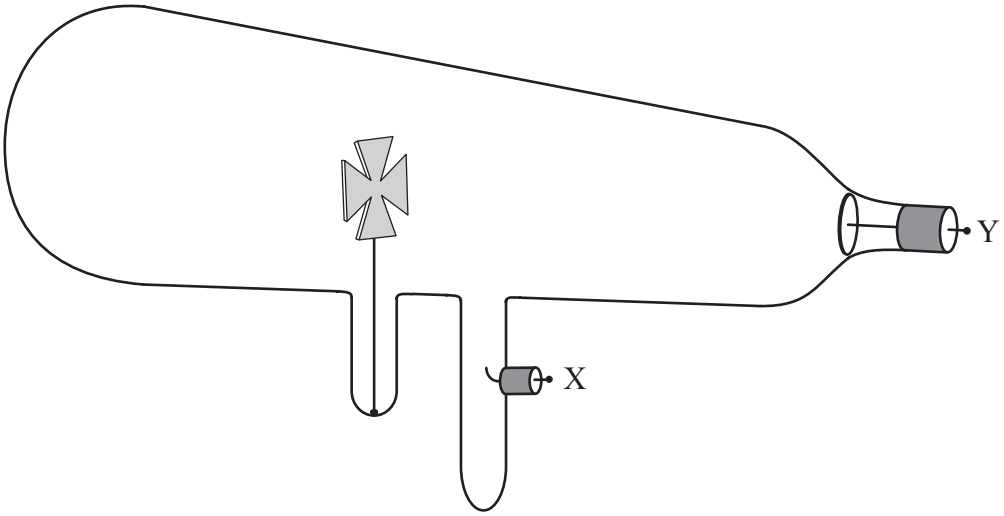
E4. This question is about cathode rays.

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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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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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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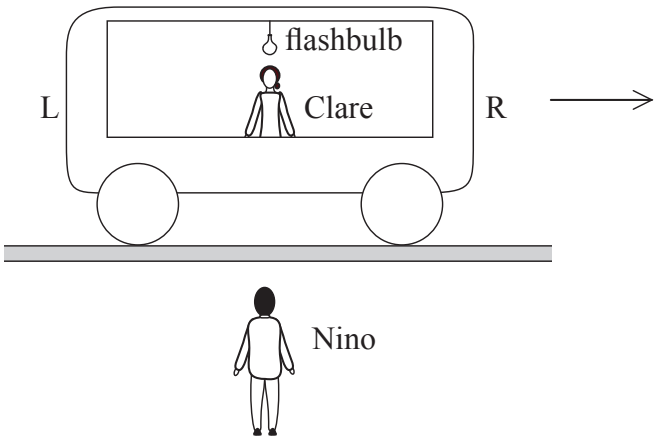
G2. This question is about simultaneity.

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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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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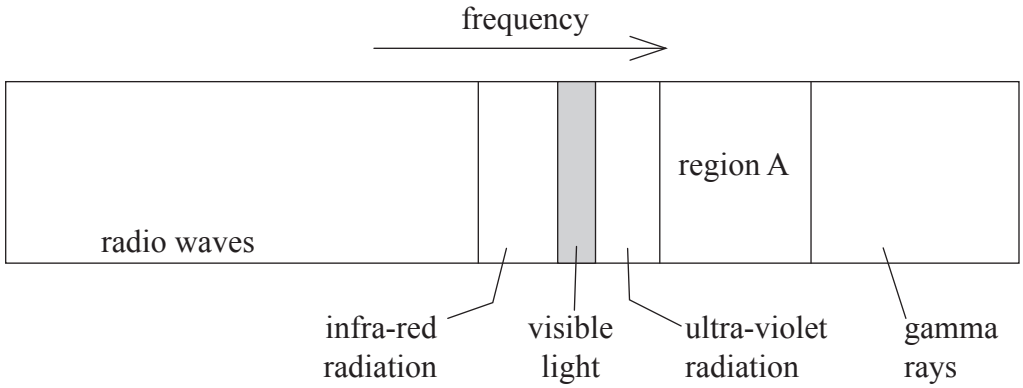
(b) The diagram below represents the electromagnetic spectrum.



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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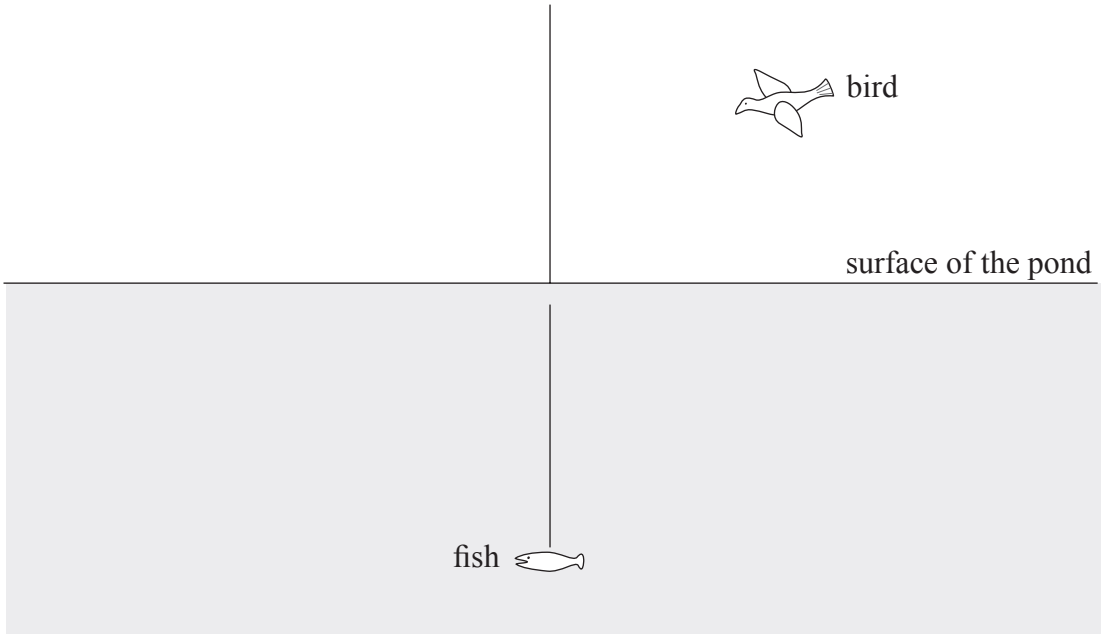
H2. This question is about refraction.

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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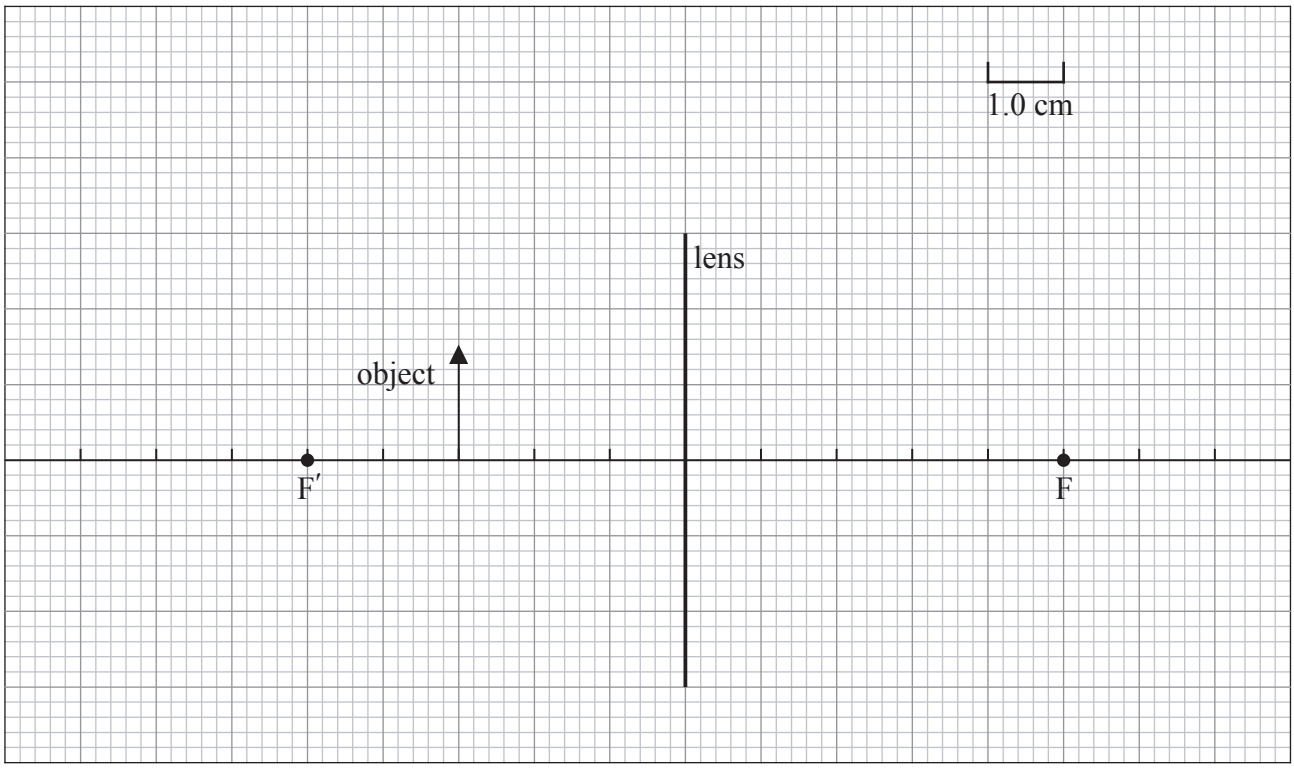
H3. This question is about magnification.

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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