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

N05/4/PHYSI/SP3/ENG/TZ0/XX+

88056506

PHYSICS
STANDARD LEVEL
PAPER 3

Friday 18 November 2005 (morning)

1 hour

Candidate session number

0	0							

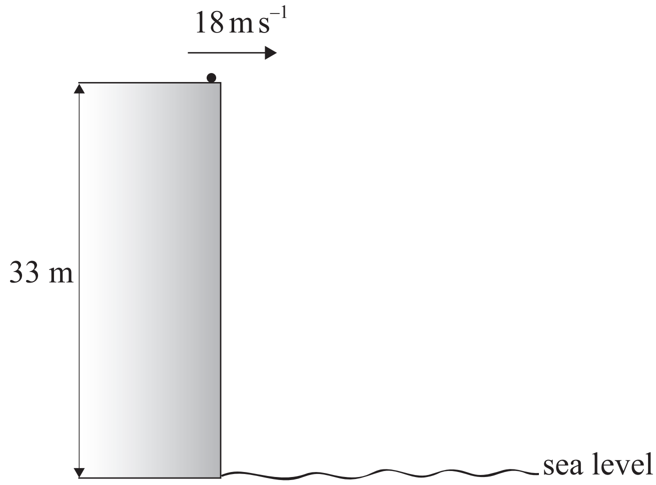
INSTRUCTIONS TO CANDIDATES

- 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.

Option A — Mechanics Extension

A1. This question is about projectile motion.

A stone is thrown horizontally from the top of a vertical cliff of height 33 m as shown below.



The initial horizontal velocity of the stone is $18\,\mathrm{m\,s^{-1}}$ and air resistance may be assumed to be negligible.

(a) State values for the horizontal and for the vertical acceleration of the stone. *[2]*

Horizontal acceleration: . . . .

Vertical acceleration: . . . .

(b) Determine the time taken for the stone to reach sea level. *[2]*

. . . .

. . . .

. . . .

(c) Calculate the distance of the stone from the base of the cliff when it reaches sea level. *[1]*

. . . .

. . . .

A2. This question is about gravitation.

(a) (i) Define *gravitational potential* at a point in a gravitational field. *[2]*

. . . .

. . . .

. . . .

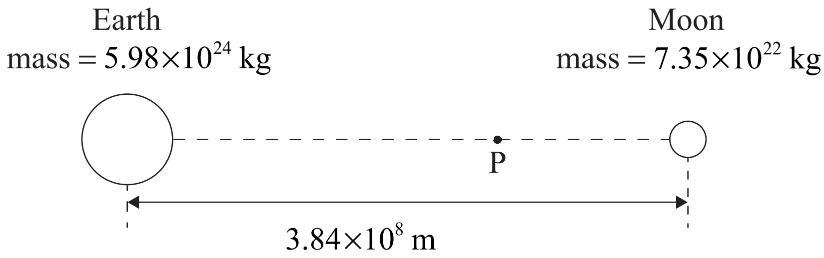
(ii) Explain why values of gravitational potential have negative values. *[2]*

. . . .

. . . .

. . . .

The Earth and the Moon may be considered to be two isolated point masses. The masses of the Earth and the Moon are 5.98×10^{24} kg and 7.35×10^{22} kg respectively and their separation is 3.84×10^{8} m, as shown below. The diagram is not to scale.



(b) (i) Deduce that, at point P, 3.46×10^{8} m from Earth, the gravitational field strength is approximately zero. *[3]*

. . . .

. . . .

. . . .

. . . .

(ii) The gravitational potential at P is $-1.28\times10^{6}\ \text{J kg}^{-1}$. Calculate the minimum speed of a space probe at P so that it can escape from the attraction of the Earth and the Moon. *[3]*

. . . .

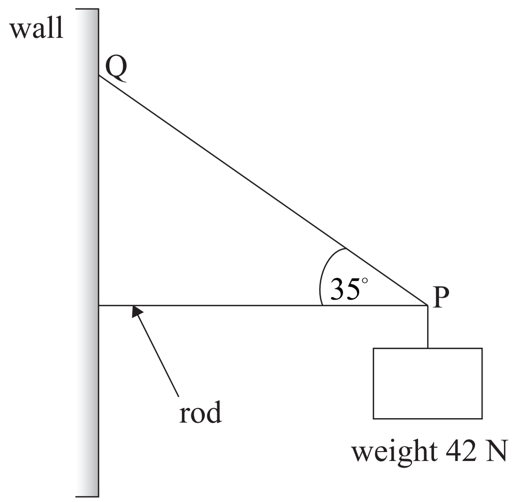
. . . .

. . . .

. . . .

A3. This question is about forces in equilibrium.

A weight of 42 N is held away from a wall by means of a rigid horizontal rod and a rope. The rope is fixed to the wall at point Q and to the end of the rod at point P as shown below.



The rope makes an angle of 35° with the rod. The rod has negligible weight.

(a) On the diagram, draw arrows to represent the direction of each of the forces acting at point P. *[2]*

(b) Determine the magnitude of the force in the rod at point P. *[3]*

. . . .

. . . .

. . . .

. . . .

Blank page

Option B — Quantum Physics and Nuclear Physics

B1. This question is about wave-particle duality.

(a) Describe the de Broglie hypothesis. *[2]*

. . . .

. . . .

. . . .

(b) An electron is accelerated from rest through a potential difference of 1250 V. Determine the associated de Broglie wavelength of the accelerated electron. *[4]*

. . . .

. . . .

. . . .

. . . .

. . . .

B2. This question is about line spectra.

(a) Light is emitted from a gas discharge tube. Outline briefly how the visible line spectrum of this light may be obtained. *[2]*

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B2 continued)

The table below gives information relating to three of the wavelengths in the line spectrum of atomic hydrogen.

Wavelength / $\times10^{-9}$ m	**Photon energy / $\times10^{-19}$ J**
1880	1.06
656	3.03
486	4.09

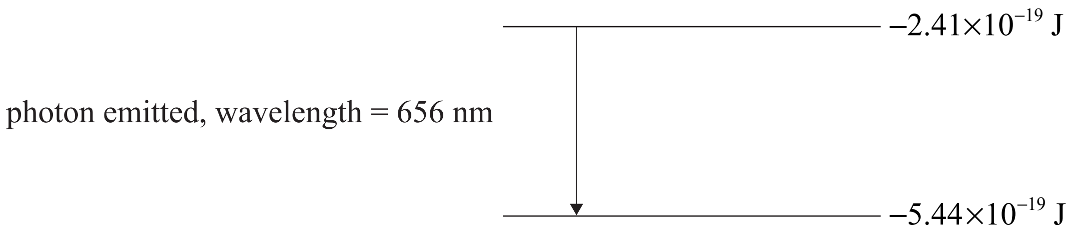
(b) Deduce that the photon energy for the wavelength of 486×10^{-9} m is 4.09×10^{-19} J. *[2]*

. . . .

. . . .

. . . .

The diagram below shows two of the energy levels of the hydrogen atom, using data from the table above. An electron transition between these levels is also shown.

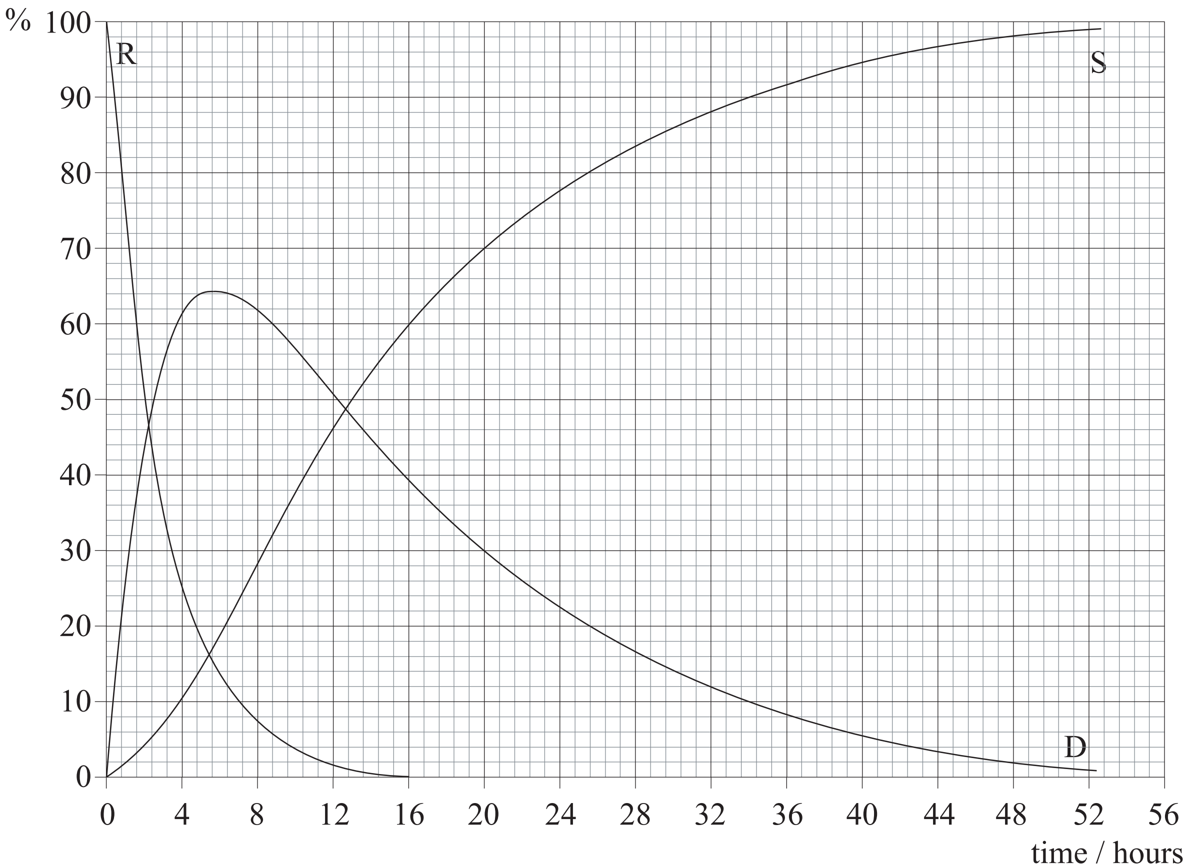


(c) (i) On the diagram above, construct the other energy level needed to produce the energy changes shown in the table above. *[1]*

(ii) Draw arrows to represent the energy changes for the two other wavelengths shown in the table above. *[1]*

B3. This question is about radioactive decay.

A nuclide R undergoes radioactive decay to form a daughter nuclide D which is also radioactive. The daughter nuclide D decays to form a stable nuclide S. The graph below shows the variation with time t of the percentage number of atoms of each of the nuclides R, D and S.



(a) Use data from the graph to determine the decay constant λ for the nuclide R. *[2]*

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B3 continued)

The graph for daughter nuclide D shows a maximum value.

(b) (i) State and explain the relation between the rates of decay of R and of D at this maximum. *[2]*

. . . .

. . . .

. . . .

Measurement of the percentage of R, D and S in a sample that initially contained 100 % of R may be used to determine the age of the sample.

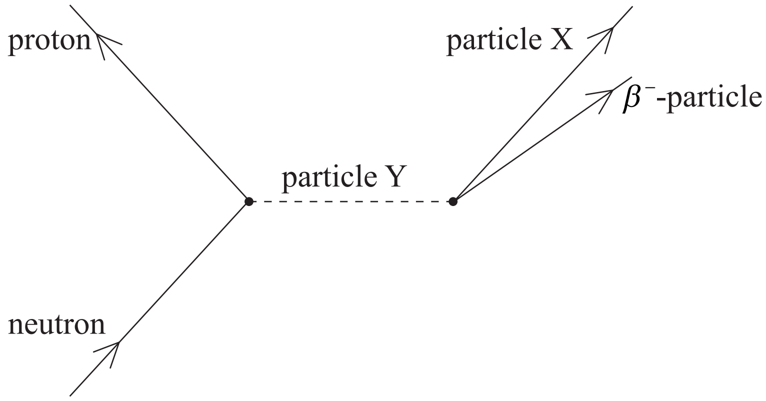
(ii) Suggest why such measurements of percentage composition would **not** provide a reliable result for samples that are about 50 hours old. *[1]*

. . . .

. . . .

B4. This question is about the decay of a neutron.

The diagram below illustrates a neutron decaying into a proton by emitting a β^--particle.



State the name of

(a) the force involved in this decay. *[1]*

. . . .

(b) the particle X. *[1]*

. . . .

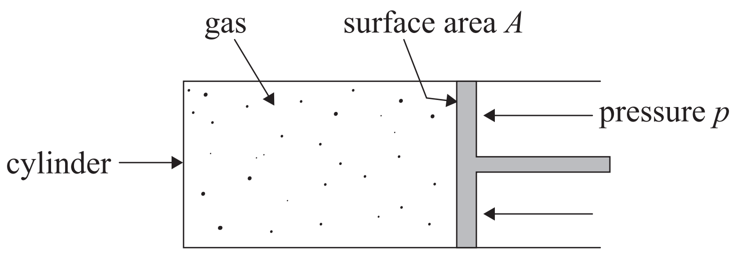
(c) the exchange particle Y involved in the decay. *[1]*

. . . .

Option C — Energy Extension

C1. This question is about an ideal gas.

An ideal gas is contained in a cylinder fitted with a frictionless piston, as shown below.



The piston has surface area *A*. A constant external pressure *p* acts on the piston.

(a) Deduce that, for an increase in volume ΔV of the gas, the external work done ΔW is given by

$$\Delta W = p\Delta V.$$ *[3]*

. . . .

. . . .

. . . .

. . . .

(b) The energy supplied to the gas for this increase in volume is found to be greater than $p\Delta V$. State and explain any change in the gas. *[2]*

. . . .

. . . .

. . . .

C2. This question is about the Carnot cycle.

(a) (i) Explain what is meant by an *adiabatic change* in a gas. *[1]*

. . . .

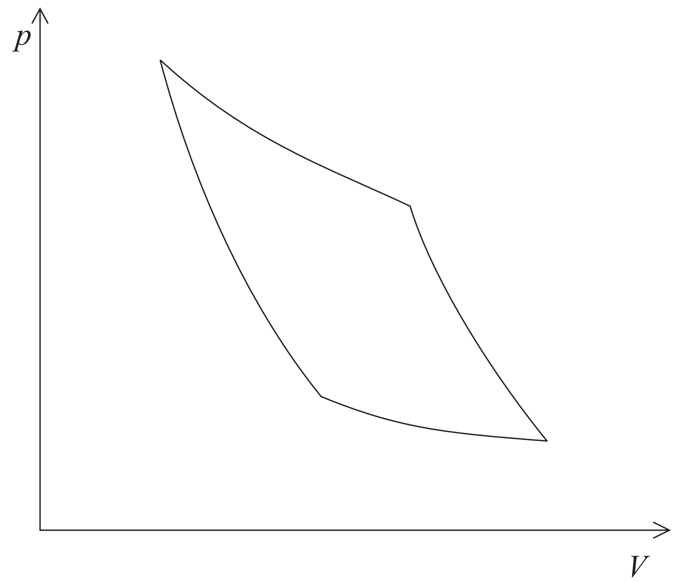
. . . .

(ii) State how, in practice, an adiabatic change may be achieved. *[1]*

. . . .

. . . .

The diagram below shows a pressure-volume (p-V) diagram for an ideal gas undergoing a Carnot cycle.



(b) On the diagram, identify

(i) one adiabatic change. Label this with the letter A. *[1]*

(ii) one isothermal change. Label this with the letter I. *[1]*

(This question continues on the following page)

(Question C2 continued)

In this Carnot cycle, the gas absorbs 164 J of energy at a temperature of 67 °C and energy is transferred to the surroundings at a temperature of 7 °C.

(c) (i) Calculate the quantity of energy transferred to the surroundings. *[2]*

. . . .

. . . .

. . . .

(ii) Determine the efficiency for this Carnot cycle. *[2]*

. . . .

. . . .

. . . .

(d) Suggest why a real engine, operating in a cycle between temperatures of 67 °C and 7 °C, would **not** achieve the efficiency calculated in (c) (ii). *[2]*

. . . .

. . . .

. . . .

C3. This question is about a wind turbine.

Air of density ρ and speed v passes normally through an area A.

(a) Deduce that the kinetic energy of the air passing through the area per unit time is given by the expression

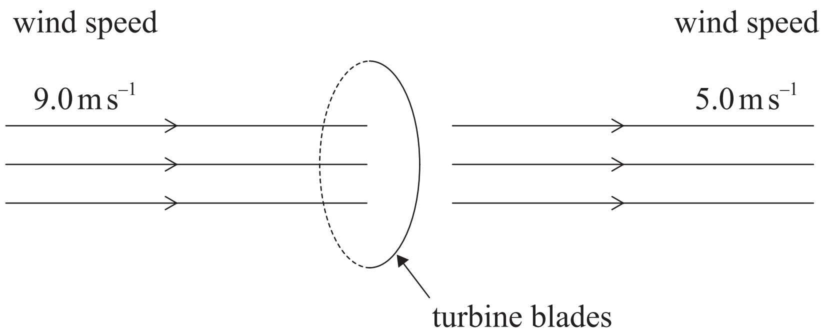
$$\text{kinetic energy per unit time} = \tfrac{1}{2}\rho A v^3 .$$ *[2]*

. . . .

. . . .

. . . .

Air of constant density $1.2\,\text{kg}\,\text{m}^{-3}$ is incident at a speed of $9.0\,\text{m}\,\text{s}^{-1}$ on the blades of a wind turbine. The turbine blades are each of length 7.5 m. The air passes through the turbine without any change of direction. Immediately after passing through the blades, the speed of the air is $5.0\,\text{m}\,\text{s}^{-1}$ as illustrated below.



The density of air immediately after passing through the blades is $2.2\,\text{kg}\,\text{m}^{-3}$. The turbine and generator have an overall efficiency of 72 %.

(b) Calculate

(i) the power extracted from the air by the turbine. *[2]*

. . . .

. . . .

. . . .

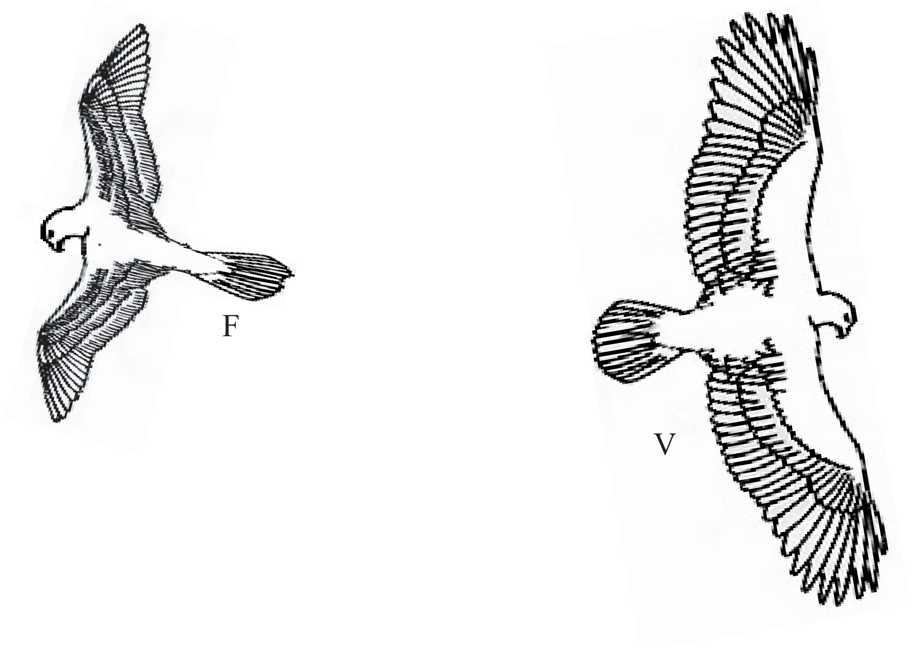
(ii) the electrical power generated. *[1]*

. . . .

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]*

. . . .

. . . .

. . . .

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

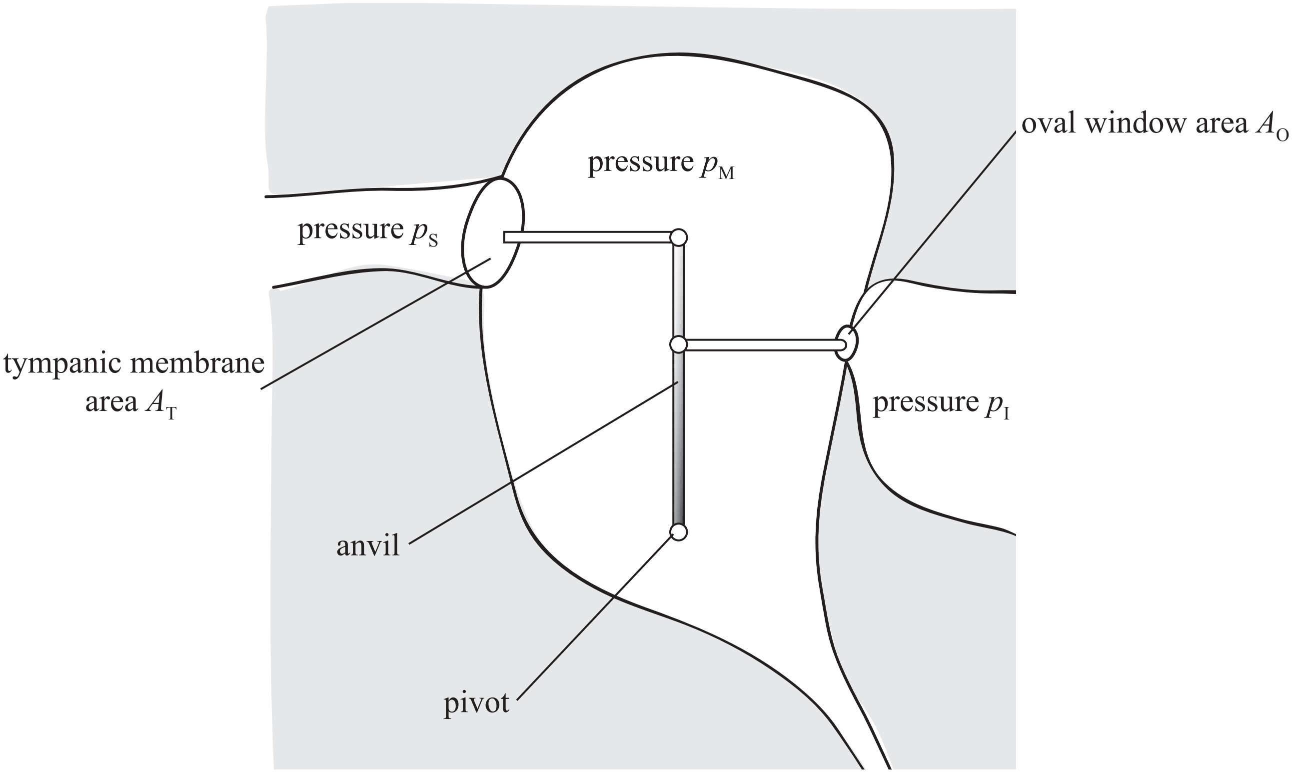
. . . .

. . . .

. . . .

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]*

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

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

. . . .

. . . .

. . . .

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]*

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

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

Blank page

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]*

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question E1 continued)

(b) Outline how retrograde motion was explained by

(i) Ptolemy. *[1]*

. . . .

. . . .

. . . .

(ii) Copernicus. *[2]*

. . . .

. . . .

. . . .

(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]*

1. . . . .

   . . . .

2. . . . .

   . . . .

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]*

. . . .

. . . .

. . . .

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

. . . .

. . . .

. . . .

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

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

. . . .

. . . .

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

1. . . . .

. . . .

2. . . . .

. . . .

E3. This question is about electricity and magnetism.

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

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

Blank page

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]*

. . . .

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

. . . .

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

. . . .

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

1. . . . .

. . . .

2. . . . .

. . . .

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]*

. . . .

. . . .

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

. . . .

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

1. . . . .

. . . .

. . . .

2. . . . .

. . . .

. . . .

F3. This question is about stellar magnitude and brightness.

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

. . . .

. . . .

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

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

. . . .

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

. . . .

. . . .

. . . .

. . . .

Option G — Relativity

G1. This question is about Special Relativity.

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

. . . .

. . . .

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

1. . . . .

. . . .

2. . . . .

. . . .

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]*

. . . .

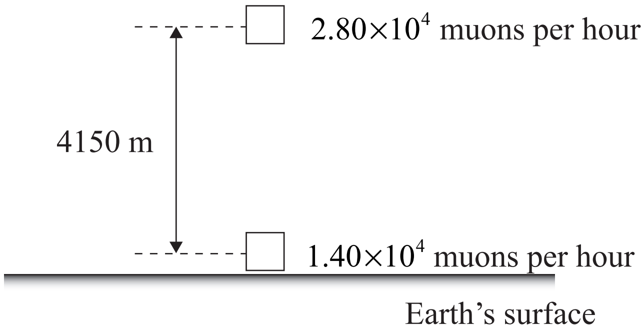
. . . .

. . . .

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 μs.

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

. . . .

. . . .

. . . .

. . . .

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

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

. . . .

. . . .

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

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

(ii) length contraction. *[2]*

. . . .

. . . .

. . . .

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]*

. . . .

. . . .

. . . .

. . . .

Option H — Optics

H1. This question is about electromagnetic waves.

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

. . . .

. . . .

. . . .

. . . .

(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]*

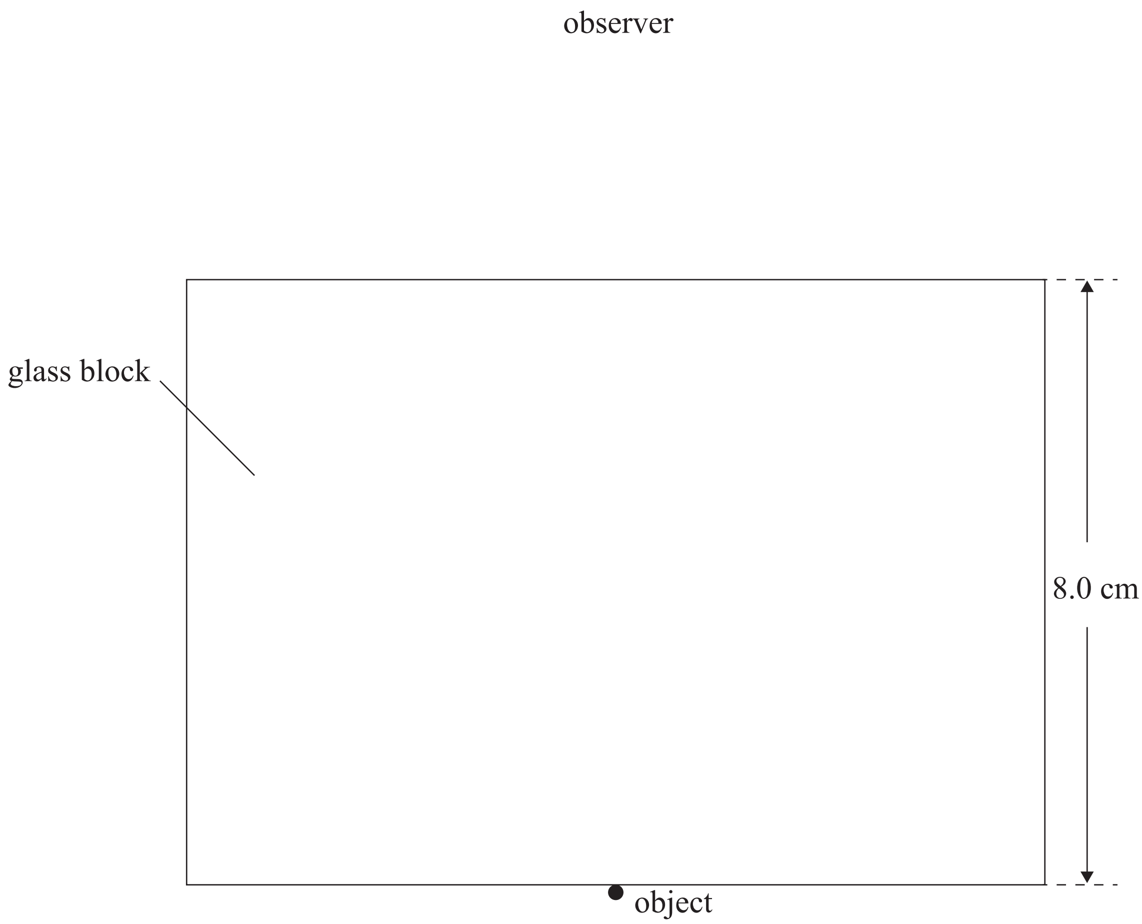
. . . .

. . . .

. . . .

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]*

. . . .

. . . .

. . . .

. . . .

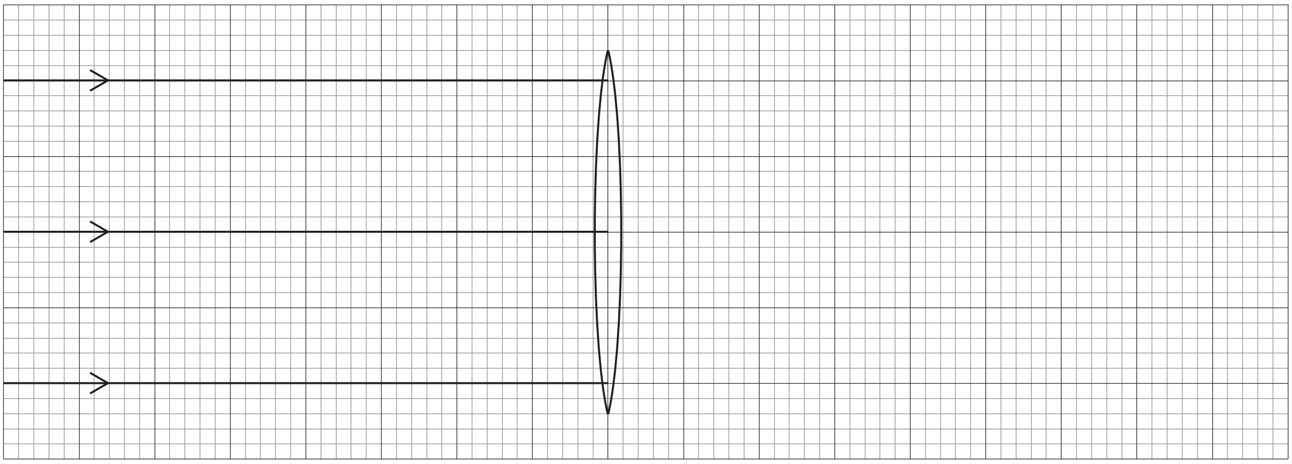
(c) Suggest why your answer in (b) is correct **only** when the object is viewed from vertically above it. *[1]*

. . . .

. . . .

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]*

. . . .

. . . .

. . . .

(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]*

. . . .

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

. . . .

. . . .

. . . .