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Baccalauréat International
Bachillerato Internacional

PHYSICS
STANDARD LEVEL
PAPER 3

Wednesday 21 May 2008 (morning)

1 hour

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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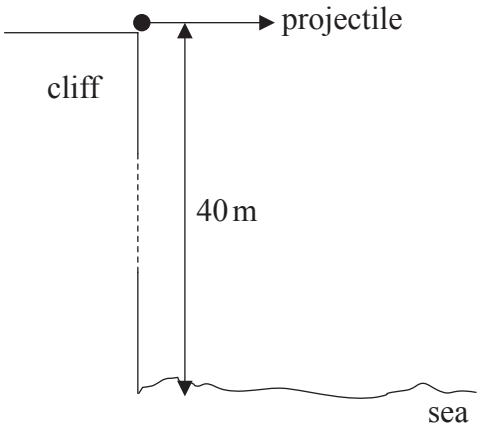
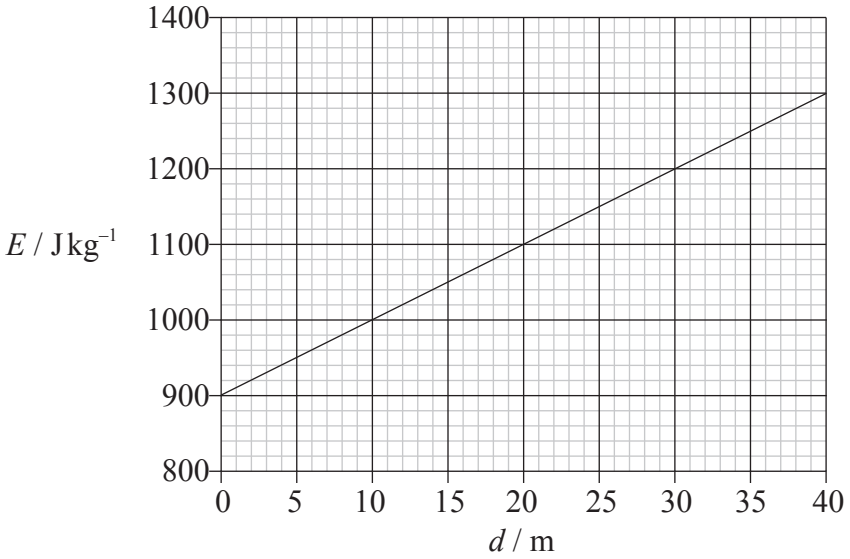
Option A — Mechanics Extension

A1. This question is about projectile motion.

A projectile is fired horizontally from the top of a vertical cliff of height 40 m.



At any instant of time, the vertical distance fallen by the projectile is d. The graph below shows the variation with distance d, of the kinetic energy per unit mass E of the projectile.



(This question continues on the following page)

(Question A1 continued)

(a) Use data from the graph to calculate, for the projectile,

(i) the initial horizontal speed. *[1]*

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(ii) the speed with which it hits the sea. *[1]*

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(b) Use your answers to (a) to calculate the magnitude of the vertical component of velocity with which the projectile hits the sea. *[2]*

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A2. This question is about orbital motion.

(a) State Kepler's third law (the law of periods). *[1]*

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(b) A satellite of mass m is in orbit of radius r about Earth. The mass of Earth is M_E and the orbital period of the satellite is T.

State, for the satellite,

(i) the name of the force that provides the centripetal force. *[1]*

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(ii) the orbital speed in terms of T and r. *[1]*

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(This question continues on the following page)

(Question A2 continued)

(c) Kepler's third law may be applied to the satellite orbiting the Earth. Use your answers to (b) to deduce that in Kepler's third law there is a constant K given by

$$K = \frac{4\pi^2}{GM_E}.$$ *[3]*

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(d) State an expression for the gravitational field strength g at the surface of the Earth in terms of M_E and the radius of Earth R_E. *[1]*

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(e) For the Earth, the gravitational field strength, g is $10\,\text{N kg}^{-1}$ and the radius R_E is $6.4 \times 10^6\,\text{m}$. Using your answers to (c) and (d), deduce that the orbital period of a satellite that is at a height R_E above the surface of Earth is $1.4 \times 10^4\,\text{s}$. *[3]*

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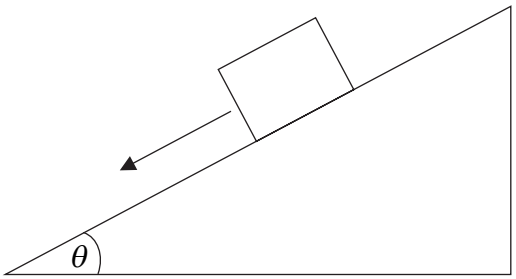
A3. This question is about friction.

(a) A block of wood of mass M is sliding down an inclined plane as shown.



The angle between the plane and the horizontal is θ. The acceleration of free fall is g.

State, in terms of M, g and θ, the component of the weight of the block

(i) parallel to the inclined plane. *[1]*

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(ii) perpendicular to the inclined plane. *[1]*

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(b) The coefficient of dynamic friction is μ_K. Deduce, in terms of M, g, θ and μ_K, an expression for the net force acting on the block parallel to the inclined plane. *[2]*

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(c) The angle θ of the inclined plane is 30°. The acceleration of the block down the plane is $0.15g$. Using your answer to (b), deduce that the value of μ_K is 0.40. *[2]*

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Option B — Quantum Physics and Nuclear Physics

B1. This question is about the de Broglie hypothesis.

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

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(b) Calculate the de Broglie wavelength associated with an adult of mass 80 kg running at a speed of $5.0\,m\,s^{-1}$. *[2]*

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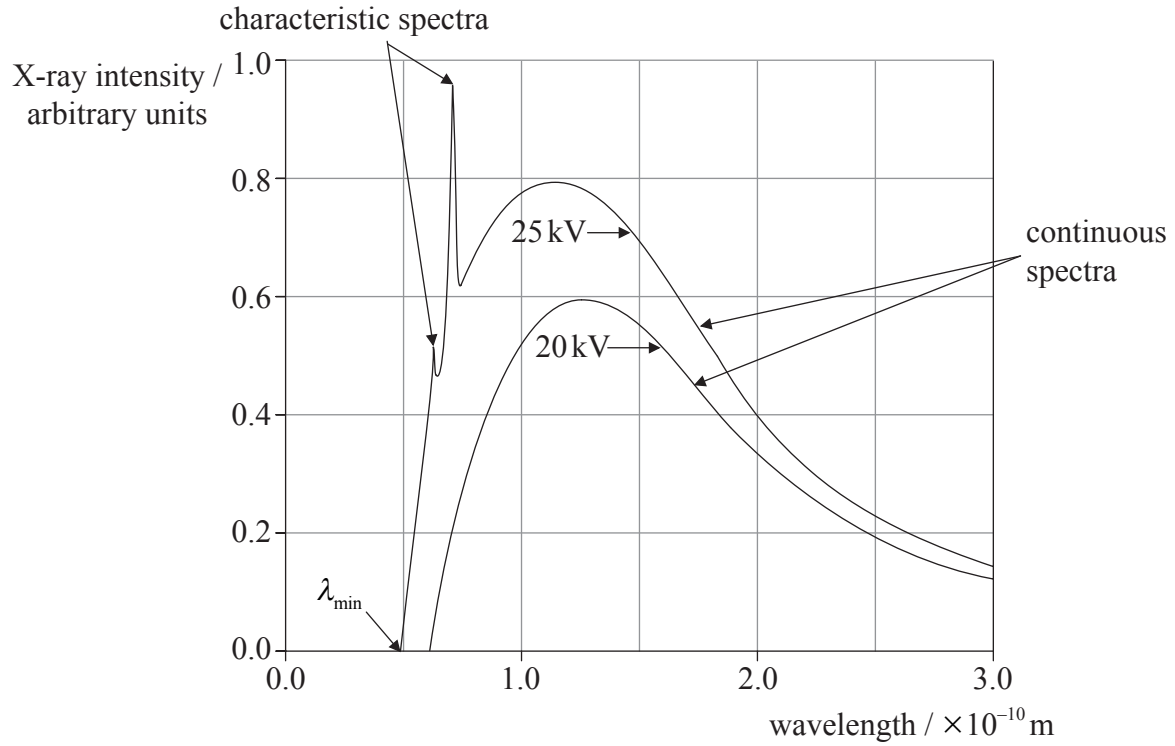
B2. This question is about X-ray spectra.

The diagram below shows the X-ray spectra produced by electrons striking a molybdenum target for two different accelerating potential differences of 25 kV and 20 kV.



(a) Explain

(i) the origin of the continuous spectrum. *[2]*

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(ii) why no characteristic spectra are produced for an accelerating potential of 20 kV. *[3]*

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(This question continues on the following page)

(Question B2 continued)

(b) Determine the minimum wavelength λ_{min} of X-rays for an accelerating potential difference of **15 kV**. *[3]*

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B3. This question is about nuclear reactions.

(a) A nucleus of barium-129, atomic number (proton number) 56 undergoes β^+ decay to form a nucleus of caesium.

State, for this decay,

(i) the proton number and neutron number of a nucleus of caesium. *[2]*

proton number: . . . . . .

neutron number: . . . . . .

(ii) the name of the other particle produced. *[1]*

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(iii) the name of the interaction responsible. *[1]*

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(iv) the change in quark structure of a nucleus of caesium. *[1]*

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(b) The half-life of barium-129 is 2.2 hours. Determine the percentage decrease in the activity during a period of 6.0 hours of a sample of barium-129. *[3]*

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Option C — Energy Extension

C1. This question is about thermodynamic processes and a diesel engine.

(a) Explain what is meant by an adiabatic change of state of a gas. *[2]*

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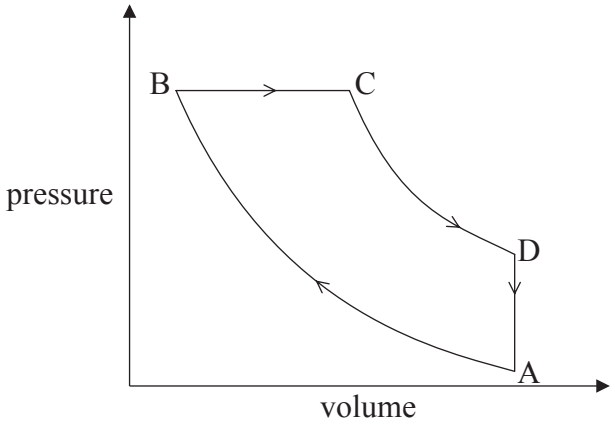
(b) The diagram below shows the relation between the pressure and the volume of the air in a diesel engine for one cycle of operation of the engine.



The changes of state A → B and C → D are adiabatic.

(i) State the name of each of the changes B → C and D → A. *[2]*

B → C: . . . . . .

D → A: . . . . . .

(ii) Identify the change during which thermal energy is transferred to the air in the engine. *[1]*

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(This question continues on the following page)

(Question C1 continued)

(c) The thermal energy transferred to the air in the engine during one cycle of operation of the engine is 900 J. The efficiency of the engine is 40 %. Determine the area ABCD of the diagram in (b). State what this area represents. *[3]*

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(d) Outline, in terms of the diagram in (b), the differences between the cycle of operation of a diesel engine and the cycle of operation of a Carnot engine. *[2]*

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C2. This question is about solar power.

(a) Distinguish, in terms of energy conversion, the difference between a photovoltaic cell and an active solar heater. *[2]*

Photovoltaic cell: . . . . . .

Active solar heater: . . . . . .

(b) An outside tank, open to the air, contains 4.0×10^3 kg of water. During daylight hours, the average temperature of the water decreases at a rate of $0.38\,\text{K}\,\text{h}^{-1}$. In order to maintain a constant temperature during daylight hours, it is proposed to heat the water using an active solar heater. The average solar power density during the day is $7.2 \times 10^2\,\text{W}\,\text{m}^{-2}$ and the specific heat capacity of water is $4.2 \times 10^3\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$.

Estimate the minimum effective area of the solar heater needed in order to keep the temperature of the water constant. *[3]*

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C3. This question is about nuclear energy.

In a nuclear reactor that uses uranium-235 as a fuel, a moderator is used to slow down the neutrons produced by the fission of the uranium.

(a) Explain why it is necessary to slow down the neutrons. *[2]*

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(b) Energy is liberated in the fission of uranium.

(i) State the form of the energy produced in the fission reaction. *[1]*

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(ii) Identify the energy transfers by which the energy in (b)(i) passes to the coolant. *[2]*

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Option D — Biomedical Physics

D1. This question is about scaling.

(a) A mother hippopotamus and a baby hippopotamus are standing on swampy ground. The linear dimensions of the mother are three times those of the baby. State the ratio of

(i) the mass of the mother to that of the baby. *[1]*

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(ii) the area of the mother's feet to that of the baby's feet. *[1]*

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(b) Use your answers in (a) to deduce that the mother will sink further into the swampy ground than the baby. *[2]*

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D2. This question is about sound and hearing.

The sound intensity level is defined by the equation

$$\text{intensity level (dB)} = 10\lg\left(\frac{I}{1.0\times10^{-12}}\right)$$

where I is the intensity of the sound.

(a) State what the number 1.0×10^{-12} represents. *[1]*

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(b) A person is listening to a sound that has an intensity of $1.0\times10^{-6}\,\text{W m}^{-2}$ at the ear. The intensity of the sound at the ear is then increased by a factor of 3. Determine the change in intensity level at the person's ear. *[2]*

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(c) The person then detects a change in loudness that corresponds to a 20 dB change in intensity level at the ear. Determine the factor by which the intensity at the ear has increased. *[2]*

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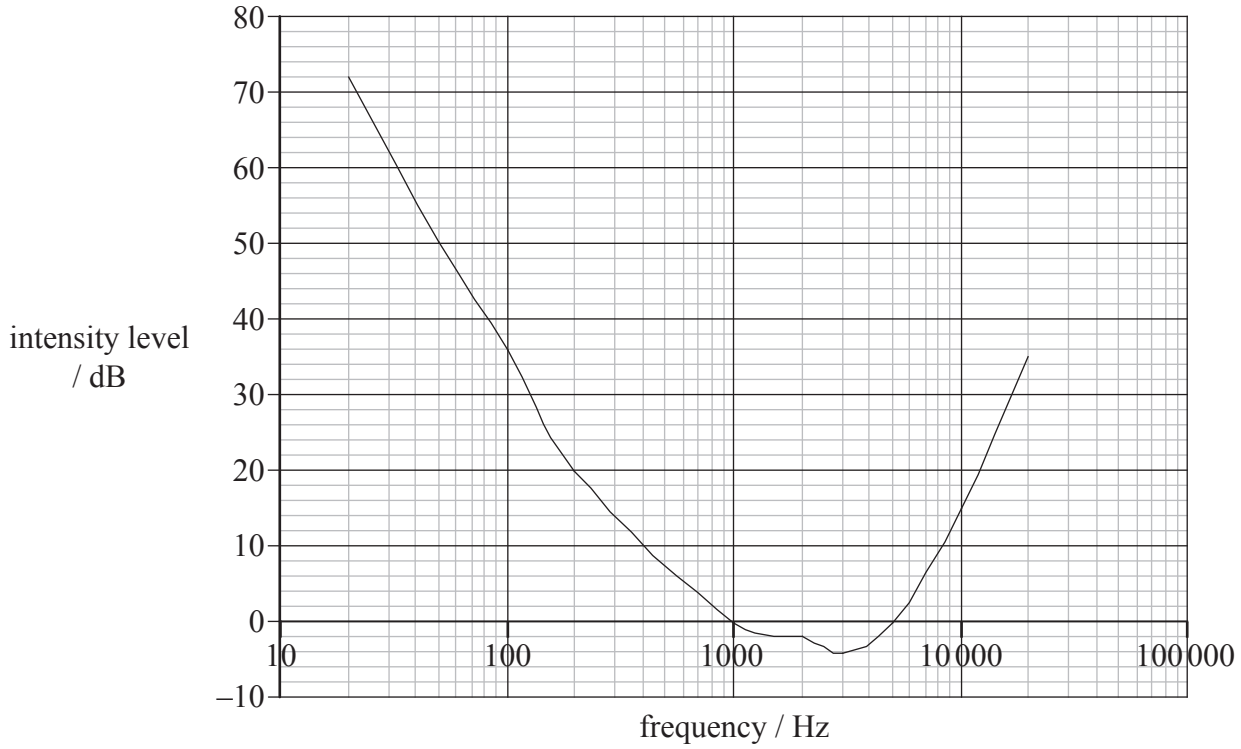
(This question continues on the following page)

(Question D2 continued)

(d) A young person with normal hearing has a hearing test. The results of the test are shown below.



Using the same axes, draw a sketch graph to show the results of a hearing test for an elderly person. *[3]*

D3. This question is about medical imaging.

Ultrasound imaging

(a) State the approximate range of ultrasound frequencies used in medical imaging. *[1]*

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(b) Distinguish between an A-scan and a B-scan. *[1]*

A-scan: . . . . . .

B-scan: . . . . . .

(c) State **one** advantage and **one** disadvantage of using ultrasound at a frequency in the upper part of the range stated in (a). *[2]*

Advantage: . . . . . .

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Disadvantage: . . . . . .

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(This question continues on the following page)

(Question D3 continued)

X-ray imaging

(d) A parallel beam of X-rays of a particular energy is used to examine a bone. At this energy, the half-value thickness of bone is 0.012 m and of muscle is 0.040 m. The beam passes through bone of thickness 0.060 m and through muscle of thickness 0.080 m. Determine the ratio

$$\frac{\text{decrease in intensity of beam produced by bone}}{\text{decrease in intensity of beam produced by muscle}}.$$

[3]

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(e) Suggest, using your answer to (d), why this beam is suitable for identifying a bone fracture. *[1]*

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Option E — The History and Development of Physics

E1. This question is about models of the solar system.

(a) State the essential difference between the Ptolemaic and Copernican models of the solar system. *[1]*

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(b) During the course of one night, the stars move across the sky but their relative positions remain unchanged. Describe how the Ptolemaic model accounts for this observation. *[2]*

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(c) The Copernican model of the universe was further developed by Kepler and then by Newton. Discuss, in relation to Kepler's work, how Newton contributed to an understanding of planetary motion. *[3]*

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E2. This question is about theories of projectile motion.

Both Aristotle and Galileo attempted to explain the motion of a projectile such as a stone after it has been thrown.

(a) Outline the theory that Aristotle proposed to explain this type of motion. *[3]*

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(b) State the law of Galileo that enabled Aristotle's theory to be replaced. *[1]*

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E3. This question is about theories of heat.

In 1840 James Joule carried out experiments to measure the mechanical equivalent of heat.

(a) Explain what is meant by the mechanical equivalent of heat and how the measurement of this quantity led to the caloric theory of heat being replaced. *[3]*

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(b) The amount of energy liberated by the combustion of 1.0 litre of petrol is sufficient to raise a body of weight 6.0×10^4 N to a height of 500 m. According to the caloric theory the amount of caloric in 1.0 litre of petrol is 7.1×10^6 units. Determine the number of joules of energy that are equivalent to 1.0 units of caloric. *[2]*

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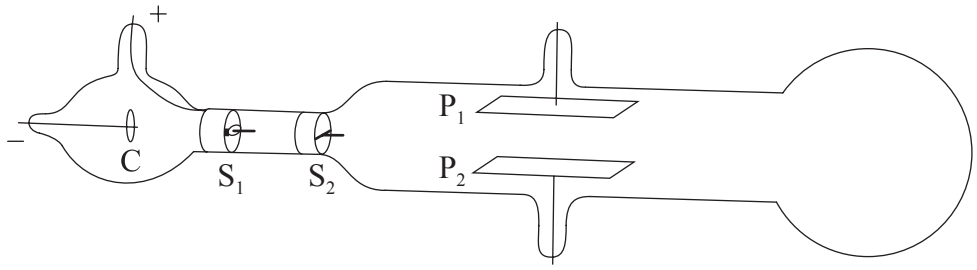
E4. This question is about the measurement of the charge to mass ratio of an electron.

The diagram below shows a cathode-ray tube similar to that used by J J Thomson in his experiment to measure the charge-to-mass ratio of the electron.



Electrons are produced at C.

(a) State the functions of the parts of the tube labelled S_1 and S_2. *[1]*

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(b) Describe how the beam of electrons can be deflected towards plate P_1. *[2]*

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(c) In the experiment a uniform magnetic field was applied to the tube.

(i) On the diagram above identify with the letter R, the region in which the field was applied. *[1]*

(ii) State the purpose of applying the magnetic field. *[1]*

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Option F — Astrophysics

F1. This question is about stellar clusters and galaxies.

(a) Distinguish between a stellar cluster and a galaxy. *[2]*

Stellar cluster: . . . . . .

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Galaxy: . . . . . .

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(b) State the value of the ratio

$$\frac{\text{order of magnitude of distance between stars in a galaxy}}{\text{order of magnitude of distance between galaxies}}.$$ *[1]*

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F2. This question is about determining the surface area of the star Wolf-359.

(a) Distinguish between apparent brightness and apparent magnitude. *[2]*

Apparent brightness: . . . . . .

Apparent magnitude: . . . . . .

(b) Outline how the surface temperature of a star is determined. *[3]*

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(This question continues on the following page)

(Question F2 continued)

(c) The following data are available for the star Wolf-359 and the Sun.

Apparent brightness of Wolf-359 $= 1.97 \times 10^{-12}\,\text{W m}^{-2}$
Distance of Wolf-359 from Earth $= 4.93 \times 10^{5}\,\text{AU}$
Surface temperature of Wolf-359 $= 4.00 \times 10^{3}\,\text{K}$
Surface temperature of Sun $= 6.00 \times 10^{3}\,\text{K}$

For Wolf-359, use the data to,

(i) suggest which method is used to measure its distance from Earth. *[2]*

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(ii) explain whether its apparent magnitude is greater **or** less than the apparent magnitude of the Sun. *[2]*

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(iii) deduce that its luminosity is $1.35 \times 10^{23}\,\text{W}$. *[3]*

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(d) Determine the surface area of Wolf-359. *[2]*

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F3. This question is about Olbers' paradox.

Newton made three assumptions about the nature of the universe. Two of these were that the universe is infinite and that it is static.

(a) State Newton's other assumption about the nature of the universe. *[1]*

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(b) Outline how Newton's model of the universe leads to Olbers' paradox. *[2]*

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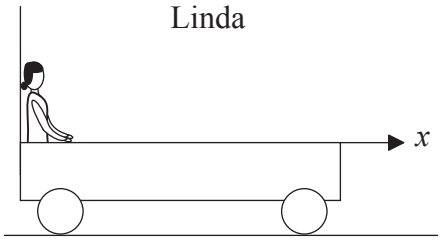
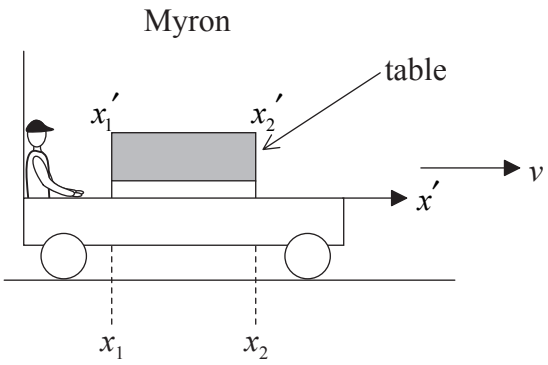
Option G — Relativity

G1. This question is about reference frames and concepts of relativity.

Two railway trucks are on level horizontal tracks parallel to each other. There is an observer in each truck. Linda's truck is stationary relative to the tracks and Myron's truck is moving with constant speed v relative to, and in a direction parallel to, the tracks.

The diagram below represents the positions of the trucks at a time $t = T$ later.





Linda considers herself to be at the origin of her frame of reference and chooses her x-axis to be parallel to the tracks. Myron considers himself to be at the origin of his frame of reference and chooses his x'-axis also to be parallel to the tracks.

(a) Explain what is meant by a frame of reference. *[2]*

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(This question continues on the following page)

(Question G1 continued)

(b) There is a table at rest with respect to Myron's frame of reference. There is a clock in each truck that is at rest relative to the truck. Myron measures one end of the table to be at x_1' and the other end to be at x_2'. As measured by Linda, at a time $t=0$ the trucks are directly opposite each other, and at a time $t = T$, the corresponding positions are x_1 and x_2 respectively.

(i) Use a Galilean transformation, to deduce that both Linda and Myron will measure the length of the table to be the same. *[2]*

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(ii) Use a relativistic transformation, to state the relation between $(x_1' - x_2')$ and $(x_1 - x_2)$. Define any other quantities used. *[2]*

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(iii) With reference to the postulates of special relativity, explain why it is important that the measurements are made simultaneously. *[3]*

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(iv) Outline how the result of the Michelson-Morley experiment supports your explanation in (b)(iii). *[2]*

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(This question continues on the following page)

(Question G1 continued)

(c) On the table, there is a lamp that Myron can turn on or off using a remote control. He switches the lamp on and then off. He measures the time interval on his clock between the lamp being turned on and then off as 0.800 s. Linda measures the time interval on her clock as 1.20 s.

(i) State and explain which observer measures the proper time. *[2]*

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(ii) Calculate the speed v of Myron's truck. *[3]*

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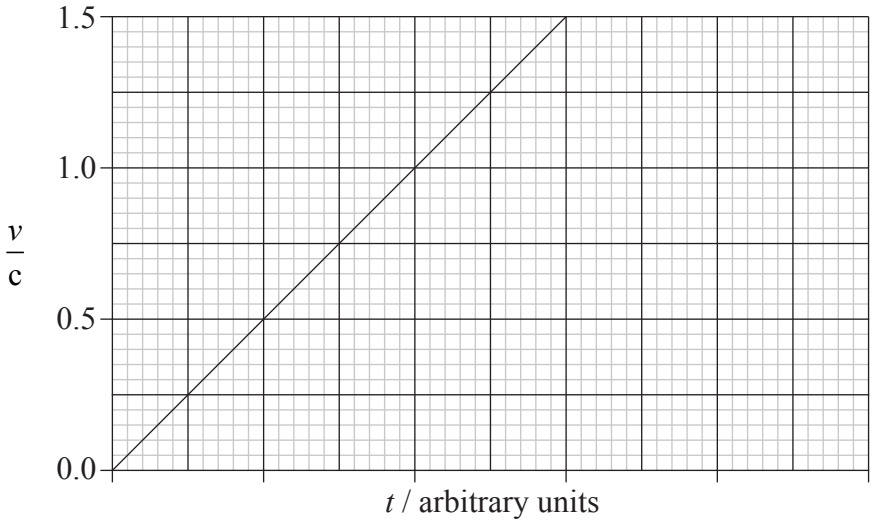
G2. A particle is accelerated from rest by a constant force. The graph below shows the variation with time t of the ratio $\frac{v}{c}$ where v is the speed of the particle and c is the free space speed of light, as calculated using Newtonian mechanics.



(a) On the graph above, draw the variation with time t of the speed v as calculated using relativistic mechanics. *[2]*

(b) A particle has rest mass $0.51\,\text{MeV}\,c^{-2}$ and it is moving at speed 0.90c. Calculate the total energy of this particle. *[2]*

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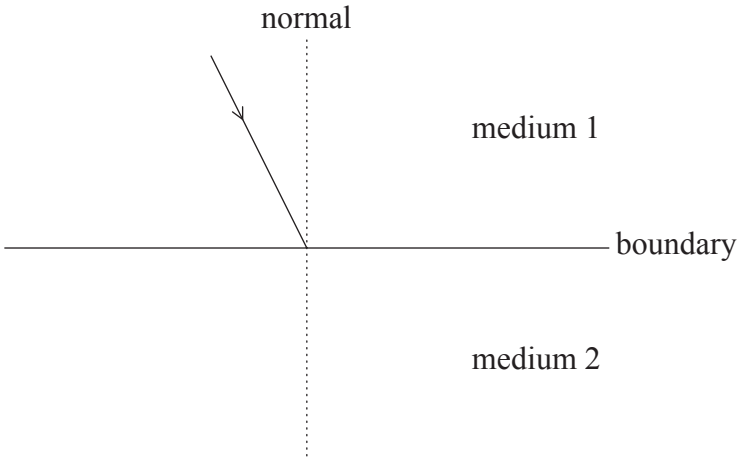
Option H — Optics

H1. The table below relates to the electromagnetic spectrum. Complete the table by stating the name of the region of the spectrum and the name of a possible source of the radiation associated with the given frequency. *[4]*

Name of associated region	Frequency / Hz	Possible source
gamma radiation	10^{18}	radioactive decay
	10^{13}	
	10^{6}	

H2. This question is about refraction.

(a) The diagram below shows a ray of monochromatic light incident on the boundary between two media. The dotted line is the normal to the boundary.



The refractive index of medium 1 is n_1 and that of medium 2 is n_2 and $n_1 > n_2$. The ray is incident at an angle to the normal that is less than the critical angle.

(i) Explain what is meant by critical angle. *[2]*

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(ii) On the diagram above, draw lines to show the paths of the ray after it is incident on the boundary. *[2]*

(b) Derive a relationship between n_1, n_2 and the critical angle ϕ_c. *[2]*

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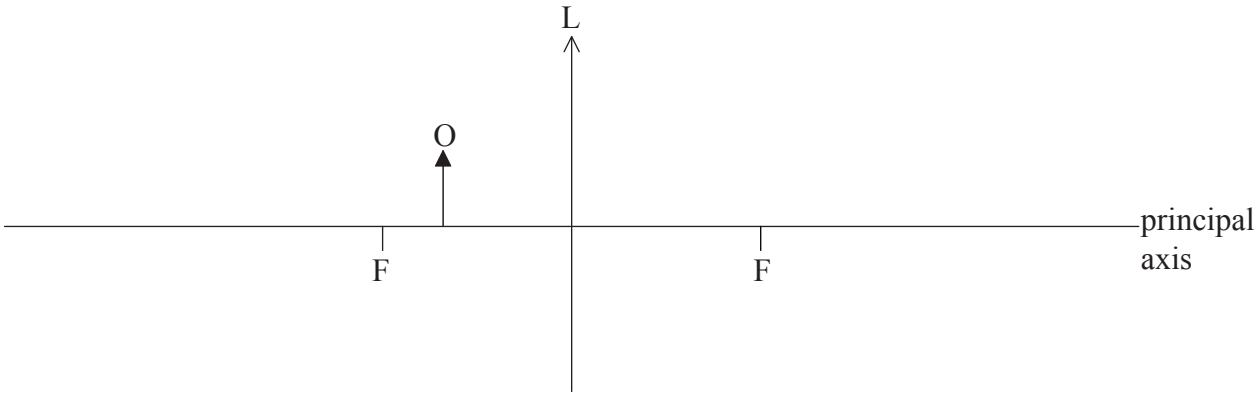
H3. This question is about image formation.

(a) A converging lens L has principal foci at F. An object O is placed in front of the lens as shown below.



(i) Define *principal axis* and *principal foci*. *[2]*

Principal axis: . . . . . .

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Principal foci: . . . . . .

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(ii) On the diagram above, construct rays to locate the position of the image formed by the lens. *[2]*

(iii) Explain whether the image is real **or** virtual. *[2]*

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(This question continues on the following page)

(Question H3 continued)

(b) The image is formed at a distance of 25 cm from the lens. The angular magnification produced is 6.0.

(i) Determine the distance of object O from the lens. *[3]*

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(ii) State the advantage of using the lens with the image formed at the near point of the eye. *[1]*

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