22086515

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 3

Wednesday 21 May 2008 (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.

0131

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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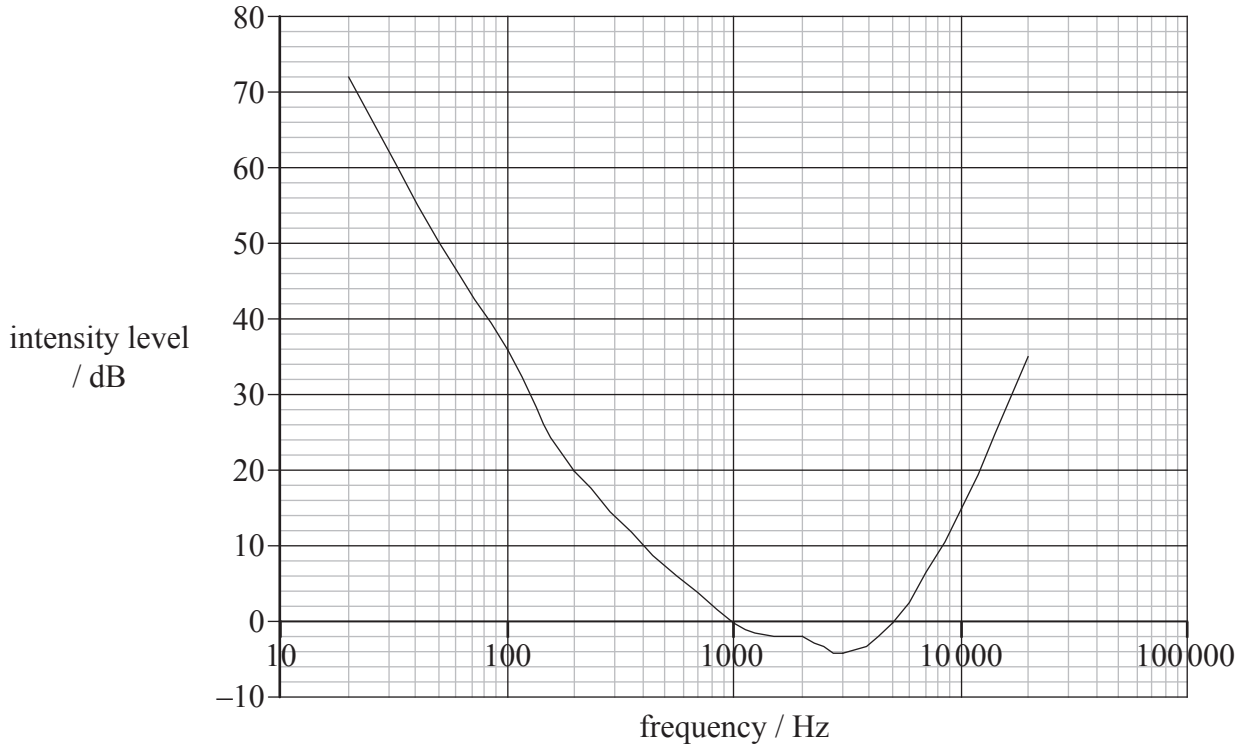
(This question continues on the following page)

(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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D4. This question is about energy used by the body.

(a) The energy available to the body in one slice of bread is about 300 kJ. Deduce that this energy is sufficient in theory, for a person of weight 700 N, to climb a hill of height 400 m. *[1]*

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(b) Explain why, in practice, the body needs much more energy than 300 kJ to climb a hill of height 400 m. *[3]*

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D5. This question is about radioactive isotopes in used in medicine.

(a) Define *biological half-life*. *[1]*

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(b) The isotope iodine-131 (I-131) is used to treat growths in the thyroid gland. The radioactive half-life of I-131 is 8.0 days and its biological half-life is 21 days. Calculate the ratio

$$\frac{\text{activity of a sample 12 days after it is introduced to the body}}{\text{initial activity of the sample at time when introduced to the body}}.$$ *[4]*

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(c) The isotope technetium-99^{m} has a radioactive half-life of six hours and is also readily absorbed by the thyroid gland. Suggest **one** reason why this isotope is a better choice than I-131 for diagnostic use. *[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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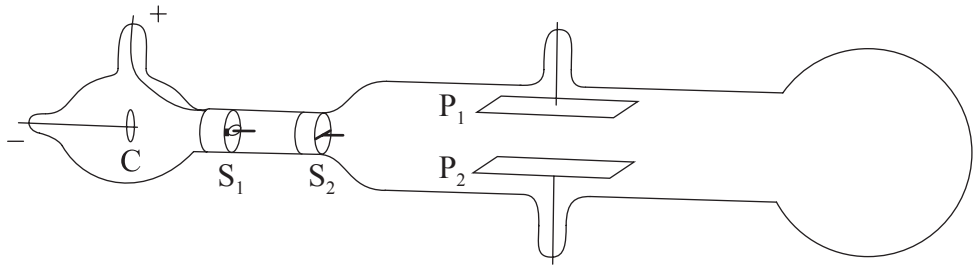
E4. This question is about the measurement of the charge to mass ratio of an electron.

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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E5. This question is about Bohr theory.

In 1913, Bohr proposed a model of the hydrogen atom that is based on two postulates. One of the postulates stated that the electron in the hydrogen atom could only occupy certain allowed energy levels. In making a transition between two of these levels, the electron would either emit or absorb a photon whose energy is equal to the energy difference between the levels.

(a) State the second postulate that Bohr made. *[1]*

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(b) The model enabled the empirical Rydberg formula $\frac{1}{\lambda} = R_{\mathrm{H}}\left(\frac{1}{n^2} - \frac{1}{m^2}\right)$ to be derived.

Outline how

(i) the Rydberg formula relates to a particular spectral series of atomic hydrogen. *[2]*

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(ii) the integers n and m in the Rydberg formula relate to the Bohr postulates. *[2]*

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(This question continues on the following page)

(Question E5 continued)

(c) The value of the wavelength at which the visible line spectrum of atomic hydrogen becomes continuous is 364.5 nm.

(i) State why for a continuous spectrum the value of m is infinity. *[1]*

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(ii) Determine the value of n that relates the visible line spectrum to the Ryberg formula ($R_H = 1.097 \times 10^7\,m^{-1}$). *[2]*

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(d) The Rydberg formula can be extended to the spectrum of singly ionized helium. Suggest why the value of R_H in the formula will be greater than that when the formula is applied to atomic hydrogen. *[2]*

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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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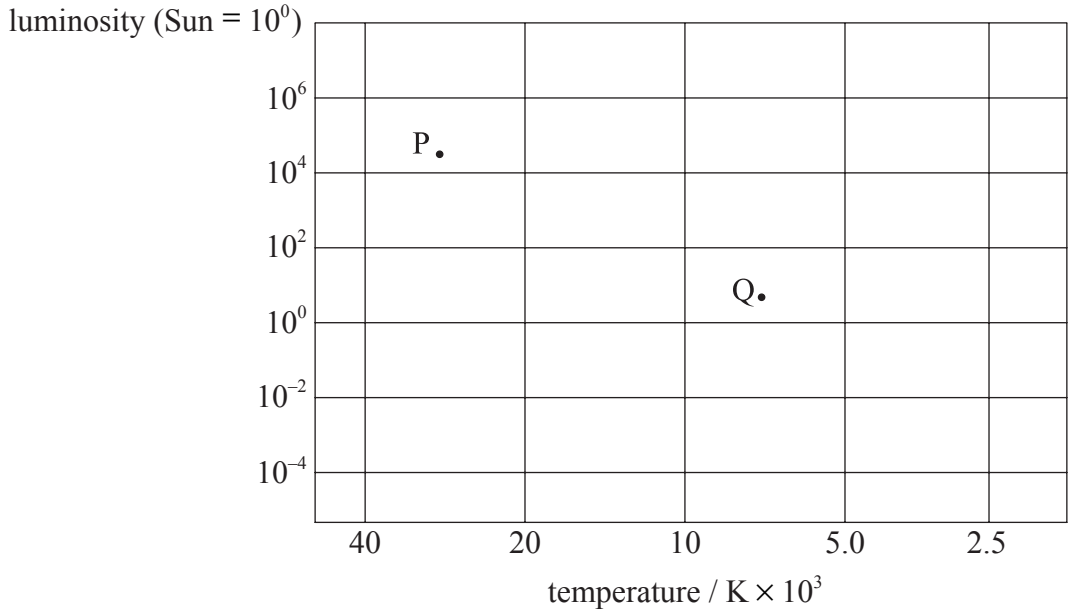
F4. This question is about Main Sequence stars.

Below is a grid of a Hertzsprung-Russell diagram.



The points labelled P and Q are two stars on the main sequence.

(a) On the diagram above, draw the evolutionary path of star Q. *[2]*

(b) State the difference in the likely fate of star P to that of the fate of the star Q. *[1]*

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(c) Explain, with reference to the Chandrasekhar limit, how it might be possible for star P to have the same fate as star Q. *[3]*

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F5. This question is about galaxies and red shift.

(a) State the names of **three** types of observed galaxy. *[1]*

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(b) Suggest why the light observed from galaxies shows red shift. *[2]*

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(c) State the reason why, the greater the observed red shift the greater the distance of the galaxy from Earth. *[1]*

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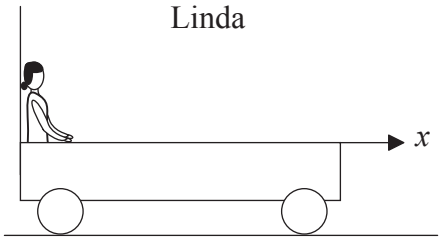
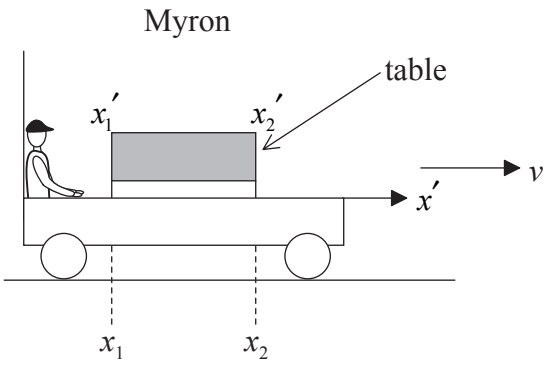
Option G — Relativity

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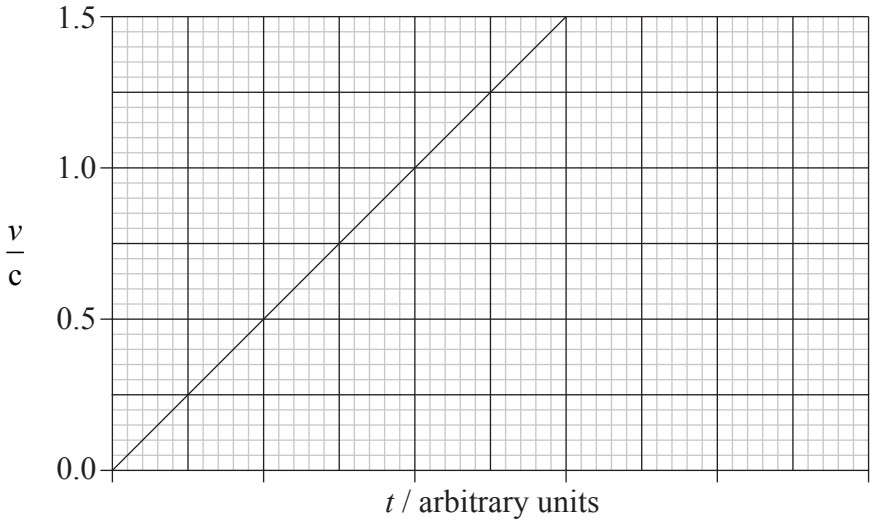
G2. A particle is accelerated from rest by a constant force. The graph below shows the variation with time t of the ratio $\frac{v}{c}$ where v is the speed of the particle and c is the free space speed of light, as calculated using Newtonian mechanics.



(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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G3. This question is about relativistic momentum.

A proton is accelerated from rest through a potential difference of $5.00 \times 10^2\,\text{MV}$. Determine the momentum of the proton after acceleration. *[4]*

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G4. This question is about spacetime.

(a) By reference to a particle moving along the *x*-axis of a coordinate system, describe the concept of spacetime. *[2]*

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(b) A satellite is in orbit about Earth.

(i) Outline how the concept of spacetime is used to account for the orbital motion of the satellite. *[3]*

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(ii) State the reason why the gravitational force of attraction between the satellite and Earth decreases with distance from Earth. *[1]*

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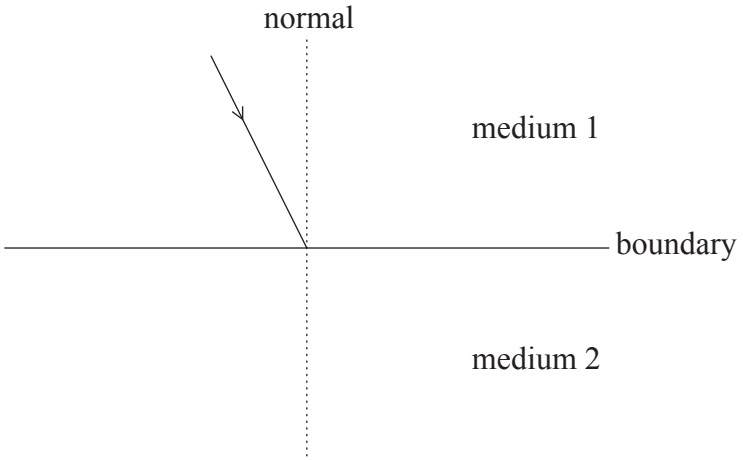
Option H — Optics

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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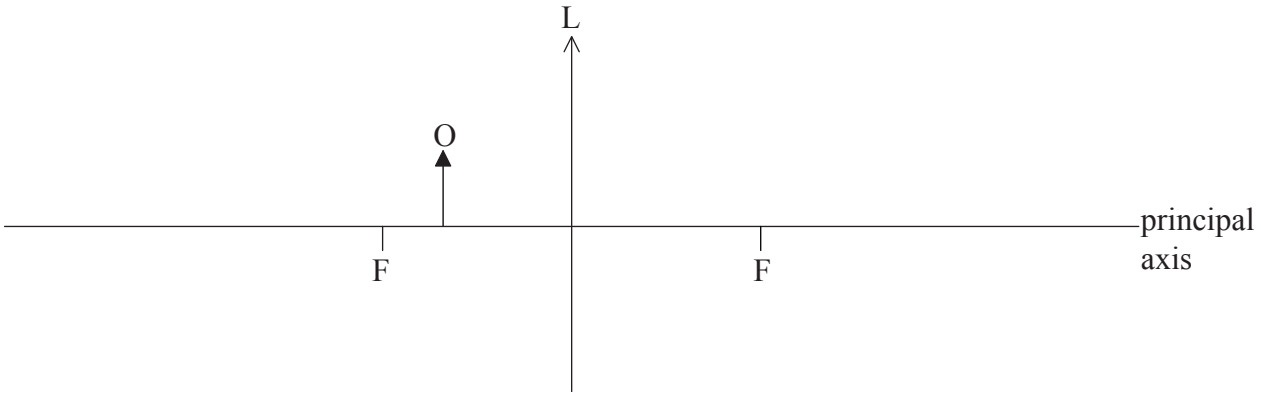
H3. This question is about image formation.

(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: . . . . . .

. . . . . .

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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H4. This question is about single-slit diffraction.

(a) Explain, by reference to secondary wavelets, the diffraction of light at a single slit. *[2]*

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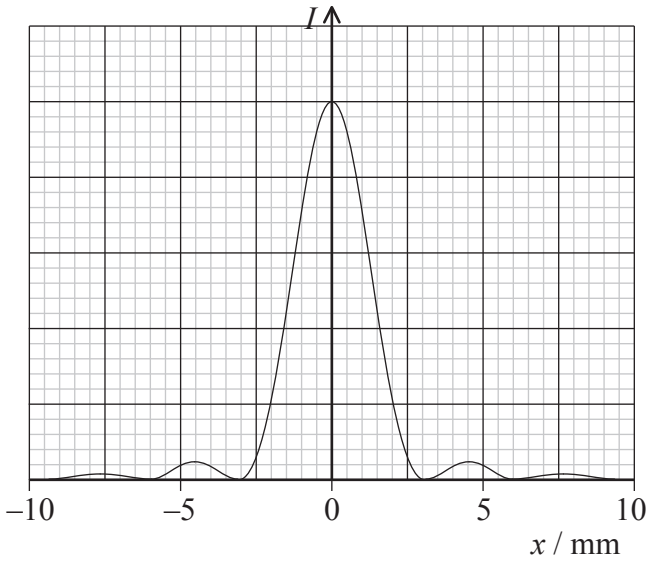
(b) Light from a helium-neon laser passes through a narrow slit and is incident on a screen 2.4 m distance from the slit. The graph below shows the variation with intensity I of the light on the screen of distance x along the screen.



(i) The wavelength of the light emitted by the laser is 630 nm. Use data from the graph above to determine the width of the slit. *[3]*

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(ii) State **two** changes to the intensity distribution of the central maximum when the single slit is replaced by one of greater width. *[2]*

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H5. This question is about thin film interference.

Outline the reason why, when white light is reflected from the surface of an oil film, a system of coloured fringes is observed. *[3]*

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