22086509

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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.

0132

Option D — Biomedical Physics

D1. This question is about scaling.

(a) The rate of oxygen demand, D, of an insect is proportional to the mass of the insect. The rate of oxygen absorption, R, is proportional to the surface area of the insect.

Determine the ratio $\frac{D}{R}$ in terms of the characteristic length, L, of the insect. *[3]*

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(b) Suggest why your answer in (a) places a practical limit on the size of insects. *[2]*

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D2. This question is about sound and hearing.

(a) Distinguish between conductive and sensory hearing loss. *[2]*

Conductive: . . . . . .

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Sensory: . . . . . .

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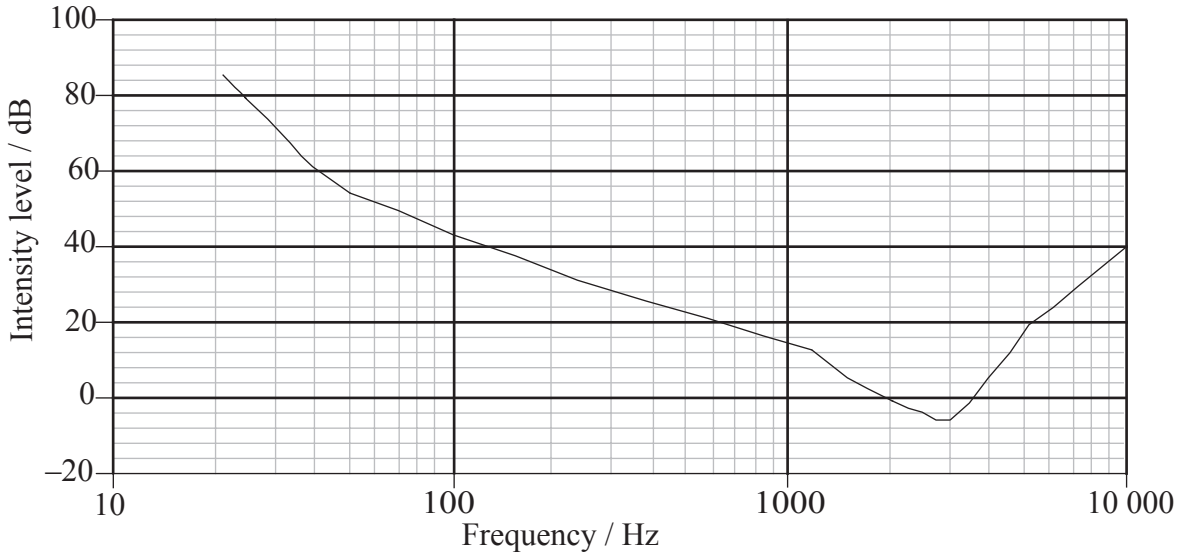
The diagram below shows a sketch of the variation with frequency *f* of the intensity level *IL* of sound heard by a young person with normal hearing.



(b) On the diagram sketch the variation with *f* of the *IL* of an elderly person. *[2]*

(c) At a frequency of 3.0 kHz a person has a hearing loss of 15 dB. For the frequency of 3.0 kHz calculate the ratio *[2]*

$$\frac{\text{minimum intensity of sound heard by person with defective hearing}}{\text{minimum intensity of sound heard by person with normal hearing}}$$

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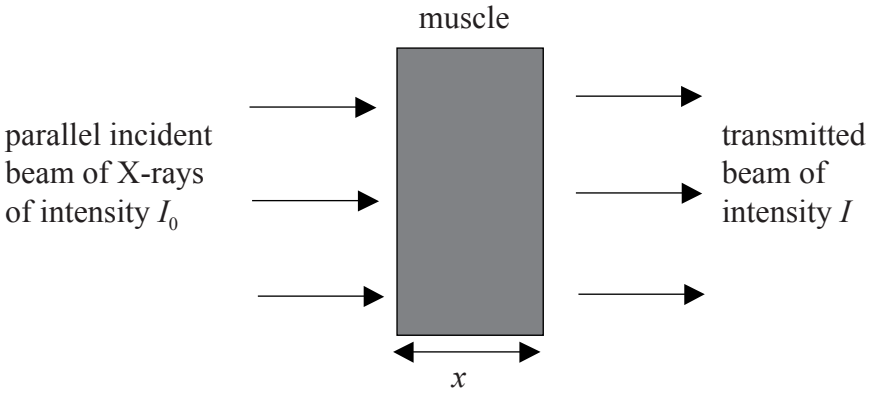
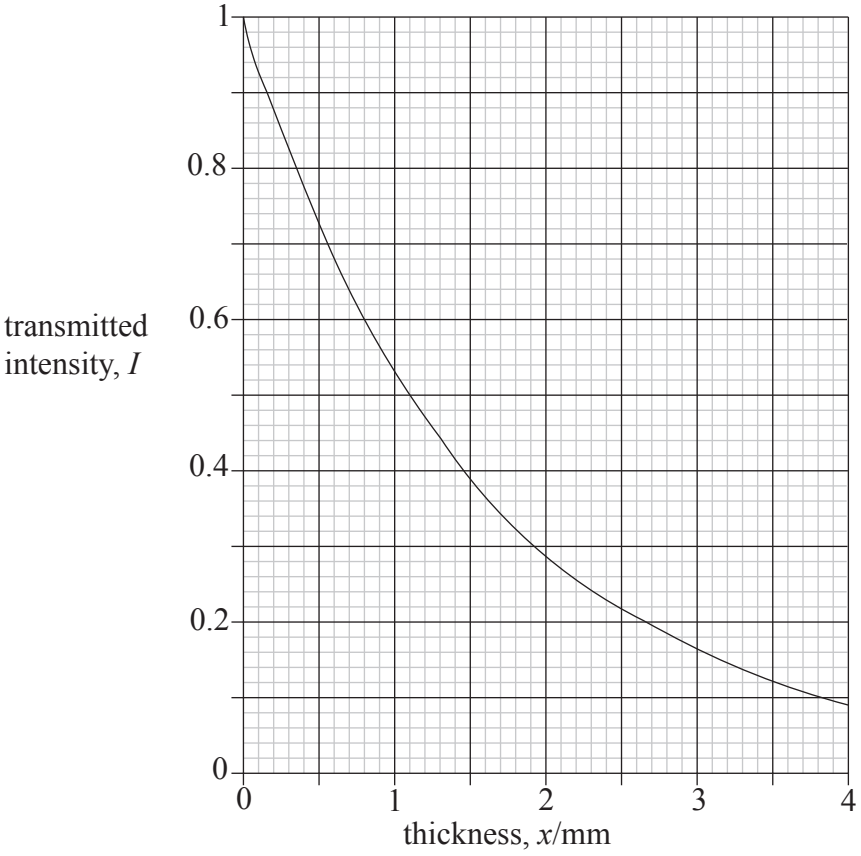
D3. This question is about X-rays.

A parallel beam of monochromatic X-rays of photon energy 30 keV is incident on muscle as shown in the diagram below. The incident intensity is I_0 and the transmitted intensity is I.



The graph below shows the variation with the thickness x of the muscle of the transmitted intensity I. The units of intensity are arbitrary.



(This question continues on the following page)

(Question D3 continued)

(a) Define *attenuation coefficient*. *[1]*

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(b) Use data from the graph to determine the attenuation coefficient of muscle. *[3]*

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(c) With reference to the attenuation coefficient of muscle and of bone, outline the formation of an X-ray image of a limb. *[2]*

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(d) Outline the basis of computed tomography (CT) scanning. *[3]*

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D4. This question is about energy changes in the body.

A man of weight 700 N does "push-ups" as shown in the diagram below. His body in the upper position makes an angle of 25° to the horizontal. The body's centre of mass is a distance of 1.10 m from the feet.

(a) Calculate the work done in completing 40 push-ups. *[3]*

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(b) During the exercise the total energy requirement of the man is approximately 150 kJ. Suggest reasons for the difference between this energy requirement and your answer in (a). *[3]*

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D5. This question is about radiation dosimetry.

(a) Define *exposure*. *[2]*

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(b) A patient is injected with a gamma ray emitter. The radiation from the source creates an exposure in the body of $8.6\times10^{-3}\,\mathrm{C\,kg^{-1}}$.

The average energy required to singly ionize an atom in the human body is approximately 40 eV and the quality factor for gamma radiation is 1. Deduce that this corresponds to a dose equivalent of 340 mSv. *[2]*

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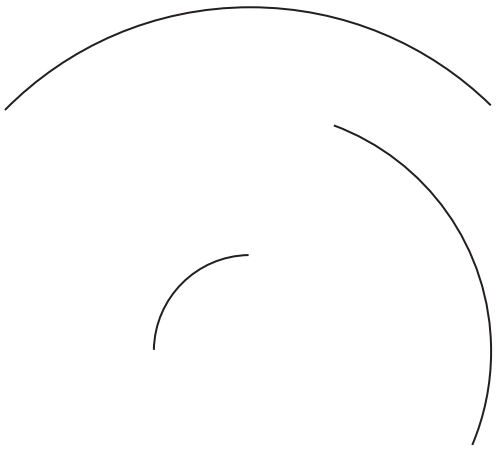
Option E — The History and Development of Physics

E1. This question is about the motion of stars.

In the course of one night, stars appear to move along arcs. The diagram below shows the images of the paths of three stars obtained by a camera in which the shutter remained open for a period of time.



(a) Describe how these paths may be explained in

(i) the Ptolemaic model. *[2]*

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(ii) the Copernican model. *[1]*

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(b) With reference to your answer to (a)(ii) estimate the time for which the camera shutter was open. *[1]*

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E2. This question is about the motion of planets.

(a) Outline the contributions of Brahe and Kepler to the understanding of planetary motion. *[2]*

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(b) Outline how Newton's contributions to the understanding of the laws of planetary motion lead to the conclusion that Kepler's understanding of planetary motion also applies to comets. *[3]*

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E3. This question is about the caloric theory of heat.

(a) Outline the caloric (phlogiston) theory of heat. *[2]*

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(b) State and explain **one** piece of evidence that does not support the caloric (phlogiston) theory of heat. *[2]*

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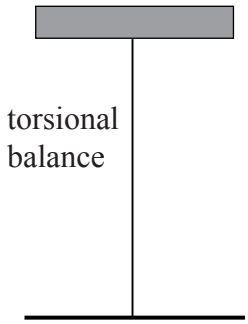
E4. This question is about the inverse square law in electrostatics.

The diagram shows part of the apparatus that may be used to verify the inverse square nature of Coulomb's electrostatic law.



(a) With the aid of the diagram describe how the inverse square nature of the law may be verified. *[5]*

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(b) Outline how Coulomb obtained charges of different known relative magnitudes. *[2]*

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E5. This question is about models of the hydrogen atom.

(a) The Bohr model provides a partially successful explanation of the spectrum of the hydrogen atom. The model predicts that the energy, E, of the electron in the hydrogen atom is given by

$$E = -\frac{2.18 \times 10^{-18}}{n^2}$$

where n is an integer and E is in joules.

(i) By reference to this equation, describe how the Bohr model accounts for the line spectrum of the hydrogen atom. *[4]*

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(ii) Calculate the shortest wavelength of light in the spectrum of atomic hydrogen. *[2]*

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(iii) State **one** characteristic of the spectrum of atomic hydrogen which cannot be accounted for by the Bohr model. *[1]*

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(b) Outline by reference to position and momentum how the Schrödinger model of the hydrogen atom is consistent with the Heisenberg uncertainty principle. *[3]*

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Option F — Astrophysics

F1. This question is about comets and stars.

(a) State **one** difference (other than size) between the orbit of a typical comet and the orbit of the Earth around the Sun. *[1]*

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(b) The average distance between the stars in a galaxy is about 2 pc. A typical galaxy has a volume of 10^{12} pc^3. Estimate the number of stars in the galaxy. *[2]*

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F2. This question is about magnitude and apparent brightness.

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

Apparent brightness: . . . . . .

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Apparent magnitude: . . . . . .

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(This question continues on the following page)

(Question F2 continued)

(b) The table gives information on the peak absolute magnitude and the peak apparent brightness of two Cepheid stars.

star	**(peak) absolute magnitude**	**(peak) apparent brightness**
Delta Cephei	–3.47	9.0×10^{-10} Wm^{-2}
Zeta Geminorum	–4.13	7.2×10^{-10} Wm^{-2}

State and explain whether Delta Cephei or Zeta Geminorum

(i) appears brighter from Earth. *[1]*

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(ii) is closer to Earth. *[2]*

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(c) The luminosity of a Cepheid star is variable. Outline the reason for this variation. *[2]*

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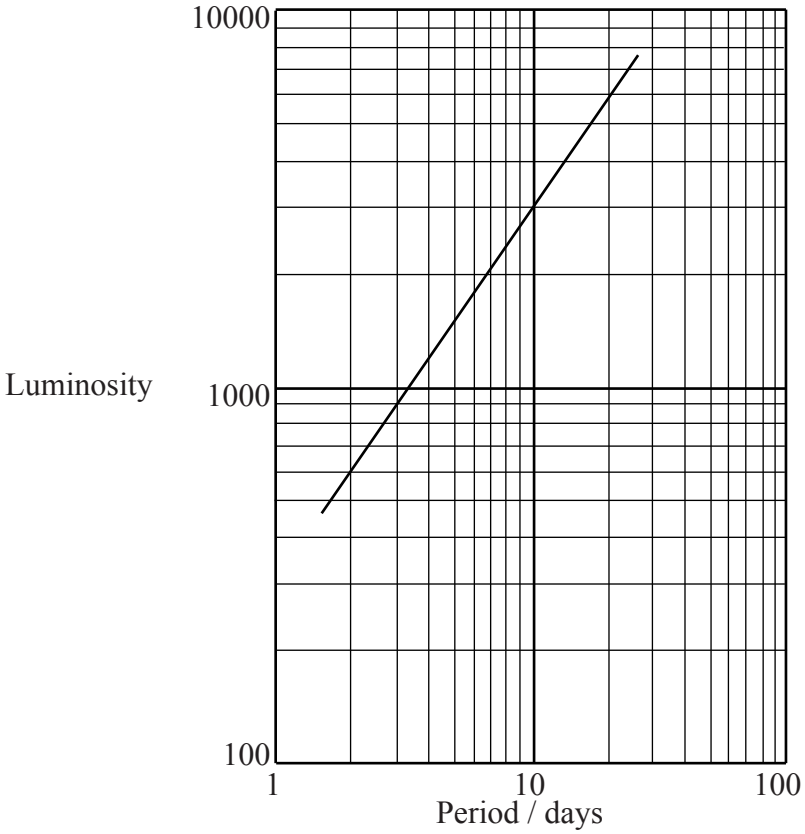
(Question F2 continued)

The graph shows the variation with period of the peak luminosity of Cepheid stars.



The luminosity is given in terms of the solar luminosity of 3.9×10^{26} W.

(This question continues on the following page)

(Question F2 continued)

(d) (i) Outline how data from the graph may be used to determine the distance of a galaxy from Earth. *[3]*

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(ii) The peak apparent brightness of Zeta Geminorum is 7.2×10^{-10} Wm^{-2} and the period of variation of luminosity is approximately 10 days.

Use data from the graph on previous page to deduce that the distance to Zeta Geminorum from Earth is about 1.1×10^{19} m. *[2]*

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F3. This question is about cosmic microwave background radiation.

(a) State what is meant by cosmic microwave background radiation. *[2]*

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(b) Describe how the cosmic microwave background radiation provides evidence for the expanding universe. *[3]*

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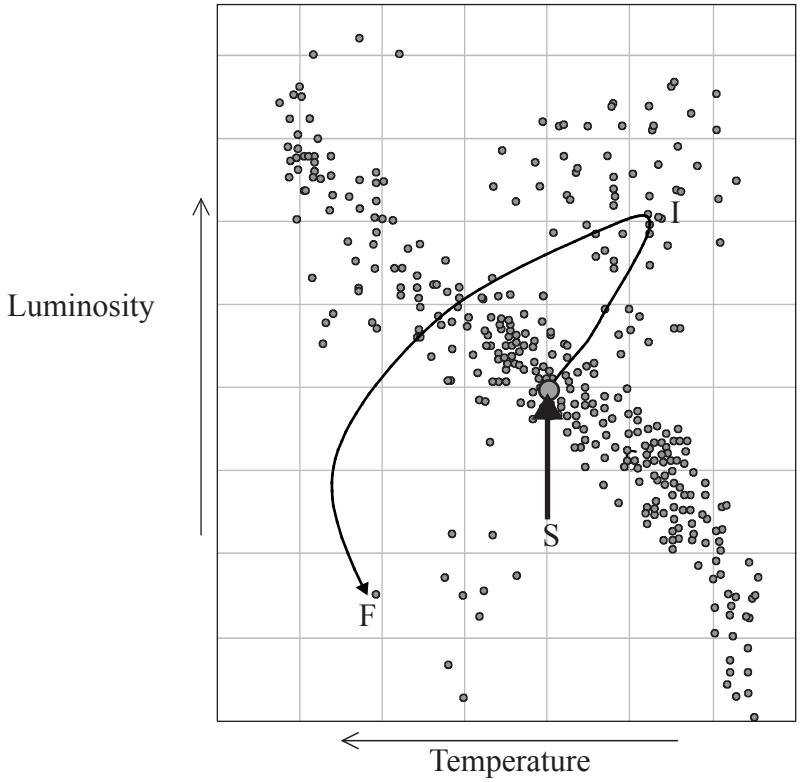
F4. This question is about stellar evolution.

A partially completed Hertsprung-Russel (H-R) diagram is shown below.



The line indicates the evolutionary path of the Sun from its present position, S, to its final position, F. An intermediate stage in the Sun's evolution is labelled by I.

(a) State the condition for the Sun to move from position S. *[1]*

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(b) State and explain the change in the luminosity of the Sun that occurs between positions S and I. *[2]*

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(This question continues on the following page)

(Question F4 continued)

(c) Explain, by reference to the Chandrasekhar limit, why the final stage of the evolutionary path of the Sun is at F. *[2]*

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(d) On the diagram on the previous page, draw the evolutionary path of a main sequence star that has a mass of 30 solar masses. *[1]*

F5. This question is about Hubble's law.

(a) State Hubble's law. *[1]*

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(b) Deduce an expression for the age T of the Universe in terms of the Hubble constant H. *[3]*

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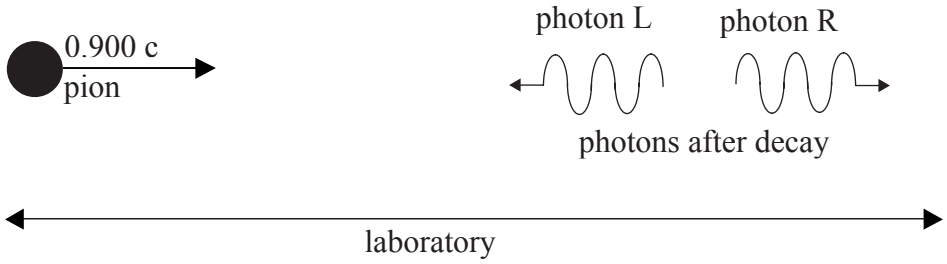
Option G — Relativity

G1. This question is about the speed of light.

A pion is an unstable particle that decays into two photons. A particular pion, travelling at 0.900 c with respect to an observer at rest in a laboratory, decays into two photons, L and R, travelling in opposite directions as shown in the diagram.



The speed of both photons as measured by the observer at rest with respect to the pion is c.

(a) Calculate the velocity of photon R with respect to the observer in the laboratory using

(i) Galilean kinematics. *[1]*

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(ii) relativistic kinematics. *[3]*

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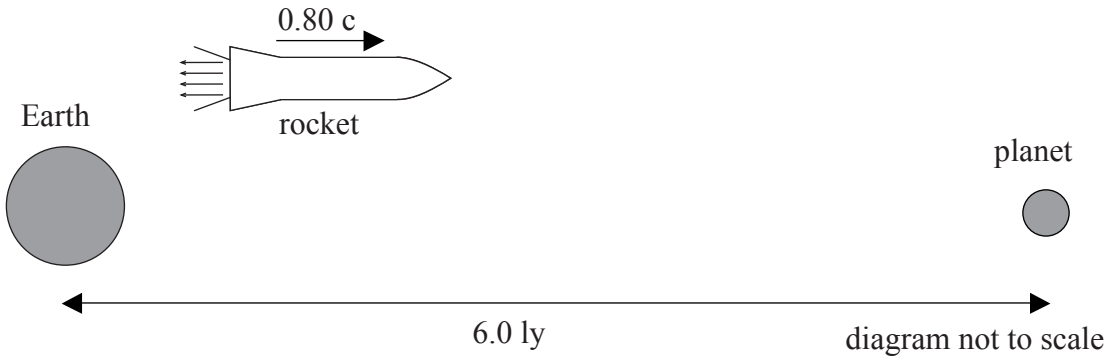
G2. This question is about relativistic kinematics.

A rocket moving at 0.80 c, relative to Earth, passes the Earth on its way to a distant planet. As measured by an observer on Earth the distance between Earth and the planet is 6.0 ly.



(a) Calculate the duration of the journey from Earth to the planet according to the observer

(i) on Earth. *[1]*

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(ii) in the rocket. *[2]*

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(This question continues on the following page)

(Question G2 continued)

(b) The rocket passes a space station that is at rest with respect to the Earth. The proper length of the rocket and the proper length of the space station are both 40 m.

(i) Define *proper length*. *[1]*

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(ii) Determine the length of the space station according to the observer in the rocket. *[2]*

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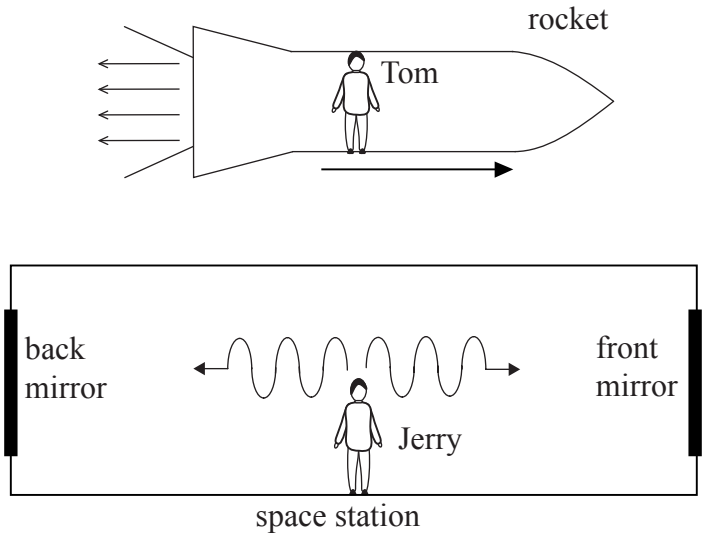
(This question continues on the following page)

(Question G2 continued)

(c) Tom is an observer in a rocket that moves past a space station. Jerry is an observer in the middle of the space station. Jerry sends two light signals towards mirrors at the front and the back of the space station. The signals are emitted simultaneously according to Tom and according to Jerry.

The signals are reflected off the mirrors and are received by Jerry.



Determine, **according to Tom**, whether

(i) the front or the back of the space station receives the signal first or whether the signals arrive simultaneously. *[2]*

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(ii) the reflected signals arrive at Jerry simultaneously. *[2]*

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G3. This question is about relativistic mechanics.

(a) A proton of rest mass 938 $MeVc^{-2}$ is accelerated from rest through a potential difference V. With respect to an observer in the laboratory the speed of the proton after acceleration is 0.998 c. Calculate the value of the accelerating potential difference as measured by the observer. *[4]*

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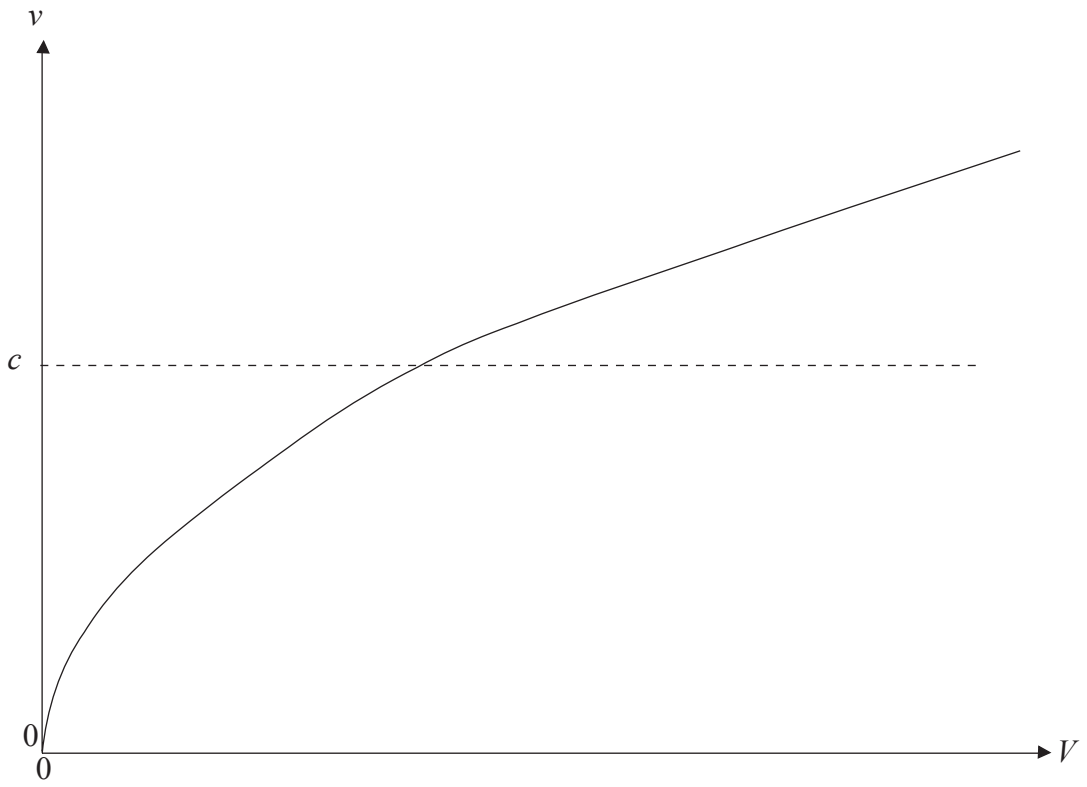
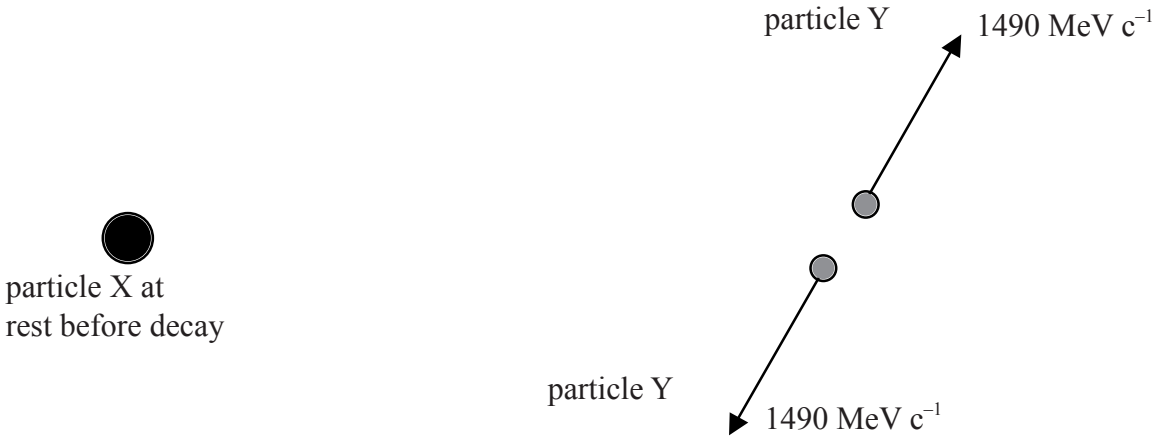
(b) The graph below shows the variation with accelerating potential difference V of the speed v of a proton after acceleration, according to Newtonian mechanics.



On the graph, draw a line to show the variation with accelerating potential difference V of the speed v of a proton according to relativistic mechanics. *[2]*

G4. This question is about a relativistic decay.

Particle X has rest mass 3520 MeV c^{-2}. It decays at rest in a laboratory, into two identical particles Y. The two particles move in opposite directions with momentum 1490 MeV c^{-1} with respect to the laborary as shown in the diagram.



Determine the rest energy, in units of MeV, of particle Y. *[4]*

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G5. This question is about black holes.

(a) Define the *Schwarzchild radius* of a black hole. *[1]*

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(b) Suggest why the Schwarzchild radius of a black hole is likely to increase with time. *[2]*

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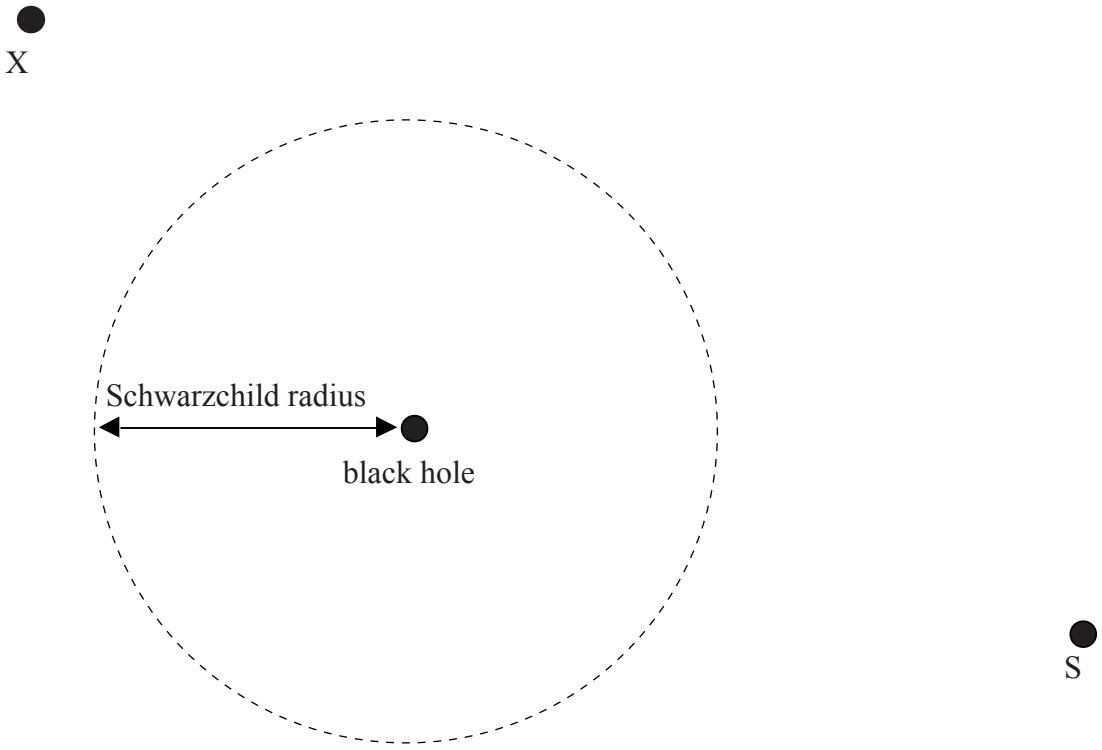
(c) The diagram shows a black hole with Schwarzchild radius *R*.



An observer at X sends a signal that is received by the spacecraft S.

(i) On the diagram, draw a line to indicate a possible path of the radio signal. *[1]*

(ii) Explain the path you have drawn. *[2]*

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Option H — Optics

H1. This question is about refraction.

(a) Define *refractive index*. *[1]*

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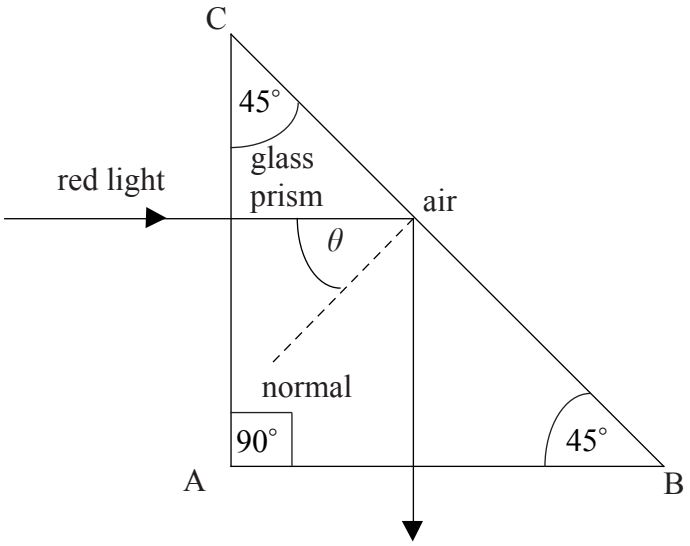
(b) The diagram below shows the path of a ray of red light incident on a 45° prism.



The light undergoes total internal reflection at face BC.

(i) State the value of the angle of incidence θ on face BC. *[1]*

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(ii) Determine the minimum refractive index of the glass of the prism for total internal reflection of the ray at face BC. *[3]*

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(c) The red light is replaced by blue light. Explain why the path of blue light is the same as that of the red light. *[2]*

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H2. This question is about image formation by a converging lens.

(a) Define the *principal focus (focal point)* of a converging lens. *[2]*

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(b) An object is placed 30 cm in front of a converging lens of focal length 15 cm. The object is moved 5.0 cm closer to the lens. Determine the displacement of the image. *[4]*

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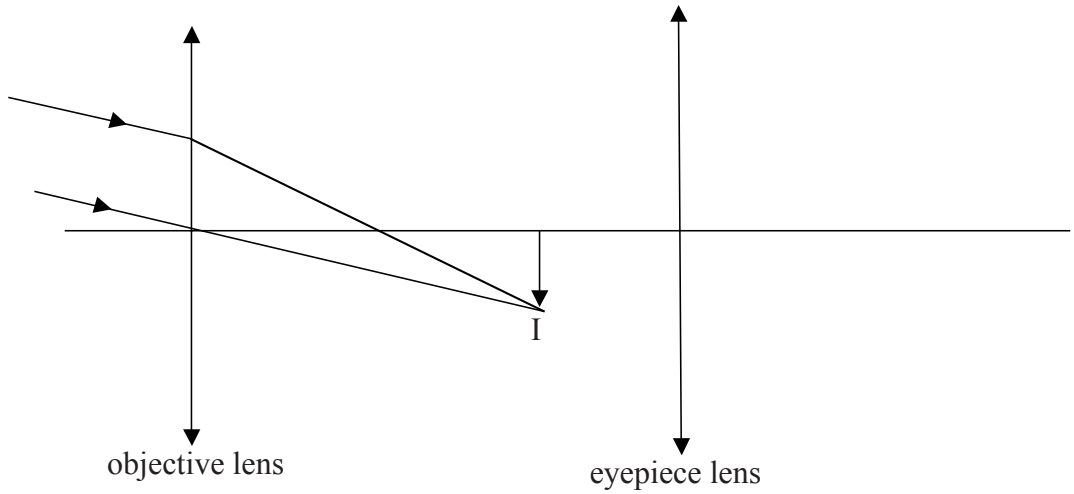
H3. This question is about an astronomical telescope.

The diagram shows two converging lenses adjusted to form an astronomical telescope.



The objective lens has a focal length f_o and the eyepiece lens has a focal length f_e. The objective lens forms an image of a distant object at I. The final image is formed at infinity.

(a) State, in terms of f_o and f_e, the separation of the objective lens and the eyepiece lens. *[1]*

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(b) On the diagram, draw rays to show the formation of the image produced by the eyepiece lens. *[4]*

(c) (i) Define *angular magnification*. *[1]*

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(ii) State, in terms of f_o and f_e, the angular magnification of the telescope. *[1]*

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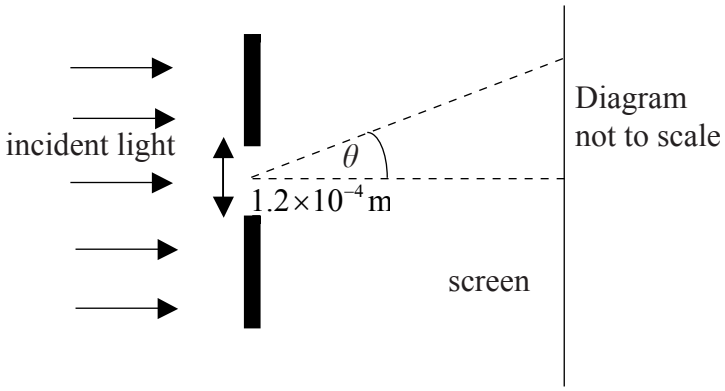
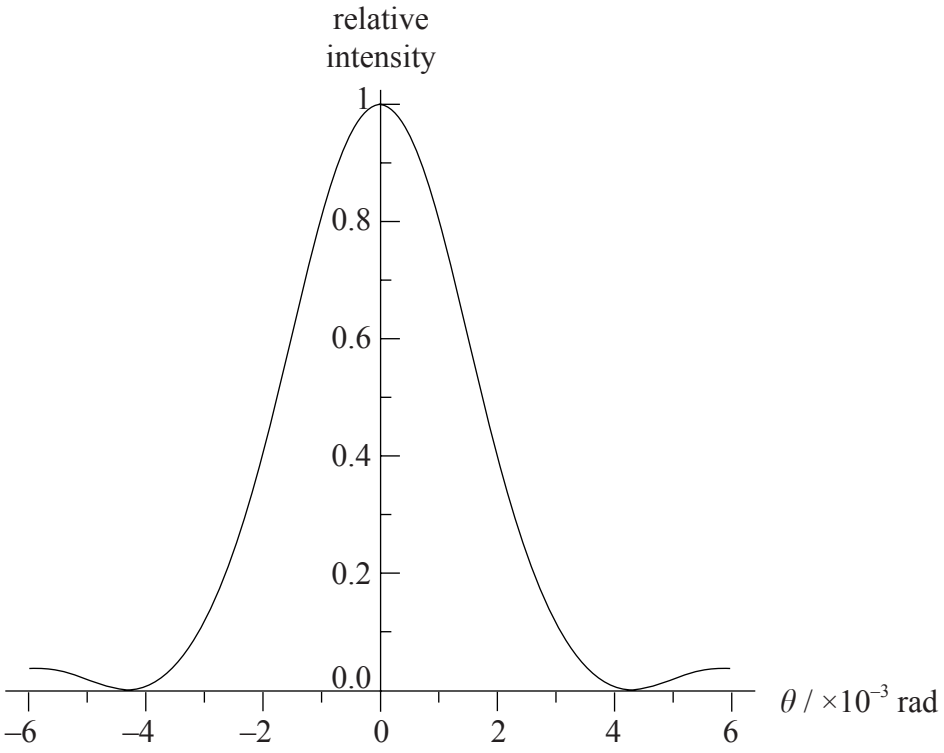
H4. This question is about diffraction.

Monochromatic light is incident on a single slit of width 1.2×10^{-4} m.



The graph shows the variation with angle θ of the intensity of the light on the screen.



(a) Use the graph to estimate the wavelength of the light. *[1]*

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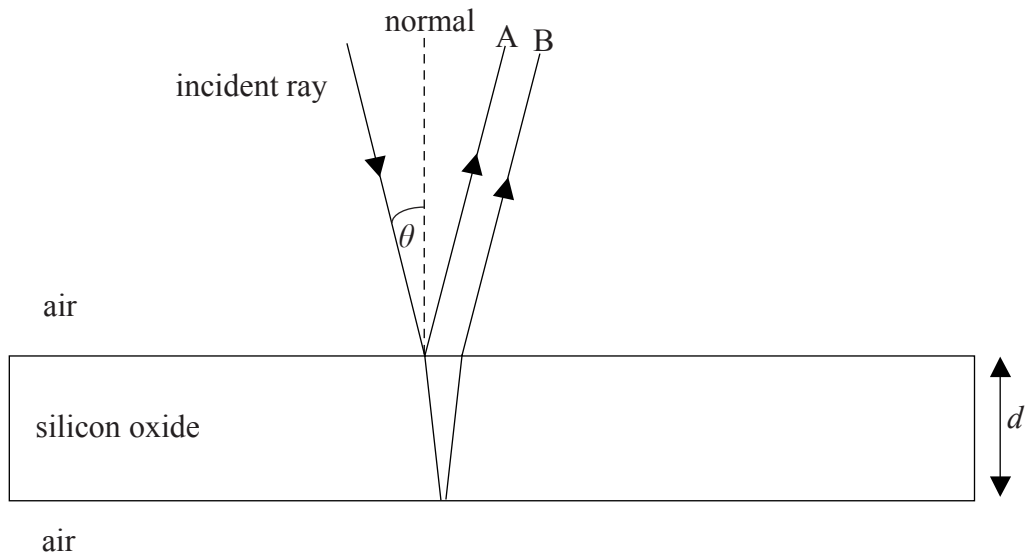
(b) Monochromatic light is incident on two parallel slits. After passing through the slits, the light is incident on a screen. The separation of the slits is approximately twice the slit width. On the axes above draw a graph to show the intensity distribution of the light on the screen. *[2]*

H5. This question is about thin film interference.

The diagram shows monochromatic light in air, that is incident on a thin film of silicon oxide of thickness *d*.



The light is incident at an angle θ to the normal to the surface. Light is reflected along directions A and B.

(a) State why light waves along A and B are coherent. *[1]*

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(b) The wavelength of the light in the silicon oxide film is 452 nm. The light is incident normally on the surface so that $\theta = 0$. Calculate the minimum thickness of the film such that light along A and B undergoes destructive interference. *[4]*

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(c) The light incident on the film is replaced by white light. State and explain the appearance of the film in this case. *[2]*

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