22086512

International Baccalaureate®
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

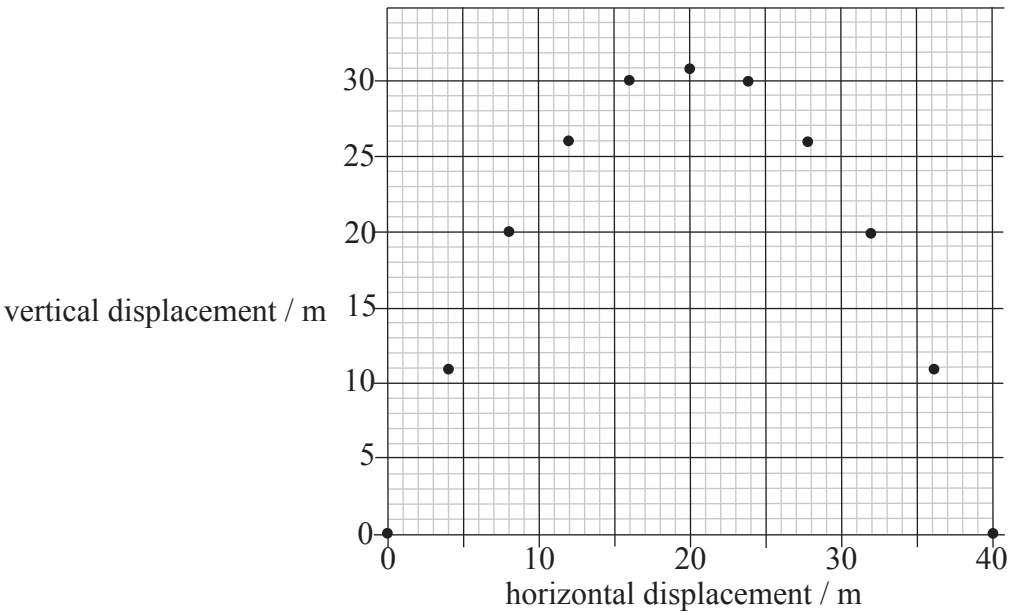
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover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

0132

Option A — Mechanics Extension

A1. This question is about projectile motion.

A ball is kicked at an angle to the horizontal. The diagram below shows the position of the ball every 0.50 s.



The acceleration of free fall is $g = 10\,\text{m s}^{-2}$. Air resistance may be neglected.

(a) Using the diagram determine, for the ball

(i) the horizontal component of the initial velocity. *[1]*

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(ii) the vertical component of the initial velocity. *[2]*

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(iii) the magnitude of the displacement after 3.0 s. *[2]*

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(b) On the diagram above draw a line to indicate a possible path for the ball if air resistance were not negligible. *[2]*

A2. This question is about orbital motion.

(a) State Newton's universal law of gravitation. *[3]*

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(b) Deduce that the period, T, of a satellite orbiting a planet of mass, M, in a circular orbit of radius, r, is given by *[4]*

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

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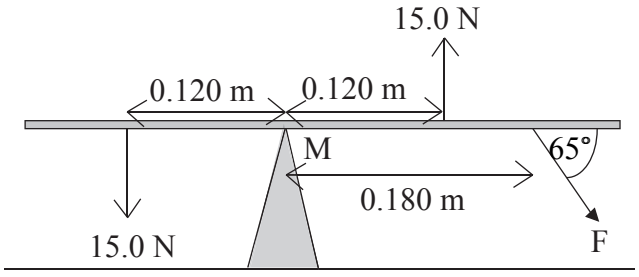
A3. This question is about rotational equilibrium.

A uniform rod is pivoted freely at its mid-point M. The rod is held horizontal by three forces as shown.



(a) Determine the total torque, about point M, produced by the two 15.0 N forces. *[3]*

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(b) The force F makes an angle of 65°. Determine the magnitude of F required to keep the rod in (a) in equilibrium. *[3]*

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Option B — Quantum Physics and Nuclear Physics

B1. This question is about models of the hydrogen atom.

(a) Outline how the Bohr model of the hydrogen atom accounts for the spectrum of hydrogen. *[3]*

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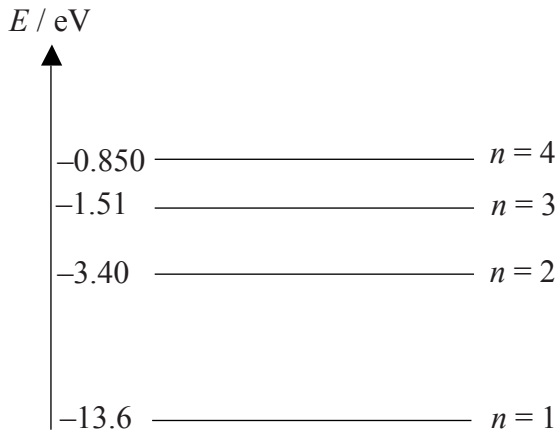
(b) The diagram below shows some of the energy levels of the hydrogen atom.



(i) Outline, by reference to the diagram, what is meant by the term *quantization of energy*. *[1]*

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(ii) Deduce that for the transition from the level $n = 2$ to the level $n = 1$, the wavelength of the photon emitted is 1.22×10^{-7} m. *[2]*

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(iii) Suggest why the lines in the spectrum of atomic hydrogen become closer together as the wavelength of the emitted photons decreases. *[2]*

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(This question is continued on the following page)

(Question B1 continued)

(c) Outline how the concept of matter waves leads to the Schrödinger model of the hydrogen atom. *[4]*

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B2. This question is about nuclear energy levels and radioactive decay.

A thallium nucleus $\left({}^{207}_{81}\mathrm{Tl}\right)$ undergoes decay to form a nucleus of lead-207 $\left({}^{207}_{82}\mathrm{Pb}\right)$.

(a) State the nuclear reaction equation for the decay of thallium-207. *[2]*

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(b) Explain for the decay of thallium-207

(i) why γ-ray photons are also emitted. *[2]*

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(ii) why the particles emitted do not all have the same energy. *[2]*

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(This question continues on the following page)

(Question B2 continued)

(c) State for the decay of thallium-207 in (a)

(i) the name of the fundamental interaction involved. *[1]*

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

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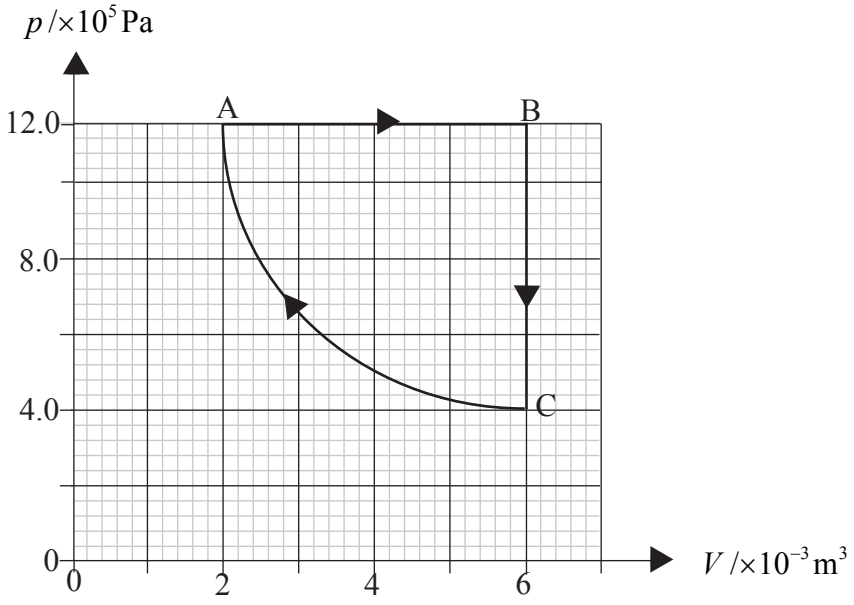
Option C — Energy Extension

C1. This question is about a heat engine.

A quantity of an ideal gas is used as the working substance of a heat engine. The cycle of operation of the engine is shown in the *p*-*V* diagram below.



The temperature of the gas at A is 300 K.

(a) Calculate the temperature, at B, of the gas. *[2]*

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(b) During the change $A \rightarrow B$ the change in internal energy of the gas is 7.2 kJ. Determine the amount of thermal energy transferred. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(c) State why, for the change $B \rightarrow C$, the change in the internal energy of the gas is numerically the same as that in (b). *[2]*

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(d) The work done on the gas in the change $C \rightarrow A$ is 2.6 kJ. Calculate

(i) the net work done in one cycle. *[2]*

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(ii) the efficiency. *[2]*

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C2. This question is about nuclear power.

(a) A fuel often used in nuclear reactors is uranium. Explain why uranium is a non-renewable energy source. *[1]*

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(b) One nuclear reaction that takes place in a reactor is

$$ {}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{236}_{92}\mathrm{U} \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + x\,{}^{1}_{0}\mathrm{n} $$

(i) State the number x of neutrons produced in this reaction. *[1]*

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(ii) Using the equation explain what is meant by a *chain reaction*. *[2]*

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(iii) Explain how, in a reactor, the production of energy in a chain reaction is controlled. *[2]*

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(This question continues on the following page)

(Question C2 continued)

(c) Outline how the energy produced in fission reactions is transferred to thermal energy. *[3]*

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(d) State **one** advantage of nuclear power production compared to fossil fuel power production. *[1]*

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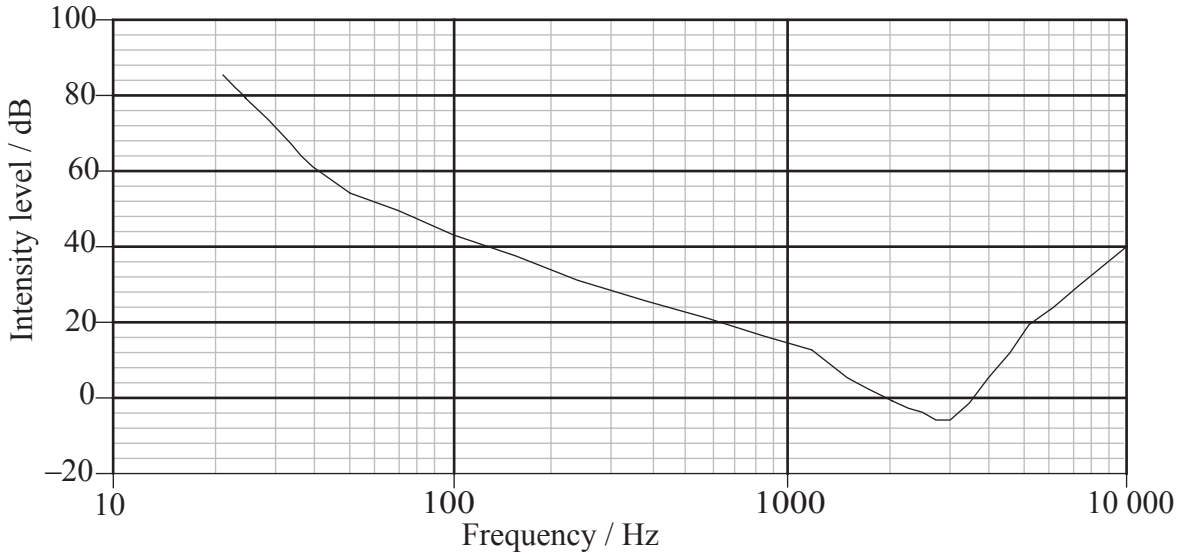
The diagram below shows a sketch of the variation with frequency *f* of the intensity level *IL* of sound heard by a young person with normal hearing.



(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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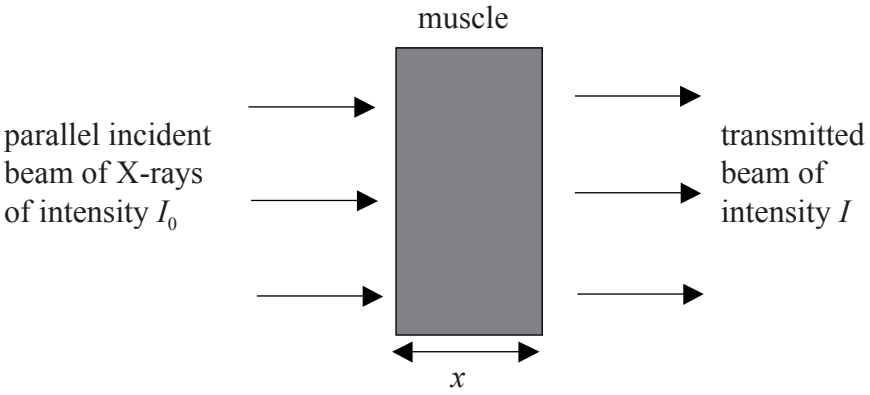
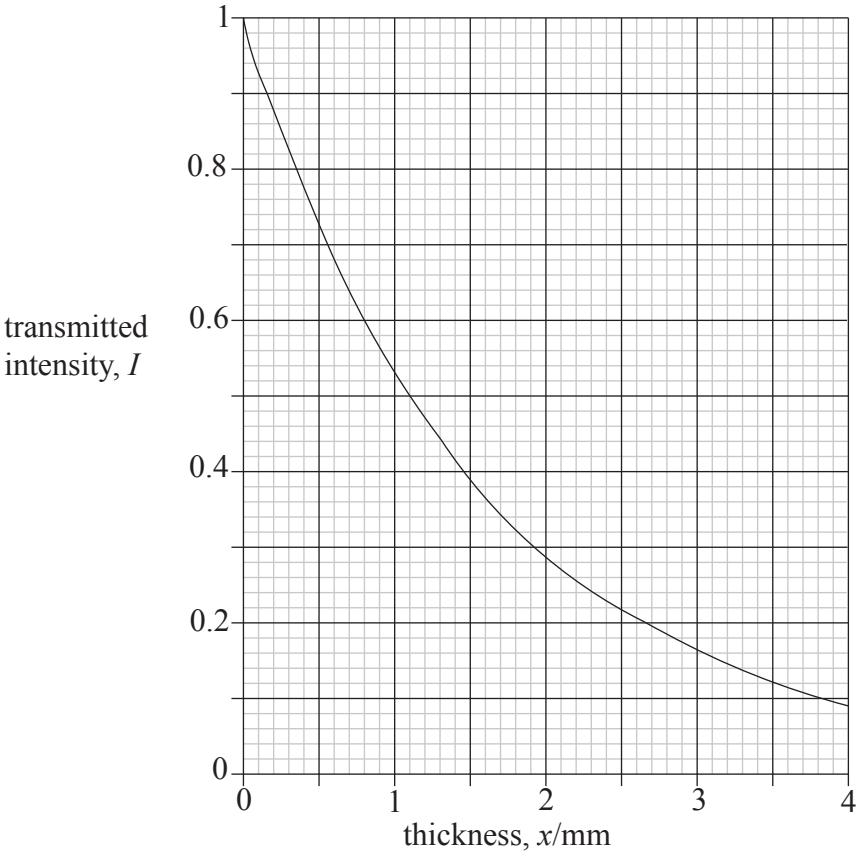
D3. This question is about X-rays.

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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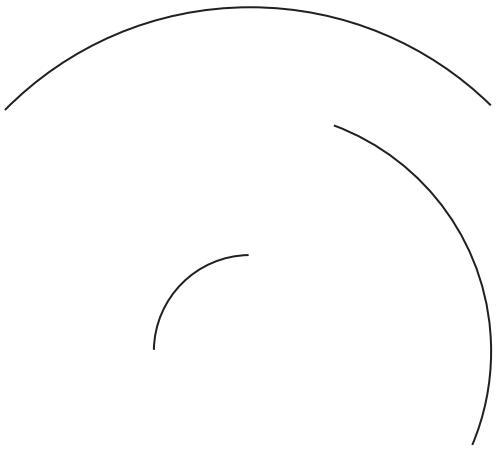
Option E — The History and Development of Physics

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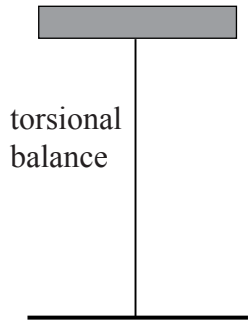
E4. This question is about the inverse square law in electrostatics.

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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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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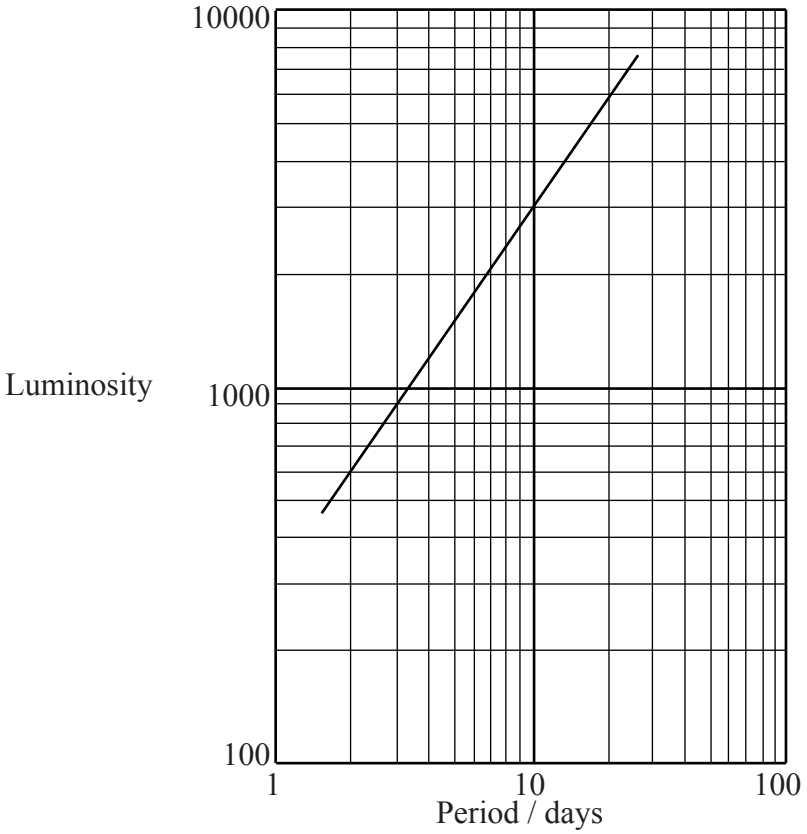
(This question continues on the following page)

(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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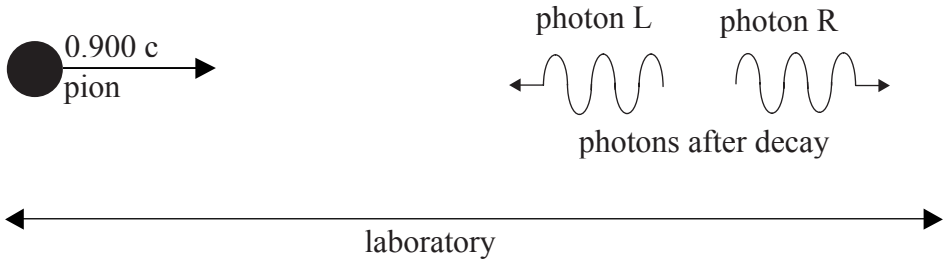
Option G — Relativity

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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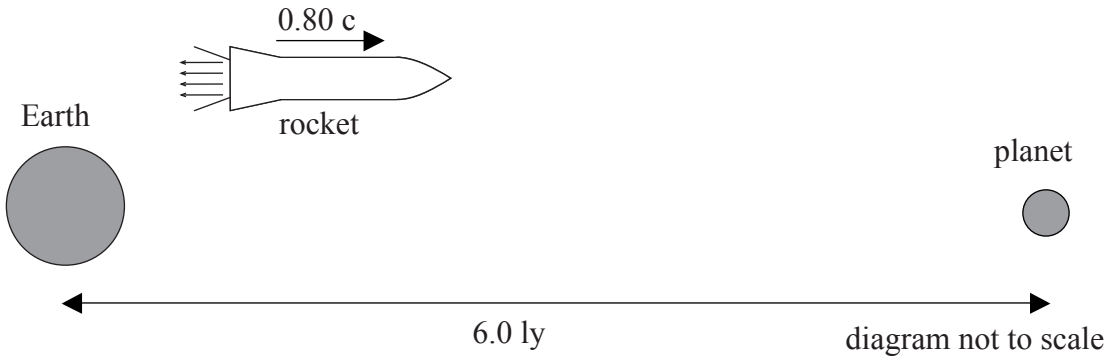
G2. This question is about relativistic kinematics.

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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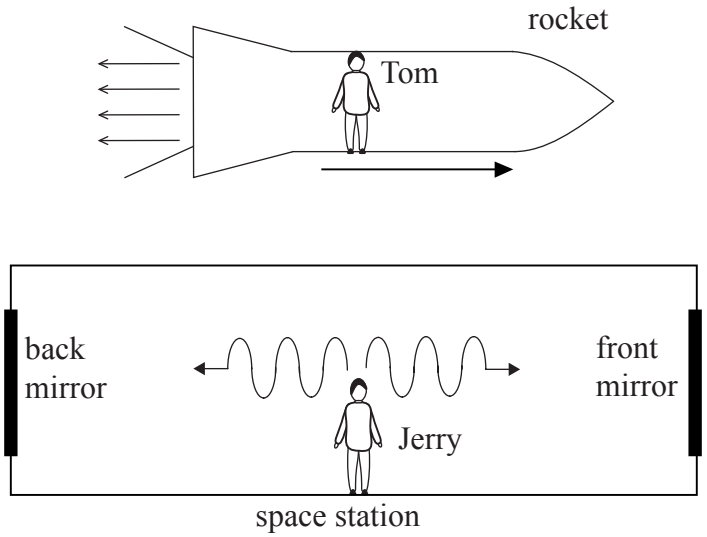
(This question continues on the following page)

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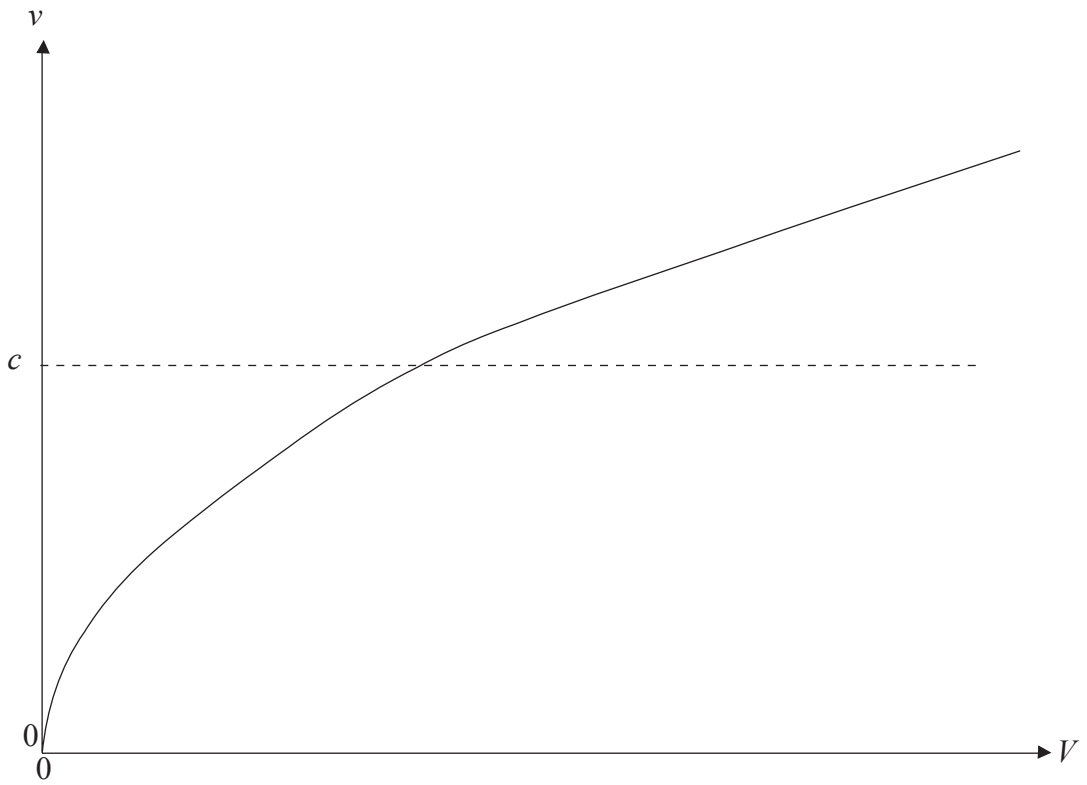
(b) The graph below shows the variation with accelerating potential difference V of the speed v of a proton after acceleration, according to Newtonian mechanics.



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]*

Option H — Optics

H1. This question is about refraction.

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

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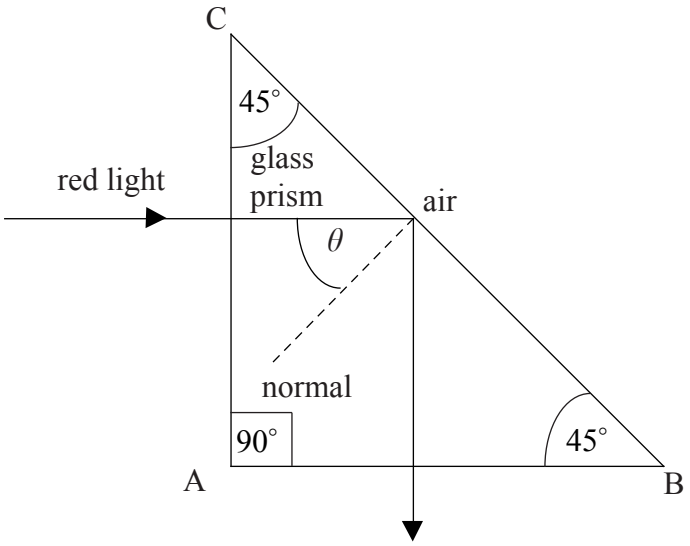
(b) The diagram below shows the path of a ray of red light incident on a 45° prism.



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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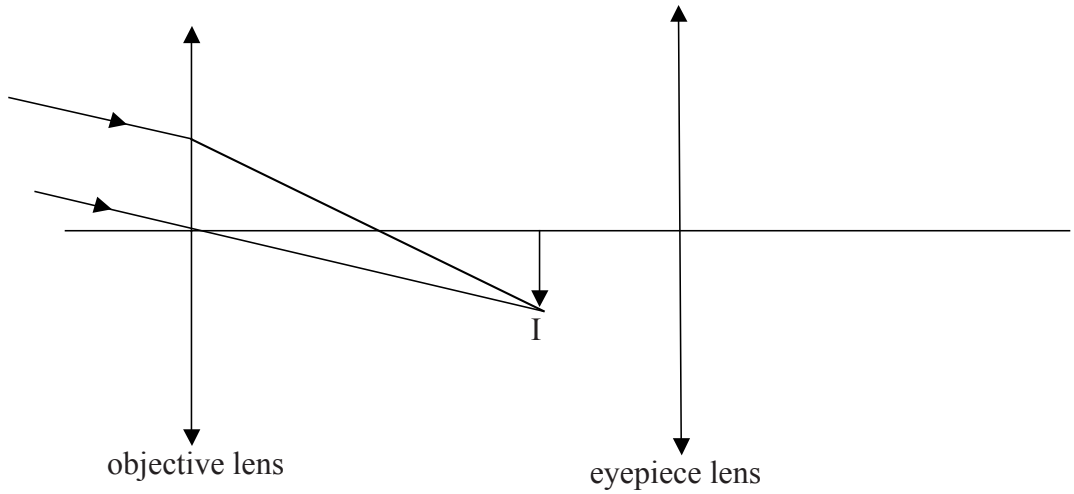
H3. This question is about an astronomical telescope.

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]*

. . . . . .

(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]*

. . . . . .