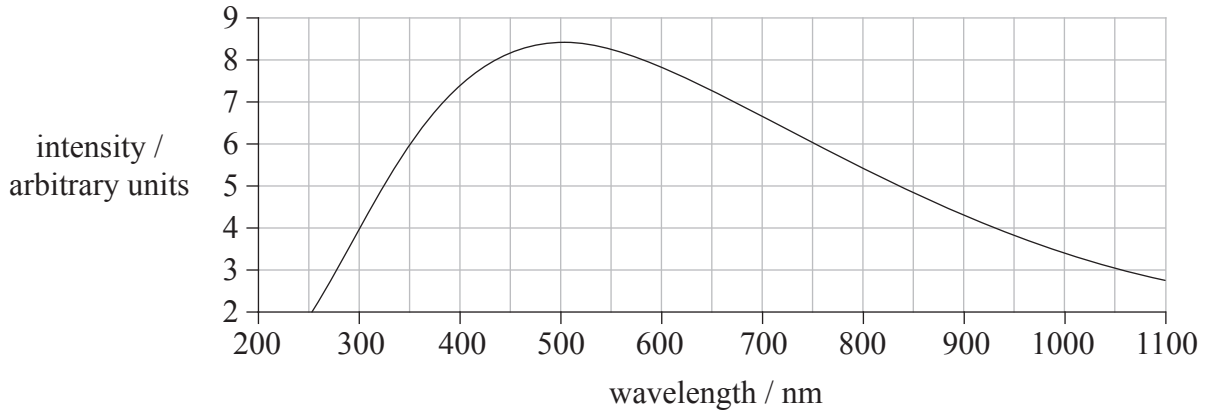


Option F — Astrophysics

F1. This question is about the Sun.

The black body spectrum of the Sun is shown below.



(a) Deduce that the surface temperature of the Sun is approximately 5800 K. [2]

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(b) The emission spectrum of the Sun is crossed by dark lines. Outline how these lines are used to determine the chemical composition of the Sun's atmosphere. [3]

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F2. This question is about the luminosity of stars.

(a) Define *luminosity*. [1]

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(b) Data for the surface temperature T and the radius R of two stars A and B are given in the table below.

	T / K	R / km
Star A	3.0×10^3	8.7×10^{11}
Star B	2.0×10^4	6.8×10^7

Using **only** data from the table, determine the ratio $\frac{\text{luminosity of A}}{\text{luminosity of B}}$. [3]

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F3. This question is about the Sun and the star Sirius A.

The table below gives data for the Sun and the star Sirius A.

Star	Apparent brightness / W m^{-2}	Luminosity (relative units)
Sun	1.4×10^3	1.0
Sirius A	1.1×10^{-7}	23

(a) Explain which star will have the greatest apparent magnitude. [2]

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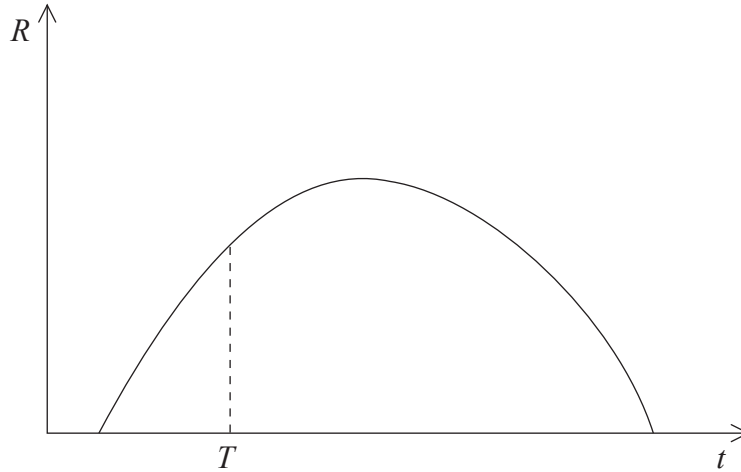
(b) Using the data from the table, deduce that the distance of Sirius from Earth is 5.4×10^5 AU. [3]

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F4. This question is about the development of the universe.

The diagram below shows the variation with time t of the radius R of the observable universe, based on a closed model of the universe. The point $t = T$ is the present time.



(a) State what is meant by a closed universe. [1]

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(b) On the diagram above, draw the variation with time t of the radius R of the observable universe, based upon an open model of the universe. [3]

(c) Explain, by reference to your answer to (b), why the predicted age of the universe depends upon the model of the universe chosen. [2]

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F5. This question is about nuclear synthesis in stars.

(a) Under certain circumstances, the gravitational collapse of a gas may initiate nuclear fusion and hence form a star. State the **two** conditions necessary for nuclear fusion to be initiated. [2]

1.

2.

(b) The nuclear fusion process of a main sequence star essentially involves the fusion of hydrogen to helium. When all the hydrogen is fused, it will develop into either a red giant or a red supergiant.

(i) State what property of the star determines whether it will become a red giant **or** red supergiant. [1]

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(ii) Compare the changes in nuclear synthesis that take place in a red giant to those that take place in a red supergiant. [3]

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F6. This question is about Hubble’s law.

(a) Two galaxies are separated by a distance d . Use Hubble’s law to derive an expression for the time T it has taken for the galaxies to reach this separation. [2]

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(b) Assuming a value of the Hubble constant $H=80\text{ km s}^{-1}\text{ Mpc}^{-1}$, and using your answer to (a), estimate that the age of the universe is about 10^{10} years. (1 year= 3.2×10^7 s) [2]

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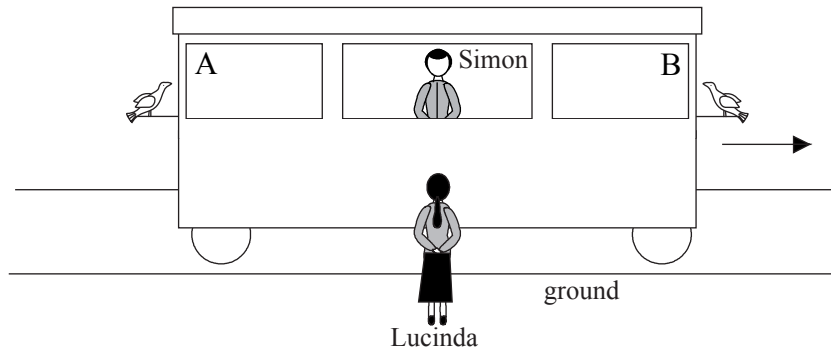


Option G — Relativity

G1. This question is about simultaneity.

In the diagram below, Simon is in a railway carriage that is travelling in a straight-line with uniform speed relative to Lucinda who is standing on the ground by the track. There is a window at each end A and B of the railway carriage. Simon determines his position to be at the midpoint of the railway carriage.

At the instant that Simon and Lucinda are opposite each other, a bird lands at end A of the carriage and another one lands at end B of the carriage. Lucinda determines that the two birds land simultaneously.



State, and explain, whether Simon will observe the landings of the birds to be simultaneous. [4]

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G2. This question is about time dilation.

The distance between a star and Earth is 5.0×10^{16} m as measured by an observer on Earth. An astronaut in a spaceship is moving from the Earth towards the star at a speed of $0.60c$ as measured by the observer on Earth.

(a) Calculate the time taken to travel from the Earth to the star as measured by

(i) the observer on Earth. [2]

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(ii) the astronaut. [2]

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(b) State, and explain, which of your answers in (a) is the proper time. [2]

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(c) At the time when the astronaut leaves the Earth, the astronaut and the observer on Earth are the same age. After reaching the star the astronaut returns to Earth. Explain any age difference between the astronaut and the observer on the astronaut's return to Earth. [3]

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G3. This question is about relativistic mass and energy.

(a) Outline why it is not possible for an object with rest mass to attain the speed of light. [3]

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(b) An electron is accelerated from rest through a potential difference of 6.00×10^6 V.

After acceleration,

(i) state the total energy of the electron in MeV. [1]

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(ii) deduce that the speed of the electron is $0.997c$. [3]

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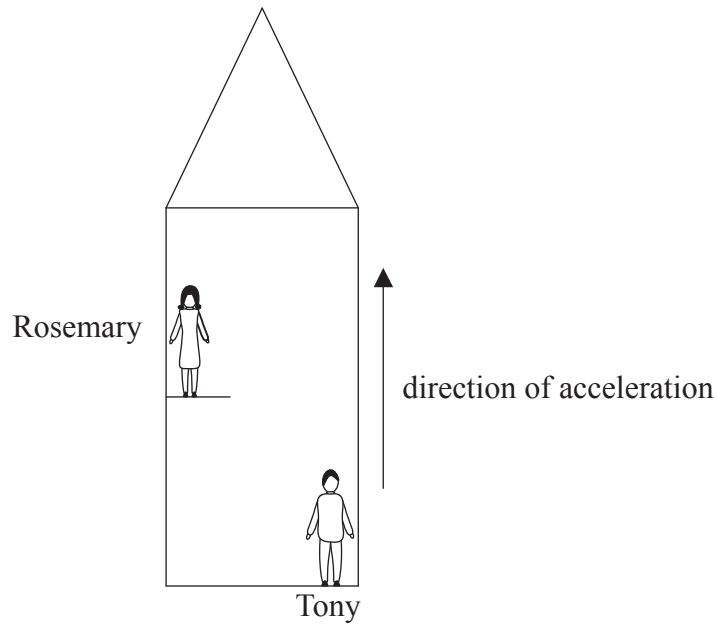
G4. This question is about relativistic momentum.

An electron is accelerated from rest through a potential difference of 2.00×10^6 V. Determine the momentum in $\text{MeV } c^{-1}$ of the electron after acceleration. (Rest mass of electron = $0.511 \text{ MeV } c^{-2}$.) [4]

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G5. Tony and Rosemary are in an accelerating spaceship as shown below.



Rosemary throws a ball in a direction horizontal to the floor that Tony is standing on.

(a) On the diagram above, draw the path of the ball as seen by Tony. [1]

(b) Describe how this situation relates to Einstein's principle of equivalence. [3]

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(c) Both Tony and Rosemary have a light source. When the acceleration of the spaceship is zero the frequency of the light emitted, as measured by Tony and Rosemary, is the same.

State

(i) how the frequency of the sources compare to Rosemary when the spaceship is accelerating in the direction shown. [1]

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(ii) the name of the phenomenon you have used in your answer to (c)(i). [1]

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Option H — Optics

H1. This question is about refraction.

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

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(b) In a certain medium, the speed of light of a particular frequency is $2.1 \times 10^8 \text{ m s}^{-1}$. Calculate the refractive index of the medium for this frequency. [2]

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(c) With reference to your answer in (b), describe what is meant by optical dispersion. [3]

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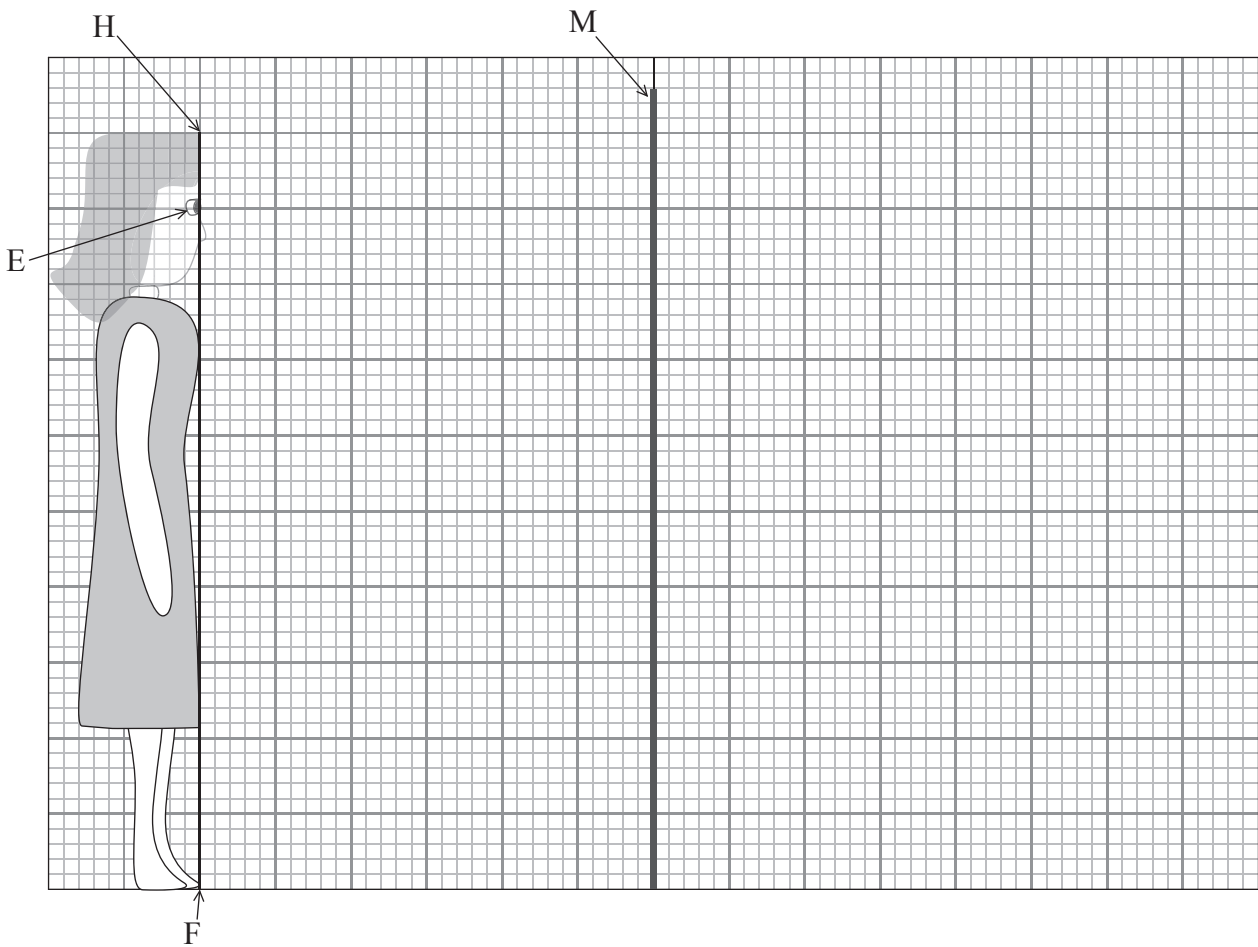


H2. This question is about image formation by a plane mirror.

(a) State the **two** laws of reflection of light. [2]

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- 2.
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(b) In the diagram below, the line labelled HF represents a person standing in front of a vertical mirror labelled M. The position of the person's eye is labelled E.



On the diagram above draw

(i) the position of the image of the person, formed by the mirror. [2]

(ii) a ray from the foot F, and a ray from the top of the head H, to show the reflection of these rays into the eye E. [2]

(This question continues on the following page)



(Question H2 continued)

- (c) The height of the person is 1.50 m and her eye is 1.35 m above the floor. The length and height of the mirror above the floor are adjusted so that she can just see the whole of her image in the mirror.

By reference to your ray diagram in (b)(ii), deduce

- (i) the minimum length of the mirror. [1]

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- (ii) the height of the lower edge of the mirror above the floor. [1]

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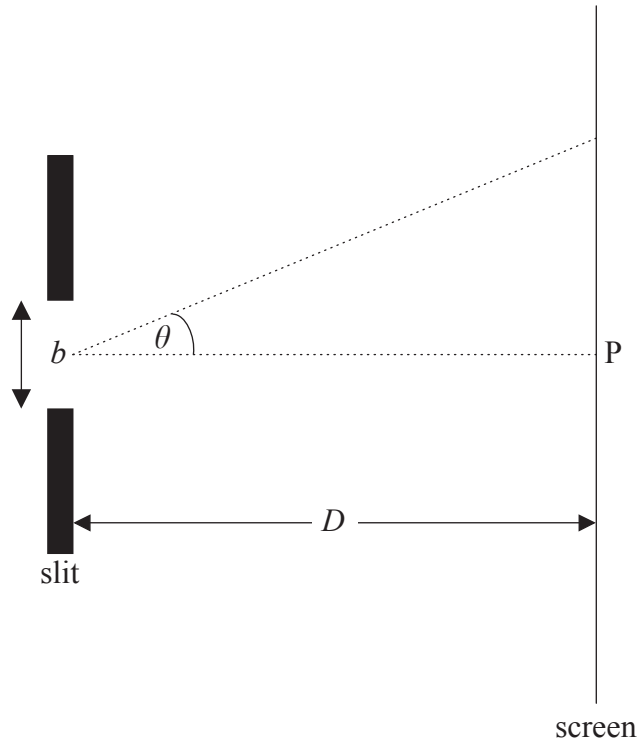
- (d) The person now stands further away from the mirror. State the effect, if any, that this has to your answers in (c)(i) and (ii). [1]

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H4. This question is about diffraction.

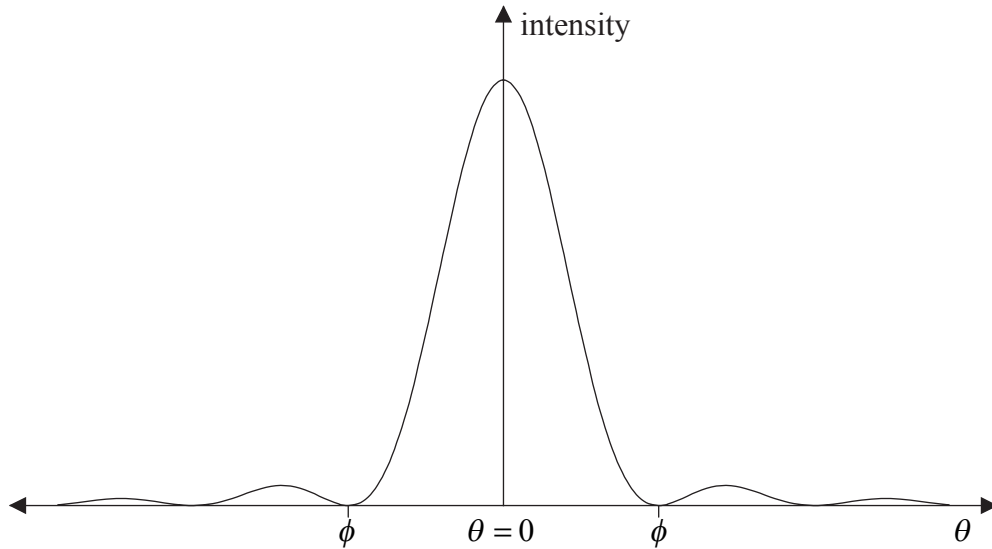
Plane wavefronts of monochromatic light of wavelength λ are incident on a rectangular slit of width b . After passing through the slit, the light is brought to a focus on a screen distance D from the slit as shown below. The width of the slit is comparable to the wavelength of the incident light and $b \ll D$. The point P on the screen is opposite the centre of the slit.



(This question continues on the following page)

(Question H4 continued)

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



(a) Explain qualitatively, this intensity distribution. [3]

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(b) The angle $\theta = \phi$ is the angular half-width of the central maximum of the intensity distribution and is given by the expression $\phi = \frac{\lambda}{b}$. Derive an expression in terms of D , λ and b for the half-width d of the central maximum. [2]

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(This question continues on the following page)



(Question H4 continued)

- (c) The single slit is replaced by two rectangular slits of width b . The distance between the centre of the slits is equal to $2b$.

On the axes below, draw a sketch of the of the intensity distribution on the screen.
(The intensity distribution of a single slit is shown by the dotted line.)

[2]

