Diploma Programme
Programme du diplôme
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Physics
Higher level
Paper 2

29 April 2026

Zone A morning | **Zone B** morning | **Zone C** morning

Session number

2 hours 30 minutes

Instructions to students

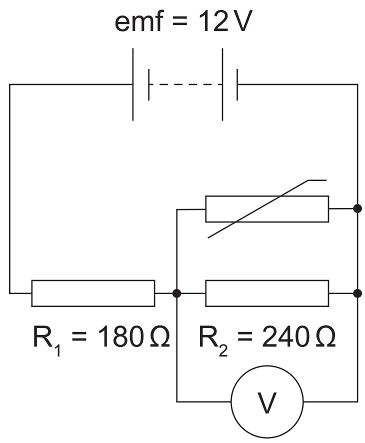
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.

2226 – 4730

23 pages

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A battery of emf 12 V and negligible internal resistance is connected to two resistors and a thermistor as shown.



(This question continues on the following page)

(Question 1 continued)

(a) At a particular temperature the reading of the voltmeter is 3.0 V.

(i) Show that, at this temperature, the current in the battery is 50 mA. [2]

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(ii) Calculate the resistance of the thermistor. [2]

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(b) The resistance of the thermistor decreases when the temperature increases. State and explain what happens to the voltmeter reading as the temperature increases. [3]

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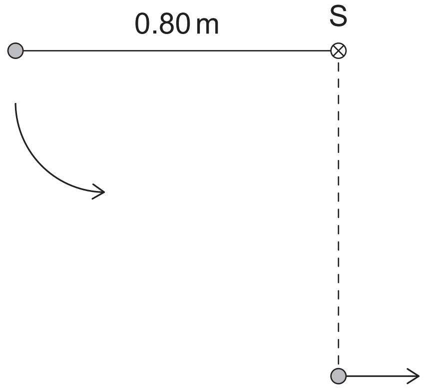
2. A small ball of mass 0.20 kg is attached to a string of length 0.80 m that is initially horizontal. The other end of the string is fixed at S. The ball is released from rest. Air resistance is negligible.

diagram not to scale



(a) At the instant the string is vertical,

(i) show that the speed of the ball is about 4 m s^{-1}. [1]

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(ii) calculate the tension in the string. [2]

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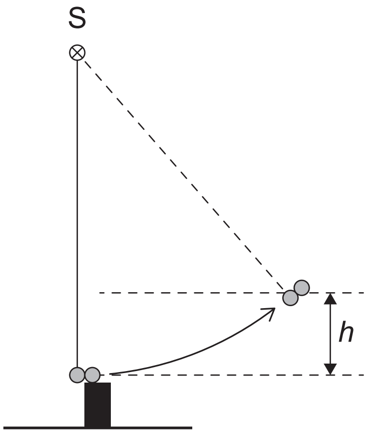
(This question continues on the following page)

(Question 2 continued)

(b) Just as the string becomes vertical, the ball in (a) collides with and sticks to an identical ball. The centre of mass of the two balls is raised to a maximum height *h*.

diagram not to scale



Determine *h*. [2]

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3. A mass of 0.25 kg of ice at –32 °C is placed in water at 0 °C. When thermal equilibrium is reached the temperature is 0 °C. The only transfers of thermal energy are between the ice and the water.

The following data are available:

Specific heat capacity of ice $= 2100\,\mathrm{J\,kg^{-1}\,K^{-1}}$

Specific latent heat of fusion of ice $= 334\,\mathrm{kJ\,kg^{-1}}$

(a) Show that when thermal equilibrium is reached about 50 g of water have turned into ice. [2]

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(This question continues on the following page)

(Question 3 continued)

(b) (i) A student states that the internal energy of the 50 g of water in (a) does not change when this mass turns into ice because the temperature is constant at 0 °C. Discuss this statement. [3]

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(ii) Calculate the decrease in the entropy of the water. [1]

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(iii) Outline how the result in (b)(ii) is consistent with the second law of thermodynamics. [2]

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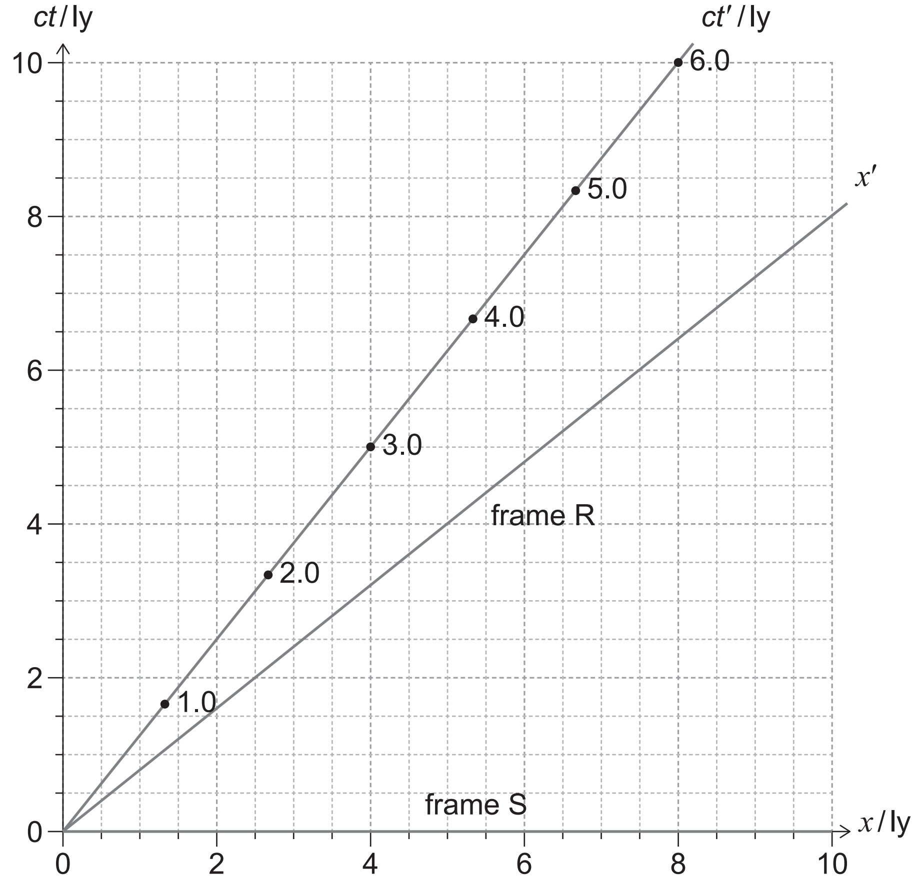
4. A rocket R moves past a space station S. The diagram shows the space–time axes of the reference frames of R and of S.



(a) Determine the speed of R relative to S. [1]

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(Question 4 continued)

(b) Event E_1 is the emission of a photon from the rocket when the rocket is 4.0 ly from S according to S. Event E_2 is the arrival of the photon at S.

(i) Draw the world line of the photon from E_1 to E_2. [1]

(ii) Calculate the space–time interval between E_1 and E_2. [1]

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(c) Calculate the time of event E_2 measured in R. [2]

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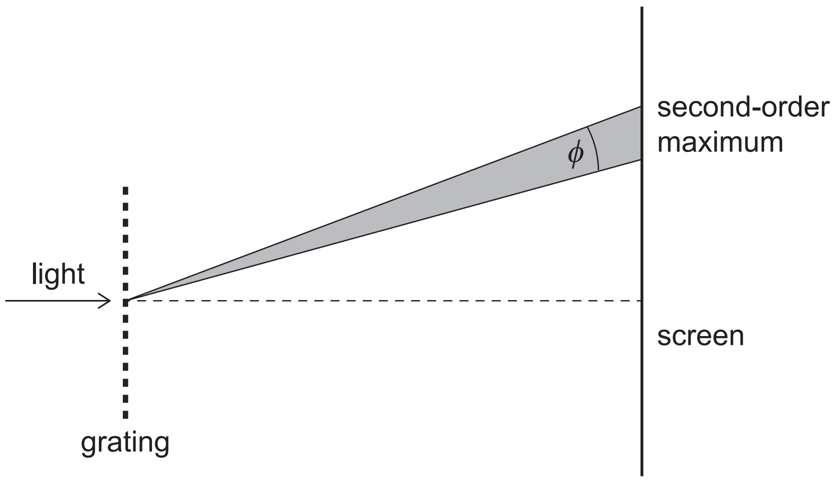
Please **do not** write on this page.

Answers written on this page
will not be marked.

5. A diffraction grating has 400 lines per mm. Light, consisting of all wavelengths from 4.00×10^{-7} m to 7.00×10^{-7} m, is incident on the grating. The **second-order** maximum is shown.

diagram not to scale



(a) Calculate the angular width ϕ of the second-order maximum. [2]

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(b) Determine the largest order for which all wavelengths of the incident light are present. [2]

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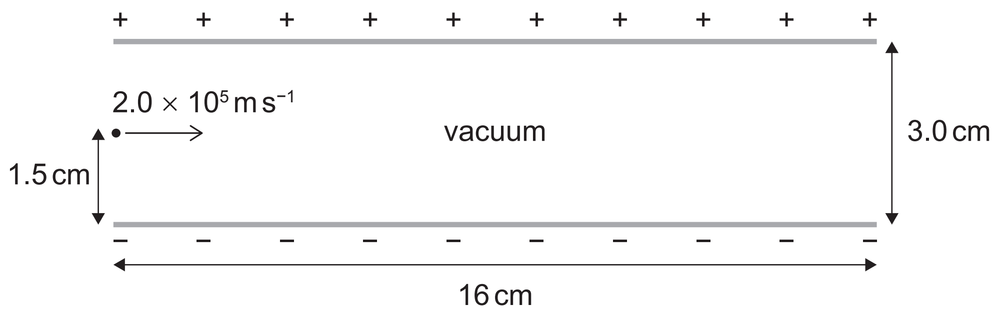
6. Two horizontal parallel plates of length 16 cm are separated by 3.0 cm in a vacuum. The potential difference between the plates is 14 V. A proton enters the region midway between the plates with an initial horizontal velocity of $2.0 \times 10^5\,\text{m s}^{-1}$ as shown. Gravitational forces and edge effects are negligible.

diagram not to scale



(a) (i) Calculate the magnitude of the electric field strength between the plates, including its unit. [2]

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(ii) Show that the acceleration of the proton is about $4.5 \times 10^{10}\,\text{m s}^{-2}$. [2]

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(Question 6 continued)

(iii) Determine whether the proton will hit the lower plate. [3]

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(b) An alpha particle enters the field at the same point and with the same initial velocity as the proton.

(i) State and explain whether the alpha particle will hit the lower plate. [2]

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(ii) A magnetic field is established between the plates so that the alpha particle is not deflected. Determine the magnitude **and** direction of the magnetic field. [2]

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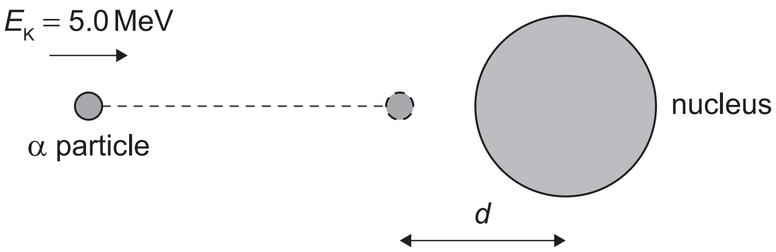
7. An alpha particle has kinetic energy $E_K = 5.0\,\text{MeV}$ when far from a nucleus. The alpha particle is directed towards the centre of the nucleus. The distance of closest approach is $d = 1.61 \times 10^{-14}\,\text{m}$.

diagram not to scale



(a) Calculate the proton number of the nucleus. [2]

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(b) (i) The nucleon number of the nucleus is 58. Show that $d \approx 3.5R$ where R is the radius of the nucleus. [2]

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(ii) State and explain whether d will change when the nucleus is replaced by one of its isotopes. [2]

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(Question 7 continued)

(c) (i) Suggest why deviations from Rutherford scattering are expected as the kinetic energy of the alpha particle increases. [2]

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(ii) Deviations will appear when $d \approx R$. Estimate the initial kinetic energy of the alpha particle for which this happens. [2]

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8. An elastic rope behaves as a spring that obeys Hooke's law with a spring constant k.

(a) State what is meant by Hooke's law. [1]

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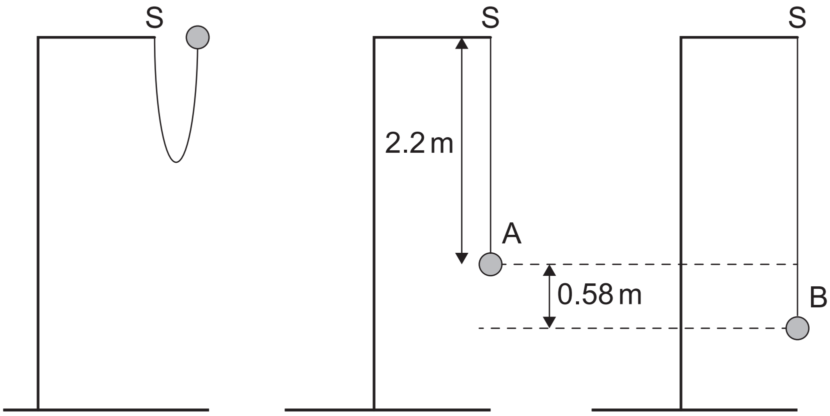
(b) A ball of mass 4.0 kg is attached to an elastic rope of an unstretched length of 2.2 m.

The other end of the rope is fixed at S. The ball is released from rest at S and falls vertically. The diagram shows the position of the ball at three different times. Air resistance is negligible.

diagram not to scale



(i) The ball falls freely to A before the rope begins to stretch. Calculate the speed of the ball at A. [2]

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(Question 8 continued)

(ii) At B the rope has reached its maximum extension of 0.58 m. Show that *k* for the rope is about 650 $N\,m^{-1}$. [2]

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(iii) State and explain whether the ball is in equilibrium at position B. [2]

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(iv) The time to fall from A to B is 0.13 s. Estimate the average force exerted on the ball by the rope. [3]

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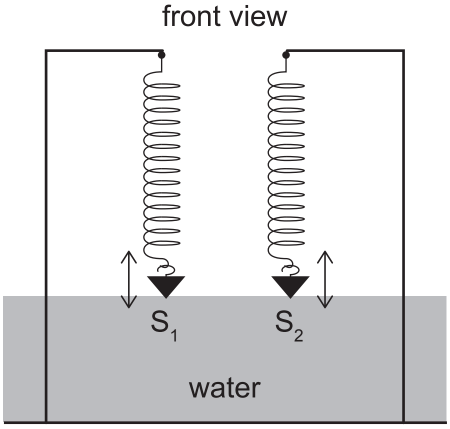
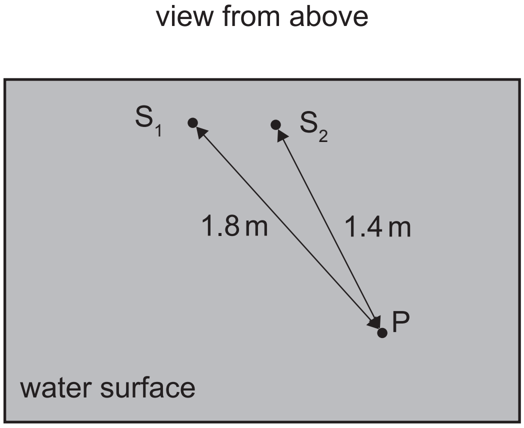
(Question 8 continued)

(c) Two identical wedges are attached to two identical vertical springs. The wedges touch a water surface at S_1 and S_2. As the wedges oscillate, they create travelling waves on the water surface. The wedges oscillate in phase with the same amplitude. P is a point on the surface of the water.

diagrams not to scale





(i) The mass of each wedge is 0.200 kg and the spring constant is 504 N m^{-1}. Damping is negligible. Show that the frequency of oscillations is about 8 Hz. [2]

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(ii) The speed of the water waves is 1.6 m s^{-1}. Show that the wavelength of the water waves is 0.20 m. [1]

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(Question 8 continued)

(iii) P is 1.8 m from S_1 and 1.4 m from S_2. Explain why the amplitude of oscillations at P will be maximum. [2]

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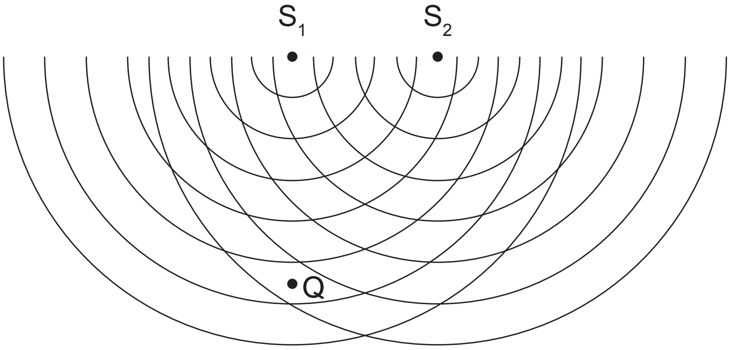
(iv) The diagram shows, at an instant of time, another point Q on the water surface and wavefronts that were emitted by S_1 and S_2.

diagram not to scale



State and explain what will be observed at Q. [2]

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(d) The frequency of oscillation of the two wedges is increased. Determine the next frequency above 8 Hz for which the amplitude at P is again a maximum. [3]

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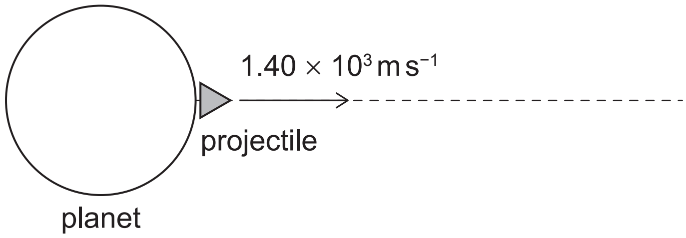
9. (a) The escape speed from the surface of a planet with no atmosphere is $1.20 \times 10^3\,\text{m}\,\text{s}^{-1}$. A projectile is launched from the surface of this planet with speed $1.40 \times 10^3\,\text{m}\,\text{s}^{-1}$.

diagram not to scale



(i) State what is meant by escape speed. [1]

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(ii) Determine the speed of the projectile at a very large distance from the planet. [3]

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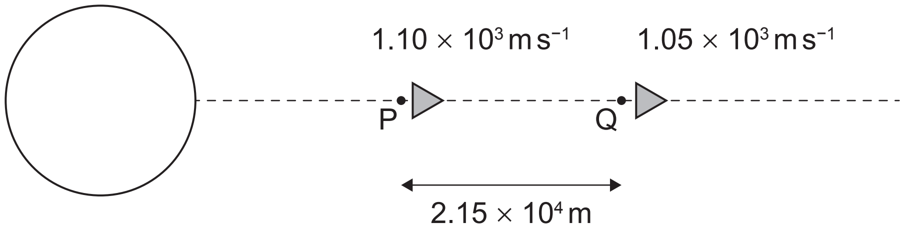
(Question 9 continued)

(iii) The speed of the projectile decreases from $1.10 \times 10^{3}\,\mathrm{m\,s^{-1}}$ at P to $1.05 \times 10^{3}\,\mathrm{m\,s^{-1}}$ at Q.

diagram not to scale



The distance PQ is $2.15 \times 10^{4}\,\mathrm{m}$.

Determine the average gravitational field strength between P and Q. [2]

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(b) (i) A celestial body has a mass of 40 solar masses. The solar mass is $2.0 \times 10^{30}\,\mathrm{kg}$. The radius of this body is $1.15 \times 10^{5}\,\mathrm{m}$. Show that the escape speed at the surface of this body is about $3 \times 10^{8}\,\mathrm{m\,s^{-1}}$. [2]

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(ii) Outline the significance of the result in (b)(i). [2]

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(Question 9 continued)

(c) (i) State the main element produced in fusion reactions in main sequence stars. [1]

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(ii) Describe how main sequence stars maintain equilibrium. [2]

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(Question 9 continued)

(d) The mass of star Lambda Cephei (λ Cephei) is 50 solar masses. One nuclear fusion reaction taking place in λ Cephei is ${}^{16}_{8}O + {}^{16}_{8}O \rightarrow {}^{28}_{14}Si + {}^{4}_{2}He$.

(i) The following data are available for atomic masses:

$${}^{16}_{8}O = 15.9949\,u; \quad {}^{28}_{14}Si = 27.9769\,u; \quad {}^{4}_{2}He = 4.0026\,u.$$

Calculate, in MeV, the energy released in this reaction. [2]

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(ii) Explain why this reaction can only happen in very massive stars. [2]

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(iii) Suggest why nuclear fusion reactions will not produce any elements heavier than iron. [1]

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(iv) Outline the likely evolution of λ Cephei. [2]

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