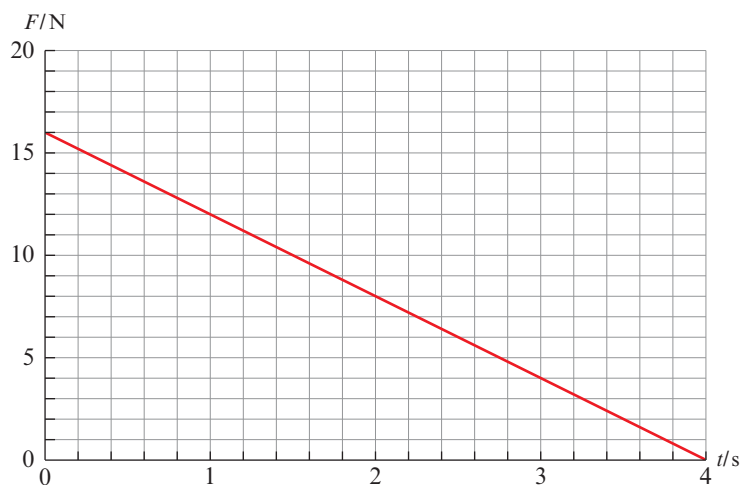# > Specimen Paper 2

HL for first exams in May 2025

Q1 [5 marks]

The graph shows the variation with time t of the net force F acting on a body of mass 2.0 kg.

Initially the body moves to the left with speed 4.0 m s^{-1}. The net force is directed to the right. During the 4.0 seconds of this motion
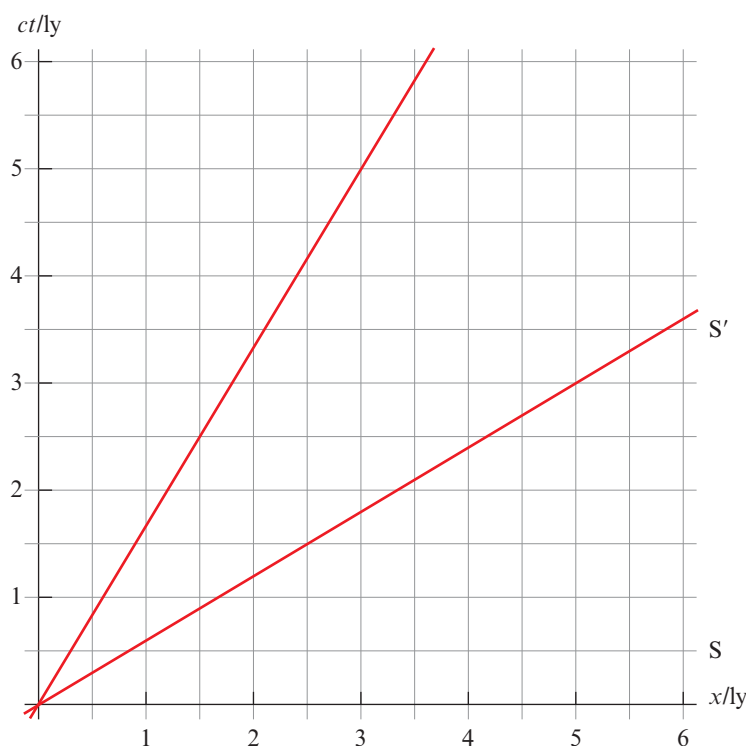
a   determine the maximum acceleration experienced by the body   [1]

b   estimate the average power developed by the force.   [4]

Q2 [5 marks]

The diagram shows the space-time axes of two inertial frames S and S′.

a   Show that speed of S′ relative to frame S is 0.60 c. **[1]**

b   S′ is moving towards a space station a distance 3.0 ly from the origin of S as measured by S. The space station is at rest relative to S.

   I   Draw the worldline of the space station. **[1]**

   II   State the time it will take S′ to reach the space station according to S clocks. [1]

   III   Determine the travel time according to S′. **[2]**

Q3 [11 marks]

a   Discuss how the Rutherford-Geiger-Marsden scattering experiment led to the conclusion of the existence of an atomic nucleus. **[2]**

b   A plutonium ($^{239}_{94}$Pu) nucleus decays by alpha decay into a nucleus of uranium (U).

   I   State the reaction equation for this decay. **[2]**

   II   The following binding energies per nucleon are available:

Plutonium	7.5603 MeV
Uranium	7.5909 MeV
Helium	7.0739 MeV

    Estimate the energy released. **[2]**

   III   The binding energy per nucleon for uranium is larger than that for plutonium. Explain this observation. **[2]**

c   Large stable nuclei have more neutrons than protons. Explain this observation. **[3]**

Q4 [10 marks]

a Distinguish between a transverse and a longitudinal wave. **[2]**

b The graph shows, at $t = 0$, the variation with distance of the displacement of particles in a medium in which a transverse wave of frequency 250 Hz is travelling to the right.
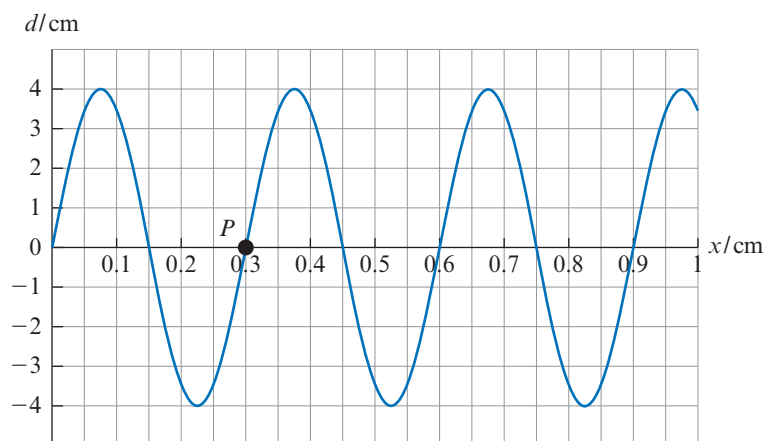
A particle P in the medium has been marked.

I Calculate the speed of the wave. **[2]**

II Draw a graph to show the variation with time t of the displacement of P. **[2]**

III State the equation giving the displacement of P in the form $x = x_0 \sin(\omega t + \phi)$ where x_0, ω and ϕ are to be determined. **[2]**

c A standing wave is formed on a string with both ends fixed. The solid line represents the wave at $t = 0$ and the dashed line at $t = T/2$ where T is the period.

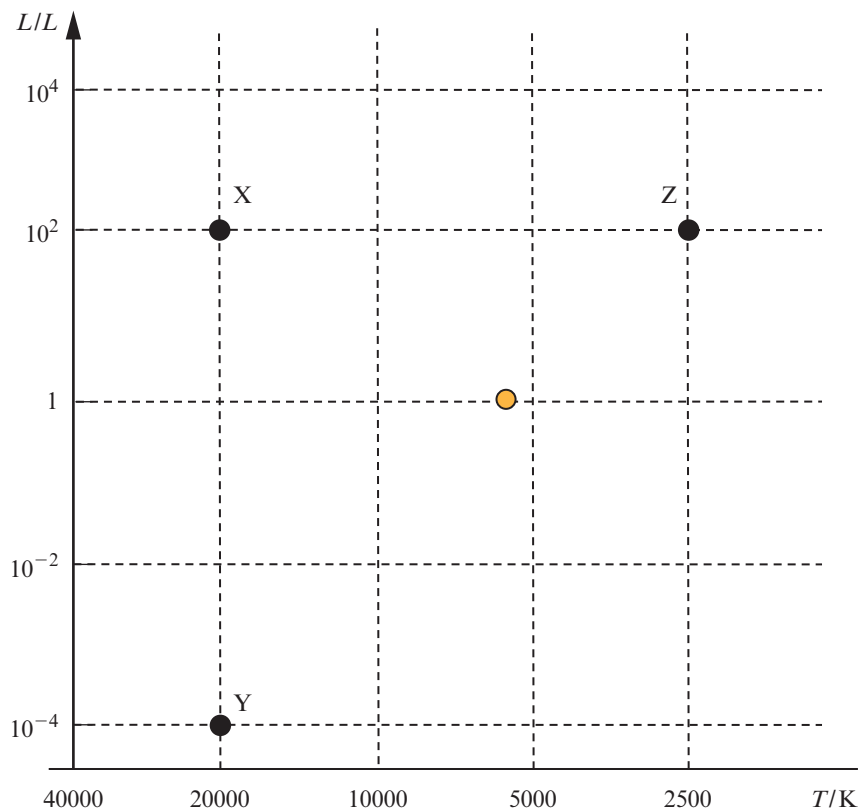The blue line represents the wave at $t = \frac{T}{8}$.
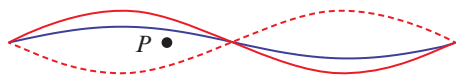
The marked point shows the **equilibrium** position of a point P on the string.
At $t = \frac{T}{8}$, draw

I a point to indicate the position of P **[1]**

II an arrow to indicate the velocity of P. **[1]**

Q5 [7 marks]

The HR diagram shows the Sun and three other stars X, Y and Z.

a   X is much hotter than Z yet X and Z have the same luminosity.
Explain this observation. **[2]**
b   Calculate the ratio $\frac{R_Z}{R_Y}$ of the radius of Z to that of Y. **[3]**
c   Gravitational pressure tends to make stars contract. X and Y are both
stable stars. State how X and Y manage to oppose their gravitational pressures.

I   X **[1]**

II   Y **[1]**

Q6 [5 marks]

Two parallel plates are oppositely charged. The potential difference between the plates is 240 V, and their
separation is 2.0 cm.

a   Draw the electric field lines for this arrangement. **[2]**
b   Calculate the electric field strength between the plates. **[1]**
c   A proton is placed on the positively charged plate and is then released.
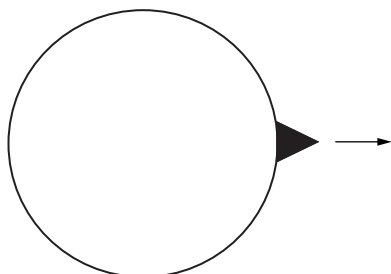The experiment is repeated with the proton replaced by an alpha particle.

Calculate the ratio

$\frac{v_p}{v_\alpha}$ of the speed of the proton to that of the alpha particle when the particles reach the negative plate. **[2]**

Q7 [7 marks]

A probe is launched from the surface of a planet with a speed that is half the escape speed.

a Outline what is meant by escape speed. **[1]**

b Determine, in terms of the radius of the planet, R, the maximum distance from the centre of the planet reached by the probe. **[3]**

c Another probe is launched from the surface of another planet. The diagram shows the probe at the instant of launch and the elliptical orbit followed by the probe.

not to scale

P
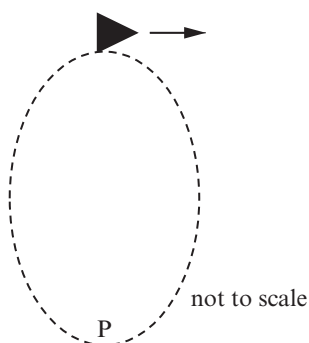
I On the diagram, draw a dot to indicate a possible centre of the planet. **[1]**

II Discuss how the speed of the probe at position P compares with the launch speed. **[2]**

Q8 [20 marks]

a A container of fixed volume holds 7.0 mol of helium ($_2^4$He) at pressure 3.0×10^5 Pa and temperature 270 K. The volume of a helium atom is about 3×10^{-30} m^3.

Calculate

I the total volume of the molecules in the container **[2]**

II the volume of the container **[2]**

III the total mass of the helium gas. **[1]**

b State and explain, by reference to the kinetic model of gases, why it is reasonable to consider helium in this container to behave as an ideal gas. **[2]**

c The gas in **a** is heated at constant volume from a pressure of 3.0×10^5 Pa and temperature 270 K to a pressure of 5.0×10^5 Pa. Calculate the new temperature of the gas. **[2]**

d Draw a line on the *P-V* diagram to represent the change in **c**. [1]


e

　I Show that the change in the internal energy of helium is about 16 kJ. [1]

　II Estimate the specific heat capacity of helium. [2]

f The emission spectrum of helium contains photons of energy 1.86 eV. Show that the wavelength of these photons is 667 nm. [2]

g The graph shows the variation of the intensity *B* of the black body radiation emitted by the Sun for wavelengths near 667 nm.
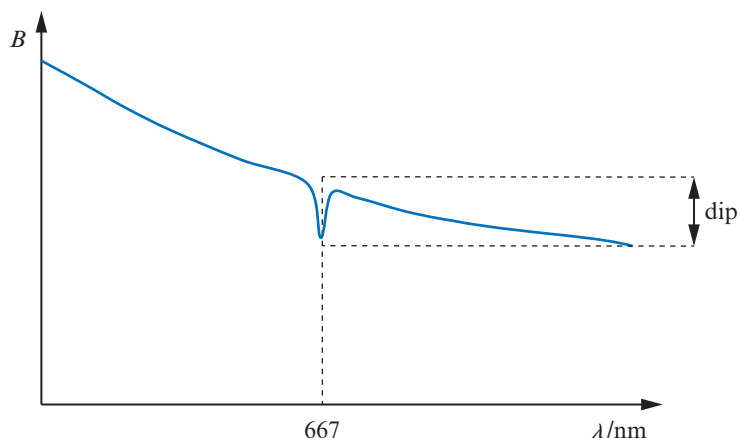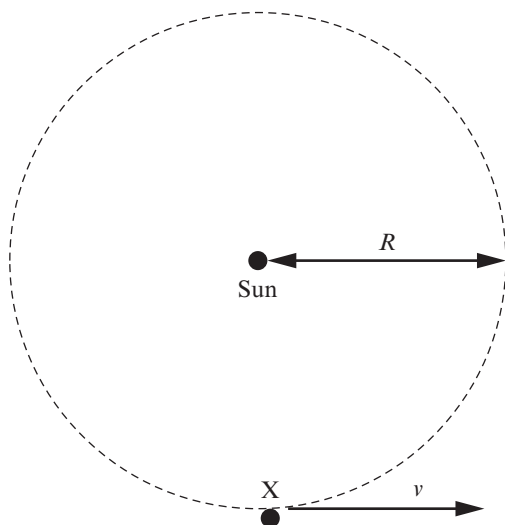

The curve shows a dip at a wavelength of 667 nm.

　**I** Outline what is meant by black body radiation. [2]

　II Explain why the presence of the dip is evidence that the Sun contains helium. [3]

Q9 [20 marks]

The Earth orbits the Sun in a circular orbit of radius $R = 1.5 \times 10^{11}$ m.

a Show that the speed v of the Earth around the Sun is about 30 km s⁻¹. [2]

b An asteroid collides with the Earth in a head-on collision when the Earth is at X. The asteroid gets embedded into Earth. The asteroid moves with the s ame speed as the Earth.
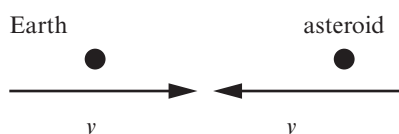
I Show that the speed u of the Earth-asteroid system immediately after the collision is given by

$u = v \dfrac{M - m}{M + m}$

where M is the mass of the Earth and m the mass of the asteroid. [1]

II The asteroid impacts the Earth with a kinetic energy of 2×10^{25} J. Show that the mass of the asteroid is about 10^{16} kg. [1]

c The mass of Earth is $M = 6.0 \times 10^{24}$ kg. Assume that the orbit of the Earth stays circular after the collision.

I Suggest, with a reason, whether the new orbital radius of Earth will increase or decrease. [2]

II Predict whether the change in **i** is significant. [1]

d Assume that all the kinetic energy of the asteroid in **b ii** goes into vaporizing rocks around the impact point. Ignore any thermal energy that will go into the asteroid itself.

The following data are available for rocks at the point of impact:

Temperature of rocks	300 K
Solid rock specific heat capacity	850 J kg⁻¹ K⁻¹
Molten rock specific heat capacity	1450 J kg⁻¹ K⁻¹
Melting temperature of rocks	1700 K
Specific latent heat of fusion of rocks	1.6×10^{5} J kg⁻¹
Boiling temperature of rocks	2600 K
Specific latent heat of vaporization of rocks	1.1×10^{7} J kg⁻¹

I   Estimate the mass of rocks that will be vaporized. [4]

II   Suggest whether the actual mass of rocks vaporized will be larger or smaller than the estimate in **I**. [2]

III   The density of rock is 2800 $kg\,m^{-3}$. Assume, for simplicity, that the shape of the crater formed by the impact of the asteroid is a cube. Estimate, in km, the side of the cube. [2]

e   Tektites are small spheres of rock and glass formed when molten rock solidifies. Argon is produced when potassium ($^{40}_{19}K$) in the rocks decays after absorbing an electron:

$$^{40}_{19}K + e^- \rightarrow \,^{\square}_{\square}Ar + \nu.$$

I   State the proton and nucleon numbers of argon. [2]

II   The half-life of potassium is 1.2×10^{10} yr. Tektites from a crater formed by an asteroid impact contain 0.996 of the potassium contained in tektites formed now.

   Determine the time of impact. [3]