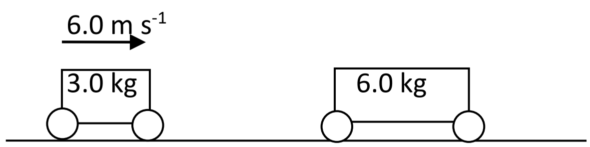
K.A. Tsokos

Specimen Paper 2 SL

Q1 [4 marks]

A cart of mass 3.0 kg moving at 6.0 m s^{-1} collides with a stationary cart of mass 6.0 kg.



(a) Explain why the total momentum of the two carts before and after the collision is the same. [2]

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(b) The two carts stick together as a result of the collision. Determine the kinetic energy lost in the collision. [2]

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Q2 [6 marks]

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

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(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]

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(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]

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Q3 [8 marks]

(a) Distinguish between a transverse and a longitudinal wave. [2]

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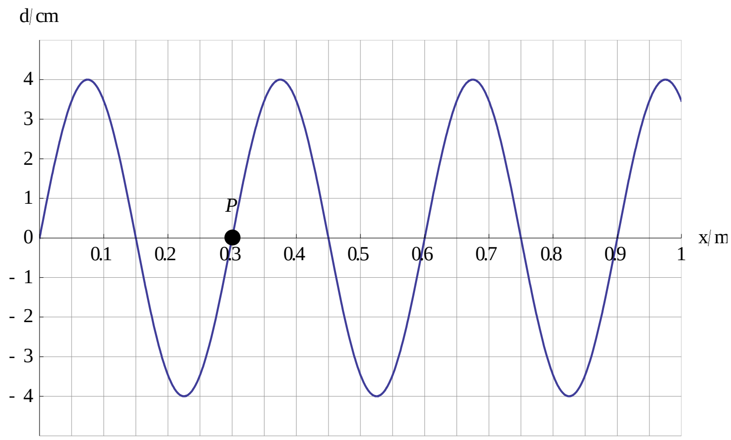
(b) The graph shows, at t = 0, the variation with distance of the displacement of particles in a medium in which a transverse wave of frequency 250 Hz is travelling to the right.



A particle P in the medium has been marked.

(i) Calculate the speed of the wave. [2]

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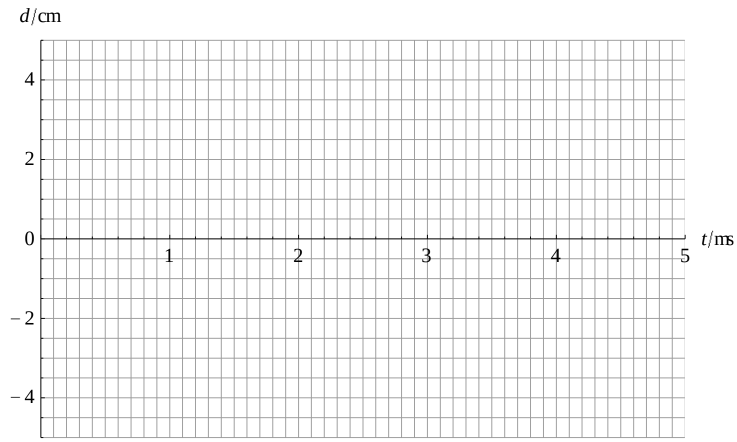
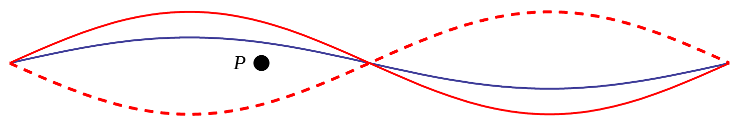
(ii) Draw a graph to show the variation with time t of the displacement of P. [2]



(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]

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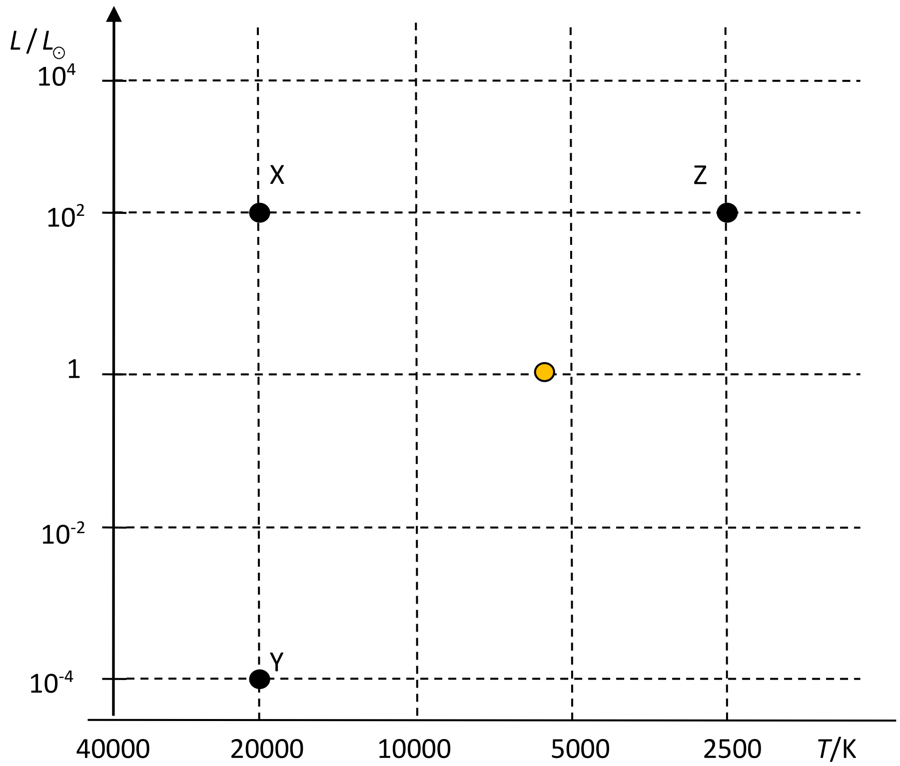
Q4 [7 marks]

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]

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(b) Calculate the ratio $\frac{R_Z}{R_Y}$ of the radius of Z to that of Y. [3]

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(c) Gravitational pressure tends to make stars contract. X and Y are both stable stars. State how X and of Y manage to oppose their gravitational pressures.

(i) X [1]

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(ii) Y [1]

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Q5 [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]

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(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]

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Q6 [20 marks]

(a) A container of fixed volume holds 7.0 mol of helium (${}^{4}_{2}He$) 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]

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(ii) the volume of the container, [2]

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(iii) the total mass of the helium gas. [1]

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(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]

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(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]

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(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]

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(ii) Estimate the specific heat capacity of helium. [2]

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

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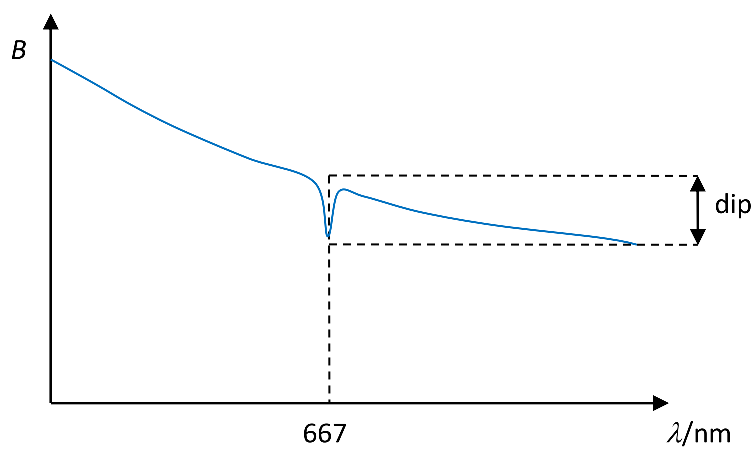
(g) The graph shows the variation of the intensity *B* of the black body radiation emitted by the Sun for wavelengths near 667 nm.



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

(i) Outline what is meant by black body radiation. [2]

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

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Markscheme

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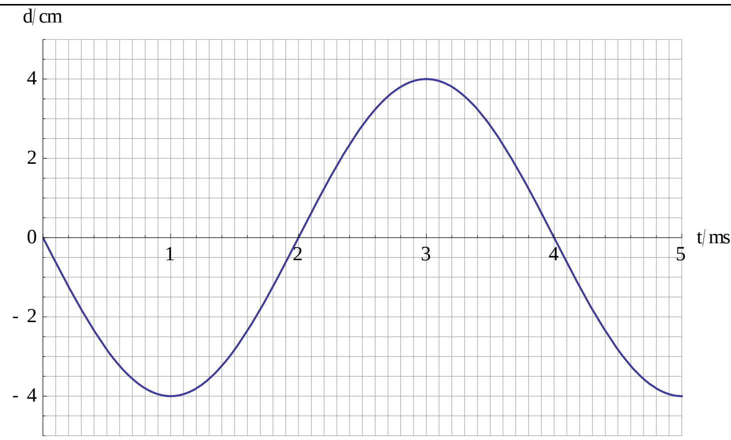
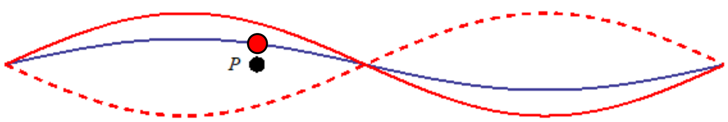
a		The total momentum stays the same when no external forces act on the system✓ The carts exert equal and opposite forces on each other so the net force is zero✓		[2]
b		$6.0\times3.0+0=(3.0+6.0)\times v\Rightarrow v=2.0\text{ ms}^{-1}$ ✓ Change in KE: $\frac{1}{2}\times3.0\times6.0^2-\frac{1}{2}\times9.0\times(2.0)^2=36\text{ J}$ ✓		[2]

2				
a		A very small percentage of the incident alpha particles were scattered at very large scattering angles✓ This required a huge electric force that could only be provided if the positive charge of the atom was concentrated in a very small, massive object✓		[2]
b	i	${}^{239}_{94}\text{Pu}\rightarrow{}^{235}_{92}\text{U}+{}^{4}_{2}\alpha$ Correct numbers for U✓		[2]
b	ii	$235\times7.5909+4\times7.0739-239\times7.5603$ ✓ 5.25 MeV✓		[2]

3				
a		In a transverse wave the displacement is at right angles to the direction of energy transfer✓ In a longitudinal wave the displacement is parallel to the direction of energy transfer ✓		[2]
b	i	$\lambda=0.30\text{ m}$ ✓ $v=f\lambda=250\times0.30=75\text{ms}^{-1}$ ✓		[2]

b	ii	 Correct shape✓ Correct period✓		[2]
c	i	 ✓		[1]
c	ii	 ✓		[1]

4				
a		Luminosity also depends on area✓ Star Z has a much larger area than X✓		[2]
b	i	$\frac{L_Z}{L_Y}=\frac{4\pi\sigma R_Z^2 T_Z^4}{4\pi\sigma R_Y^2 T_Y^4}=10^6$ ✓ $\frac{R_Z}{R_Y}=\sqrt{10^6\times\frac{20000^4}{2500^4}}$ ✓ $\frac{R_Z}{R_Y}=6.4\times10^4$ ✓		[3]
c	i	X: by radiation pressure caused by fusion reactions✓		[1]
c	ii	Y: by electron degeneracy pressure✓		[1]

5				
a		Uniform lines from left to right in the interior✓ Edge effects✓		[2]

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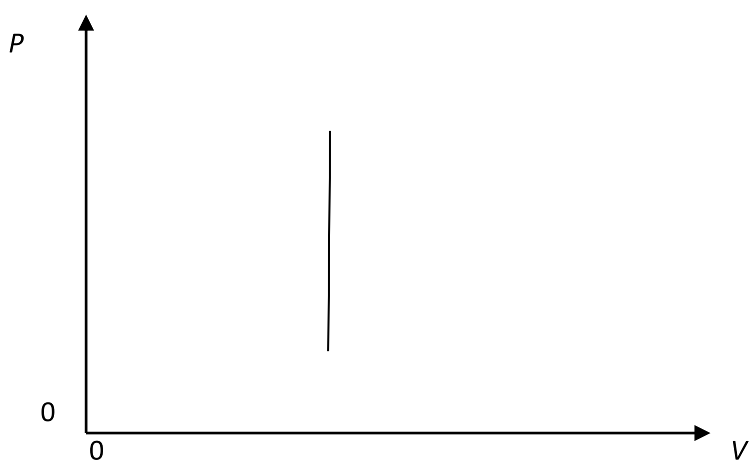
b		$E=\frac{V}{d}=\frac{240}{2.0\times10^{-2}}=1.2\times10^{4}\ \text{NC}^{-1}$ ✓		[1]
c		$W=Fd=qEd=q\frac{V}{d}d=qV=\frac{1}{2}mv^{2}\Rightarrow v=\sqrt{\frac{2qV}{m}}$ ✓ $\frac{v_{p}}{v_{\alpha}}=\sqrt{\frac{q_{p}m_{\alpha}}{q_{\alpha}m_{p}}}=\sqrt{\frac{1}{2}\times4}=\sqrt{2}$ ✓		[2]

6				
a	i	$N=7.0\times6.02\times10^{23}=4.2\times10^{24}$ ✓ $4.2\times10^{24}\times3.0\times10^{-30}=1.3\times10^{-5}\ \text{m}^{3}$ ✓		[2]
a	ii	$V=\frac{RnT}{P}$ ✓ $V=\frac{8.31\times7.0\times270}{3.0\times10^{5}}=5.2\times10^{-2}\ \text{m}^{3}$ ✓		[2]
a	iii	$7\times4=28\ \text{g}$ ✓		[1]
b		One of the assumptions of the kinetic theory of gases states that the volume of the molecules is negligible compared to the volume of the gas ✓ Here $\frac{V_{\text{molecules}}}{V_{\text{gas}}}=\frac{1.3\times10^{-5}}{5.2\times10^{-2}}=2.5\times10^{-4}$ which is very small ✓		[2]
c		$\frac{P_{1}}{T_{1}}=\frac{P_{2}}{T_{2}}\Rightarrow T_{2}=T_{1}\times\frac{P_{2}}{P_{1}}$ ✓ $T_{2}=270\times\frac{5.0}{3.0}=450\ \text{K}$ ✓		[2]
d		 Vertical straight line ✓		[1]

e	i	$\Delta U = \frac{3}{2}Rn\Delta T = \frac{3}{2}\times 8.31\times 7.0\times(450-270) = 15706\text{ J}$ ✓		[1]
e	ii	Realization that $Q = \Delta U$ ✓ $c = \frac{Q}{m\Delta T} = \frac{15705}{0.028\times(450-270)} = 3.1\times 10^{3}\text{ J kg}^{-1}\text{ K}^{-1}$ ✓		[2]
f		$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$ ✓ $\lambda = \frac{1.24\times 10^{-6}}{1.86} = 666.6 \approx 667\text{ nm}$ ✓		[2]
g	i	[2] max from Electromagnetic radiation with an infinite rage of wavelengths✓ With a peak determined by temperature ✓ Radiation emitted by a body at some finite kelvin temperature ✓ Radiation with an intensity proportional to the 4th power of the kelvin temperature✓		[2] max
g	ii	Helium has energy levels separated by 1.86 eV✓ This energy difference is unique to helium✓ The dip implies that photons of this energy are absorbed ✓ By helium		[3]