SPECIMEN PAPERS

SET 3

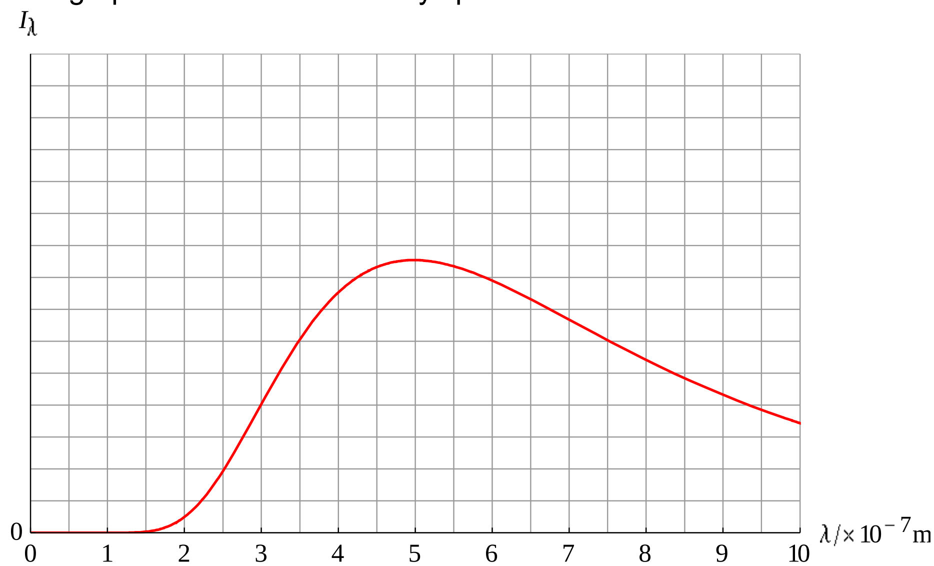
Paper 2 SL

Time allowed: 1 hour 30 minutes.

A calculator and the data booklet are required.

The total number of marks for this paper is 50.

1. The graph shows the black body spectrum of a star.



(a) Determine the surface temperature of the star. [2]

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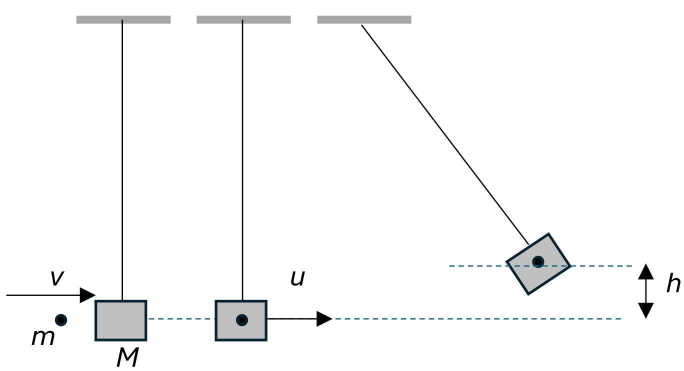
(b) On the axes draw a graph to show the black body spectrum of another star with a higher surface temperature than that of the star in (a). [1]

2. A pellet of mass *m* moving at horizontal speed *v* collides with a block of mass *M* that hangs from a vertical string. The pellet gets stuck in the block. The pellet and block move together with initial speed *u* raising their center of mass by a maximum height *h*.



The following data are available:

$m = 0.025$ kg

$M = 1.20$ kg

$v = 65$ m s^{-1}

(a) Calculate *u*. [2]

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(b) Determine the maximum height *h*. [2]

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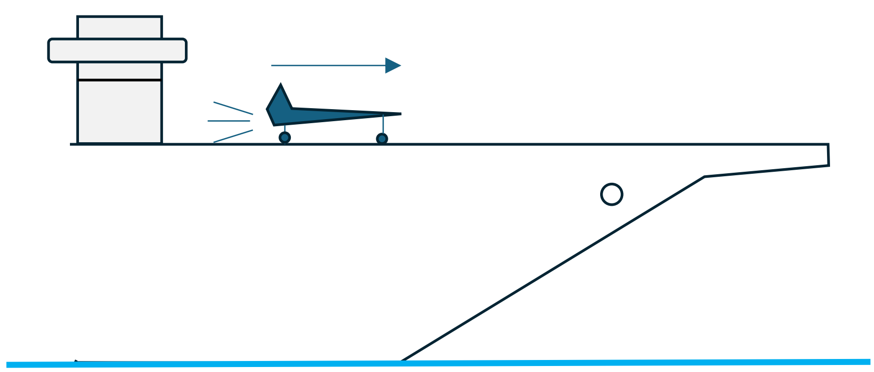
3. A plane of mass 8100 kg is taking off from an aircraft carrier. The plane accelerates uniformly from rest and reaches a takeoff speed of 82 m s^{-1} over a distance of 120 m. The engines exert a thrust force of 84 kN. The catapult wire also exerts a constant force on the plane accelerating it forward. An air resistance force of average value 55 kN acts on the plane.



(a) Calculate

(i) the time taken to take off, [1]

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(ii) the average power developed by the engine, [1]

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(iii) the force due to the catapult wire. [2]

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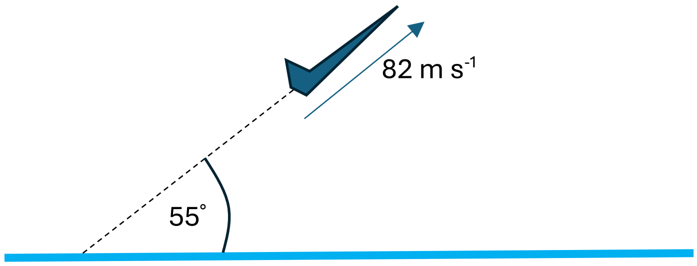
(b) After takeoff the plane is climbing at an angle of 55° to the horizontal with constant speed 82 m s^{-1}. The magnitude of the air resistance force is unchanged.



(i) State and explain whether the plane is in equilibrium. [2]

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(ii) Calculate the thrust force due to the engine. [2]

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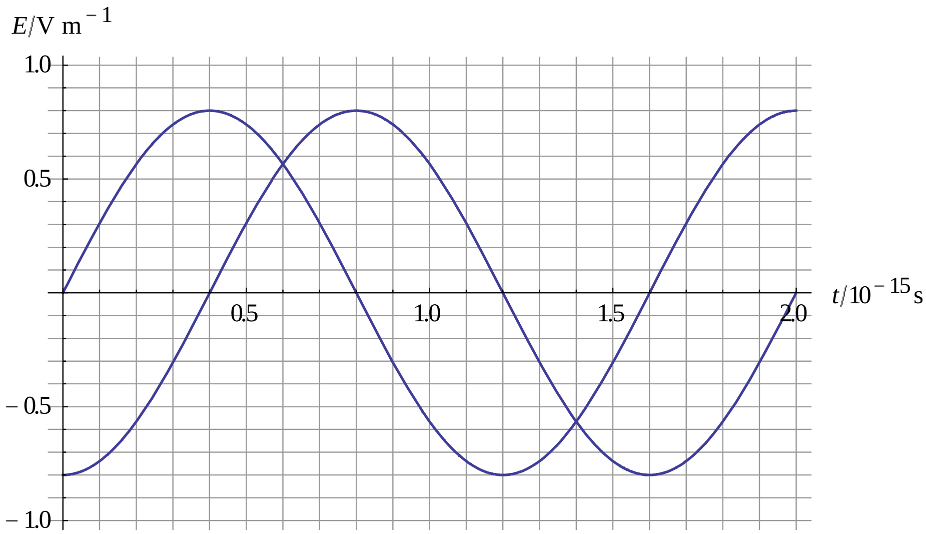
4. Coherent light is incident on two narrow parallel slits. An interference pattern is formed on a screen far from the slits.

(a) The graph shows the variation with time of the displacement *E* of the waves arriving at a point P on the screen from each of the slits.



(i) Outline why the unit for the displacement is given as V m^{-1}. [2]

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(ii) Calculate the wavelength of the waves. [2]

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(iii) Determine the phase difference between the waves. [2]

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(b) State and explain whether P is at the center of a bright fringe, the center of a dark fringe or neither. [2]

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5. An ideal gas is confined within a container of volume 0.12 m^3 at pressure 2.0×10^5 Pa and temperature 310 K.

(a) Calculate the number of molecules of the gas. [2]

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(b)

(i) Calculate the average kinetic energy of the molecules. [1]

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(ii) Determine the internal energy of the gas. [1]

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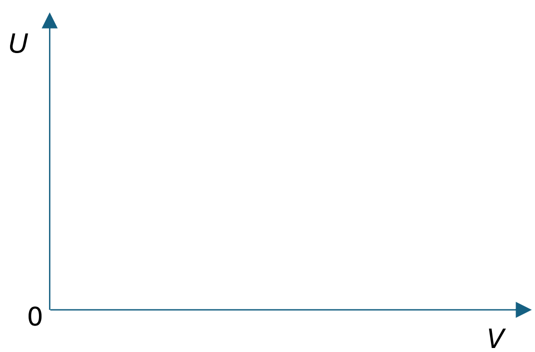
(c) The pressure of the gas is kept constant and the volume is varied.

(i) Draw a graph to show the variation with volume *V* of the internal energy *U* of the gas. [2]



(ii) State, by reference to the kinetic theory of gases, **one** feature of the graph in (i) that would not apply to a real gas. [1]

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6.

(a) The protons in the nucleus repel each other. Outline how nuclei can be stable. [2]

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(b) A nucleus of tritium ($^{3}_{1}\mathrm{H}$) decays by beta minus decay into helium. The reaction equation is $^{3}_{1}\mathrm{H} \rightarrow {}^{?}_{?}\mathrm{He} + \mathrm{e}^{-} + ?$

State the proton and nucleon number of the helium nucleus produced and state the name of the missing particle. [3]

Proton number:……………………………………………………………………………
Nucleon number:…………………………………………………………………………..
Missing particle:…………………………………………………………………………

(c) The following **atomic** masses are available:

Tritium	3.016049 u
Helium	3.016029 u

(i) Calculate the energy released. [2]

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(ii) State and explain whether the electron produced in the reaction in (b) has a kinetic energy equal to the energy found in (c)(i). [2]

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(d) An electron produced in the decay of tritium has kinetic energy 0.45×10^{-2} MeV. Show that the speed of this electron is about 4×10^{7} m s^{-1}. [2]

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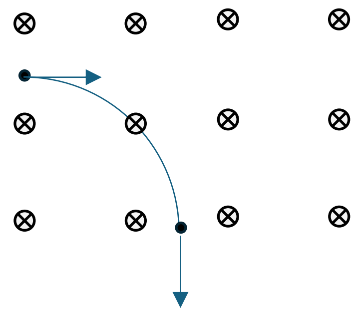
(e) The electron in (d) enters a region of uniform magnetic field 5.0 mT directed into the plane of the page. The electron's path is a quarter circle.



(i) Explain why the path of the electron is circular. [2]

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(ii) Show that the radius of the electron is given by $R = \frac{m_c v}{eB}$. [1]

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(iii) Determine the time the electron spent in the region of magnetic field. [2]

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(iv) Suggest why the speed of the electron remains constant while in the region of magnetic field. [2]

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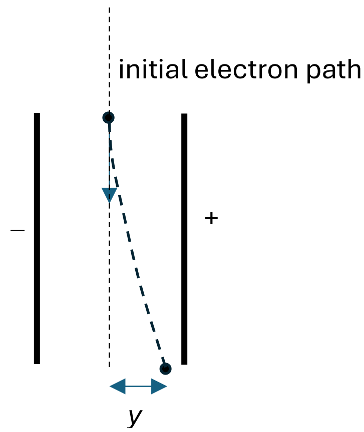
(f) The electron in (e) enters the region between two parallel oppositely charged plates after leaving the region of magnetic field. The electric field strength in between the plates is 5.8×10^{4} N C^{-1}. The time spent in between the plates is 2.2×10^{-9} s.



Determine the deviation *y* of the electron from its original straight-line path. [2]

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Markscheme

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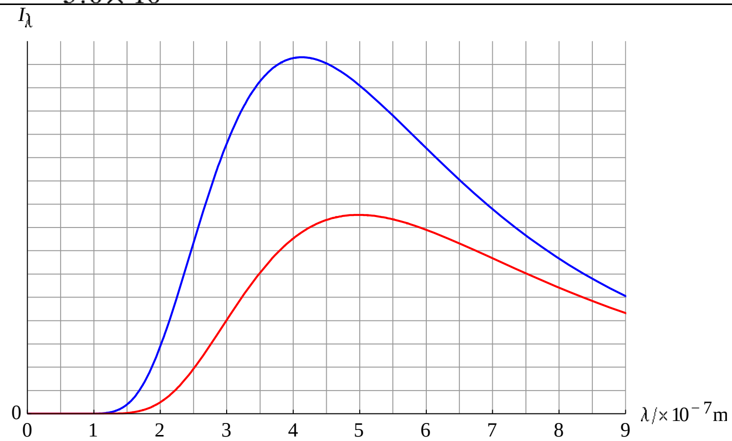
a		Peak wavelength 5.0×10^{-7} m ✓ $T=\frac{2.9\times 10^{-3}}{5.0\times 10^{-7}}=5800\ \text{K}$ ✓		[2]
b		 Blue curve above red curve with peak shifted left ✓		[1]

2				
a		$mv=(m+M)u \Rightarrow u=\frac{mv}{m+M}$ ✓ $u=\frac{0.025\times 65}{0.025+1.20}=1.326\ \text{m s}^{-1}$ ✓		[2]
b		$\frac{1}{2}(m+M)u^2=(m+M)gh$ ✓ $h=\frac{u^2}{2g}=\frac{1.326^2}{2\times 9.8}=9.0\times 10^{-2}\ \text{m}$ ✓		[2]

3				
a	i	$s=\frac{u+v}{2}t \Rightarrow t=\frac{2s}{u+v}=\frac{2\times 120}{0+82}=2.9268\approx 2.9\ \text{s}$ ✓		[1]
a	ii	$\bar{P}=F\frac{u+v}{2}=\frac{84\times 10^3\times 82}{2}=3.4\times 10^6\ \text{W}$ ✓		[1]
a	iii	$a=\frac{82}{2.9268}=28.0\ \text{m s}^{-2}$ ✓ $F+C-R=ma \Rightarrow C=ma+R-F=8100\times 28.0+55\times 10^3-84\times 10^3=198\ \text{kN}$ ✓		[2]
b	i	Yes it is ✓ Because it travels on a straight line with constant speed/net force is zero ✓		[2]
b	ii	$F-Mg\sin\theta-R=0$ ✓ $F=Mg\sin\theta+R=8100\times 9.8\times \sin 55^\circ+55\times 10^3=120\ \text{kN}$ ✓		[2]

4				
a	i	Light is an electromaghnetic wave ✓ The displacement of this wave is the electric field <<which has units of V m^{-1}>> ✓		[2]
a	ii	The period is 1.6×10^{-15} s ✓ So $\lambda = cT = 3\times10^{8}\times1.6\times10^{-15} = 4.8\times10^{-7}$ m ✓		[2]
a	iii	The separation of two consecutive peaks is a qaurter of a period ✓ So the phase difference is $\frac{\frac{T}{4}}{T}\times2\pi = \frac{\pi}{2}$ ✓		[2]
b		The phase differenc at the center of a bright frnge is 0 and that at a dark fringe is π ✓ So neither since the phase difference is not 0 or π ✓		[2]

5				
a		$PV = NkT \Rightarrow N = \frac{PV}{kT}$ ✓ $N = \frac{2.0\times10^{5}\times0.12}{1.38\times10^{-23}\times310} = 5.61\times10^{24} \approx 5.6\times10^{24}$ ✓		[2]
b	i	$\overline{E}_K = \frac{3}{2}kT = \frac{3}{2}\times1.38\times10^{-23}\times310 = 6.42\times10^{-21} \approx 6.4\times10^{-21}$ J ✓		[1]
b	ii	$U = NE_K = 5.61\times10^{24}\times6.42\times10^{-21} = 3.6\times10^{4}$ J ✓		[1]
c	i	$U \sim T$ and $T \sim V$ since P is constant so $U \sim V$ ✓ So straight line through origin with positive gradient ✓		[2]
c	ii	Real gas molecules have volume and so the graph cannot be extended to the origin ✓		[1]

6				
a		There is an additional force acting between protons as well as neutrons ✓ The strong nuclear force is attractive and balances the electrical force of repulsion ✓		[2]
b		Proton number: 2 ✓ Nucleon number: 3 ✓ Missing particle: antineutrino ✓		[3]
c	i	$\Delta M = \left(3.016049 - m_e\right) - \left(3.016029 - 2m_e\right) - m_e = 3.016049 - 3.01602 = 2.0 \times 10^{-5}\ \text{u}$ ✓ $Q = \Delta M c^2 = 2.0 \times 10^{-5} \times 931.5 = 1.86 \times 10^{-2}\ \text{MeV}$ ✓		[2]
c	ii	No ✓ The energy in (c)(i) is shared with the antineutrino ✓		[2]
d		$\frac{1}{2}mv^2 = E \Rightarrow v = \sqrt{\frac{2E}{m}}$ ✓ $v = \sqrt{\frac{2 \times 0.45 \times 10^{-2} \times 10^6 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}} = 3.978 \times 10^7\ \text{m s}^{-1}$ ✓		[2]
e	i	The initial velocity is normal to the magnetic field ✓ The magnetic force is normal to the velocity and so provides the centripetal force ✓		[2]
e	ii	$evB = m_e \frac{v^2}{R}$ ✓ Hence result		[1]
e	iii	$T = \frac{1}{4}\frac{2\pi R}{v} = \frac{1}{4}\frac{2\pi m_e}{eB}$ ✓ $T = \frac{1}{4}\frac{2\pi \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 5.0 \times 10^{-3}} = 1.8\ \text{ns}$ ✓		[2]
e	iv	To change the KE and hence speed, work must be done on the electron ✓ The work done by the magnetic force is zero since the force is at right angles to the velocity ✓		[2]
f		$a = \frac{F}{m_e} = \frac{eE}{m_e}$ ✓ $y = \frac{1}{2}at^2 = \frac{1}{2} \times \frac{1.6 \times 10^{-19} \times 5.8 \times 10^4}{9.1 \times 10^{-31}} \times \left(2.2 \times 10^{-9}\right)^2 = 2.468 \approx 2.5\ \text{cm}$ ✓		[2]