SPECIMEN PAPERS

SET 3

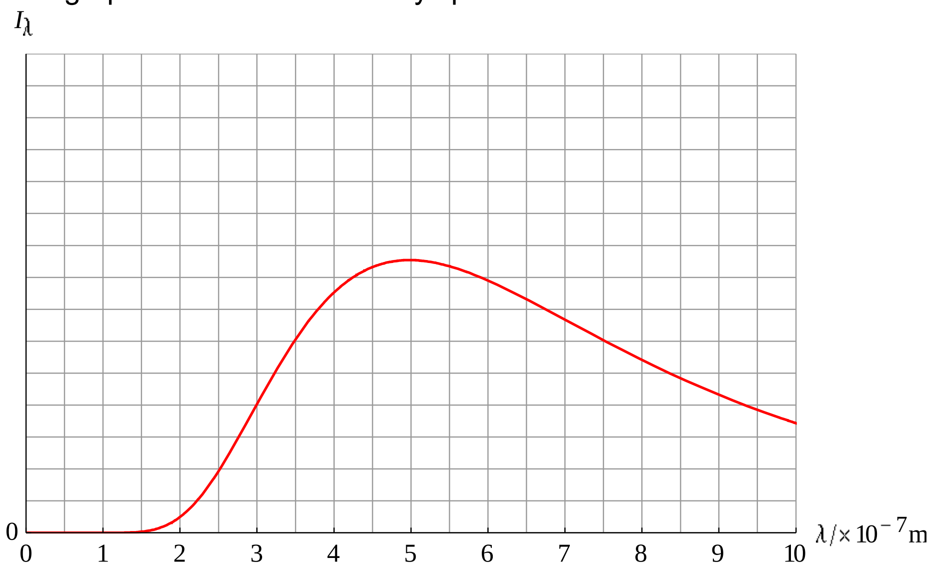
Paper 2 SL

Time allowed: 1 hour 30 minutes.

A calculator and the data booklet are required.

The total number of marks for this paper is 50.

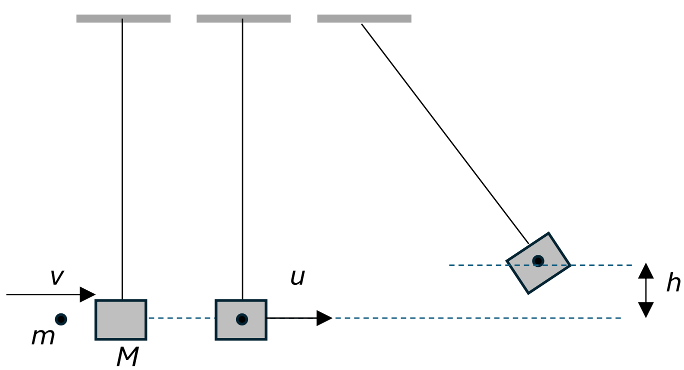
1. The graph shows the black body spectrum of a star.



(a) Determine the surface temperature of the star. [1]

(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). [2]

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

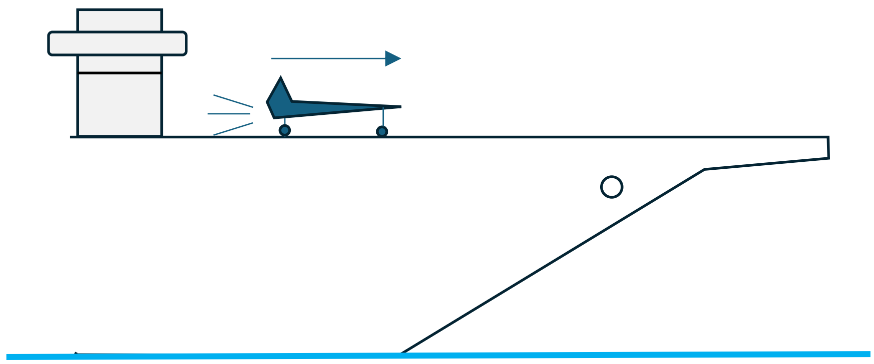
$M = 1.20$ kg

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

(a) Calculate *u*. [2]

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

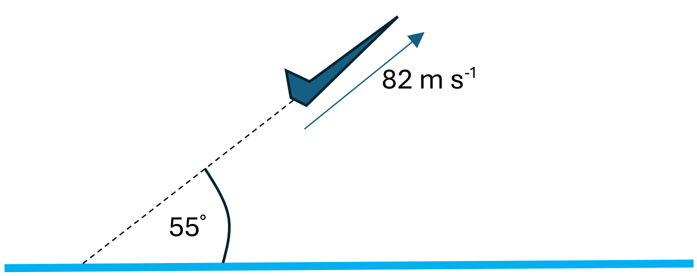
3. A plane of mass 8100 kg is taking off from an aircraft carrier. The plane accelerates uniformly from rest and reaches a takeoff speed of 82 m s^{-1} over a distance of 120 m. The engines exert a thrust force of 84 kN. The catapult wire also exerts a constant force on the plane accelerating it forward.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



(a) Calculate

(i)	the time taken to take off,	[1]
(ii)	the average power developed by the engine,	[1]
(iii)	the force due to the catapult wire.	[2]

(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.

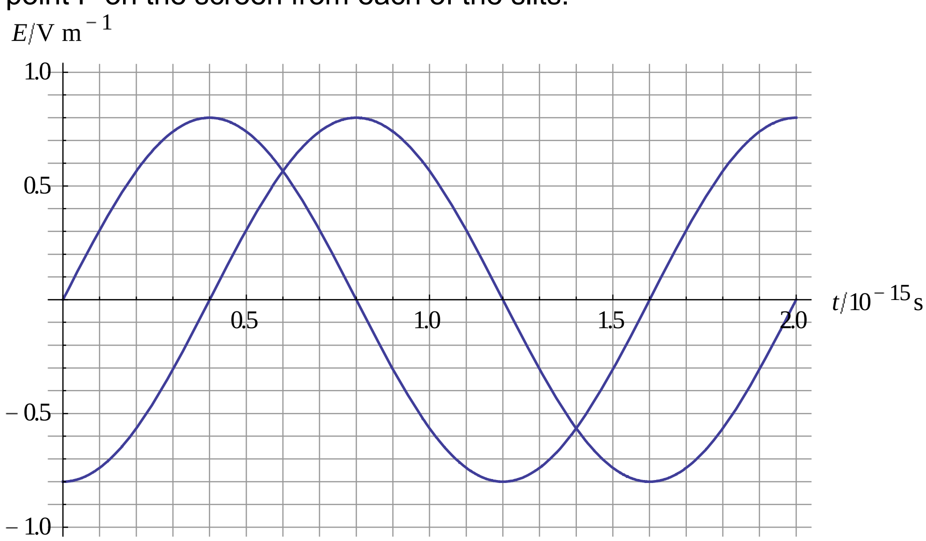


(i) State and explain whether the plane is in equilibrium. [2]

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

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]

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

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

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

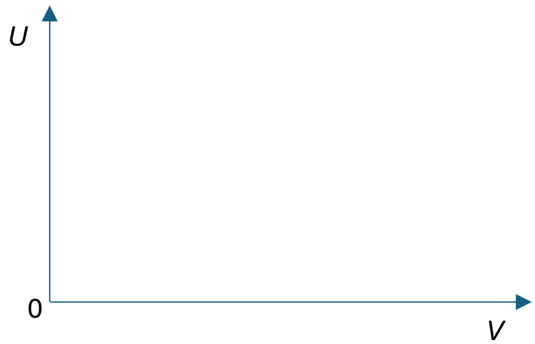
5. An ideal gas is confined within a container of volume 0.12 m^3 at pressure 2.0×10^5 Pa and temperature 310 K.

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

(b)

(i) Calculate the average kinetic energy of the molecules. [1]
(ii) Determine the internal energy of the gas. [1]

(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]

6.

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

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

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:

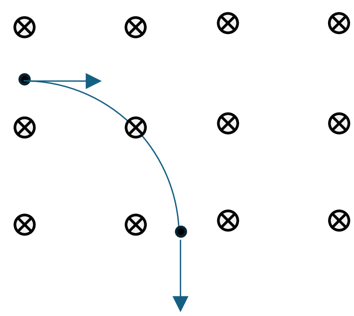
(c) The following **atomic** masses are available:

Tritium	3.016049 u
Helium	3.016029 u

(i) Calculate the energy released. [2]
(ii) Suggest whether tritium or helium has the largest binding energy per nucleon. [2]

(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]

(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.



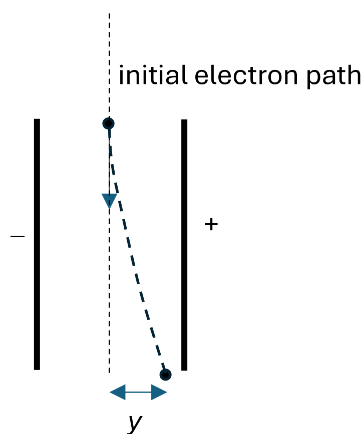
(i) Explain why the path of the electron is circular. [2]

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

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

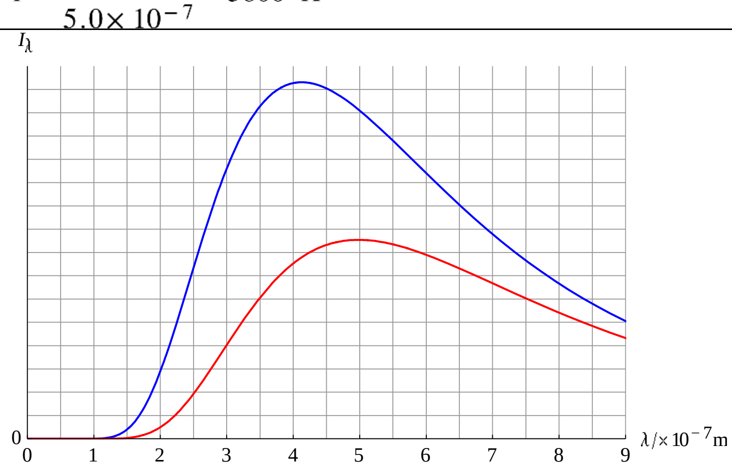
(iv) Suggest why the speed of the electron remains constant while in the region of magnetic field. [2]

(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]

Markscheme

1				
a		Peak wavelength 5.0×10^{-7} m ✓ $T=\frac{2.9\times10^{-3}}{5.0\times10^{-7}}=5800\ \text{K}$ ✓		[2]
b		 Blue curve above red curve with peak shifted left ✓		[1]

2				
a		$mv=(m+M)u\Rightarrow u=\frac{mv}{m+M}$ ✓ $u=\frac{0.025\times65}{0.025+1.20}=1.326\ \text{m s}^{-1}$ ✓		[2]
b		$\frac{1}{2}(m+M)u^2=(m+M)gh\Rightarrow h=\frac{u^2}{2g}=\frac{1.326^2}{2\times9.8}=9.0\times10^{-2}\ \text{m}$ ✓		[1]

3				
a	i	$s=\frac{u+v}{2}t\ \Rightarrow\ t=\frac{2s}{u+v}=\frac{2\times120}{0+82}=2.9268\approx2.9\ \text{s}$ ✓		[1]
a	ii	$\overline{P}=F\frac{u+v}{2}=\frac{84\times10^3\times82}{2}=3.4\times10^6\ \text{W}$ ✓		[1]
a	iii	$a=\frac{82}{2.9268}=28.0\ \text{m s}^{-2}$ ✓ $F+C-R=ma\Rightarrow C=ma+R-F=8100\times28.0+55\times10^3-84\times10^3=198\ \text{kN}$ ✓		[2]
b	i	Yes it is ✓ Because it travels on a straight line with constant speed/net force is zero ✓		[2]
b	ii	$F-Mg\sin\theta-R=0$ ✓ $F=Mg\sin\theta+R=8100\times9.8\times\sin55^\circ+55\times10^3=120\ \text{kN}$ ✓		[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 $\lambda = cT = 3\times10^{8}\times1.6\times10^{-15} = 4.8\times10^{-7}\ \text{m}$ ✓		[2]
a	iii	The separation of two consecutive peaks is a qaurter of a period ✓ So the phase difference is $\frac{\frac{T}{4}}{T}\times 2\pi = \frac{\pi}{2}$ ✓		[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	$\bar{E}_K = \frac{3}{2}kT = \frac{3}{2}\times1.38\times10^{-23}\times310 = 6.42\times10^{-21} \approx 6.4\times10^{-21}\ \text{J}$ ✓		[1]
b	ii	$U = NE_K = 5.61\times10^{24}\times6.42\times10^{-21} = 3.6\times10^{4}\ \text{J}$ ✓		[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	$\Delta M=\left(3.016049-m_{\text{e}}\right)-\left(3.016029-2m_{\text{e}}\right)-m_{\text{e}}=3.016049-3.01602=2.0\times 10^{-5}\text{ u}$ $Q=\Delta Mc^{2}=2.0\times 10^{-5}\times 931.5=1.86\times 10^{-2}\text{ MeV}$		[2]
c	ii	Helium is more tightly bound since tritium decays into it/helium is to the right of tritium on the BE curve <<and both are to the left of the peak>> Hence helium has the largest BE per nucleon ✓		[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	$evB=m_{\text{e}}\frac{v^{2}}{R}$ ✓ Hence result		[1]
e	iii	$T=\frac{1}{4}\frac{2\pi R}{v}=\frac{1}{4}\frac{2\pi m_{\text{e}}}{eB}$ ✓ $T=\frac{1}{4}\frac{2\pi\times 9.1\times 10^{-31}}{1.6\times 10^{-19}\times 5.0\times 10^{-3}}=1.8\text{ ns}$ ✓		[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		$a=\frac{F}{m_{\text{e}}}=\frac{eE}{m_{\text{e}}}$ ✓ $y=\frac{1}{2}at^{2}=\frac{1}{2}\times\frac{1.6\times 10^{-19}\times 5.8\times 10^{4}}{9.1\times 10^{-31}}\times\left(2.2\times 10^{-9}\right)^{2}=2.468\approx 2.5\text{ cm}$ ✓		[2]