SPECIMEN PAPERS

SET 2

Paper 2 SL

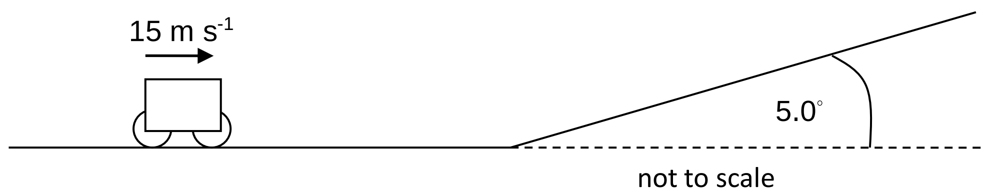
Time allowed: 1 hour 30 minutes.

A calculator and the data booklet are required.

The total number of marks for this paper is 50.

1. [5 marks]

(a) A car of weight 9800 N is travelling at constant speed 15 m s^{-1} on a straight horizontal road. The engine of the car develops a useful power of 32 kW.



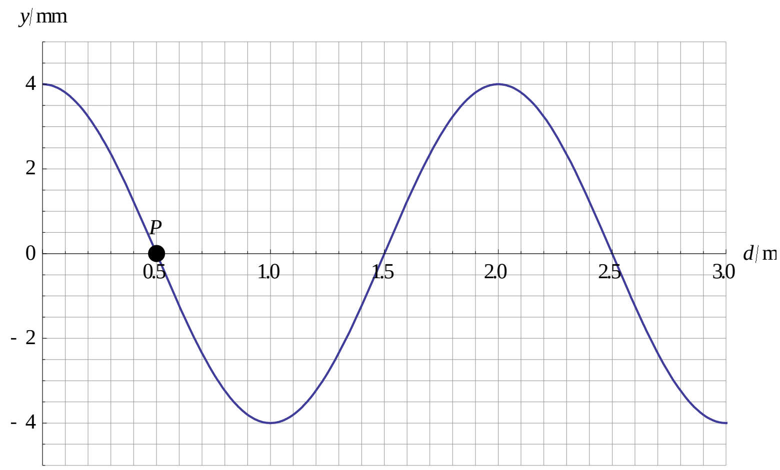
(i) Determine the resultant force opposing the motion of the car. [2]

(ii) The car now enters an inclined plane that makes an angle 5.0° with the horizontal. The magnitude of the force opposing the motion remains the same. Calculate the additional power the engine must develop so that the car continues up the incline at the same speed. [3]

2. [9 marks]

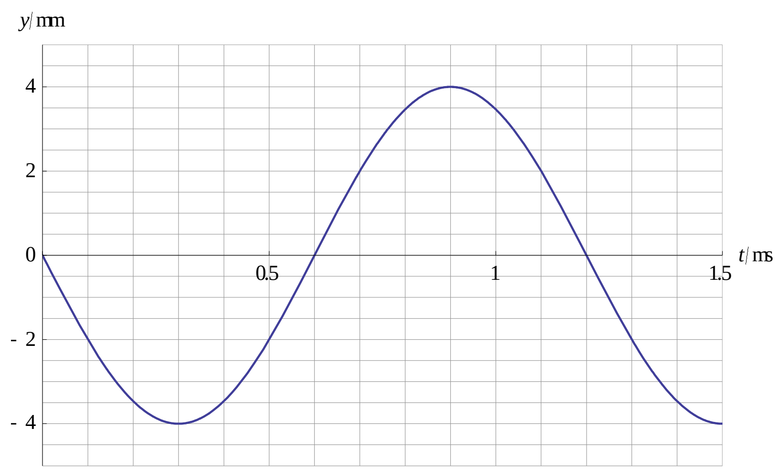
(a) State one piece of evidence that shows that waves carry energy. [1]

(b) A wave travels through a medium. Graph 1 shows the variation with distance of the displacement of particles in the medium at $t = 0$. The **equilibrium** position of a particle P in the medium has been marked.



Graph 1

Graph 2 shows the variation with time of the displacement of particle P.



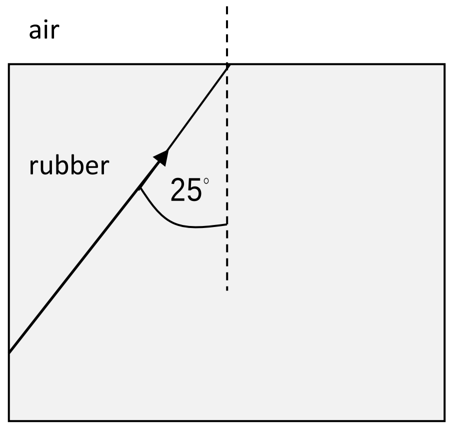
Graph 2

Determine

(i) the direction of the wave, [1]

(ii) the speed of the wave. [2]

(c) The wave in (b) is a sound wave travelling in a sheet of rubber surrounded by air. The speed of sound in air is 340 m s^{-1}.



The ray makes an angle of 25° with the normal to the sheet as shown. Determine the angle between the ray in air and the normal. [2]

(d) The wave in (c), after entering air, is directed towards the open end of a pipe whose other end is closed. Determine the minimum length of the pipe such that a standing wave will be established in the pipe. [3]

3. [7 marks]

A tiny droplet of water falling though air experiences a drag force given by Stokes' law.

(a) Explain the origin of this force. [2]

(b) Determine the units of viscosity in terms of fundamental S.I. units. [1]

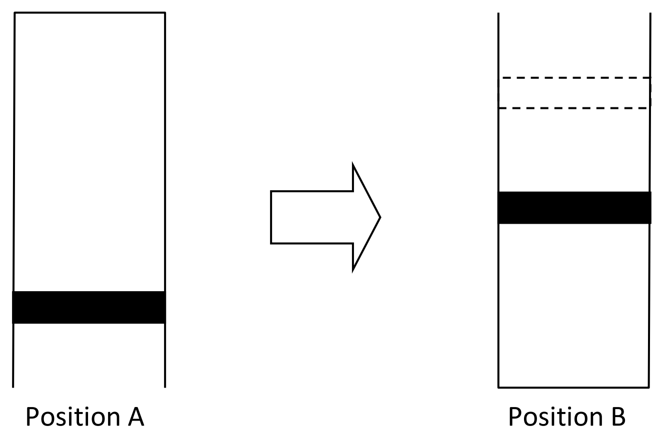
(c) The atmosphere contains tiny droplets of water of radius $5.0 \times 10^{-6}\ \mathrm{m}$. The density of water is $1000\ \mathrm{kg\,m^{-3}}$ and the viscosity of air in SI units is 1.8×10^{-5}. Ignore the buoyant force on the droplet.

(i) Show that the terminal speed of the droplet is $v = \dfrac{2\rho g}{9\eta} r^2$. [3]

(ii) Calculate this terminal speed. [1]

4. [9 marks]

(a) A tube with a cross sectional area 2.40×10^{-2} m^2 is filled with 0.500 mol of a gas at 3.00×10^{2} K. A movable piston seals the tube so the gas cannot escape. The atmospheric pressure is 1.00×10^{5} Pa. When the tube is turned upside down (position A to position B) the pressure of the gas increases by 1.50×10^{4} Pa without any change in temperature.



not to scale

(i) Determine the mass of the piston. [3]

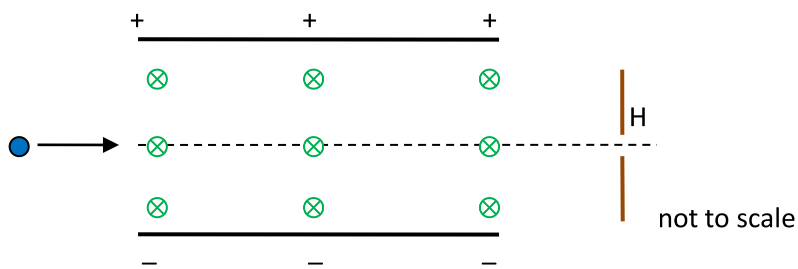
(ii) Show that the volume of the gas in position A is about 1.3×10^{-2} m^3. [2]

(iii) Show that the volume in position B is about 1.2×10^{-2} m^3. [2]

(b) With the tube in position B, the gas is heated at constant pressure, so it expands to the volume in (a)(ii). Calculate the temperature of the gas. [2]

5. [20 marks]

A beam of singly ionized atoms of the same element enters the region between two parallel, oppositely charged plates in vacuum. The atoms have a range of speeds. A uniform magnetic field *B* of magnetic flux density 0.40 T is established between the plates, directed into the page. The potential difference between the plates is 2.50 kV and the plates are 8.0 mm apart. The initial direction of the beam is aligned with a small hole H beyond the plates.

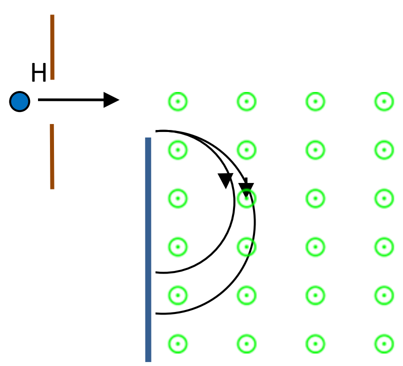


(a) (i) Determine the electric field between the plates. [1]

(ii) Explain why all the atoms that emerge through H have the same speed. [3]

(iii) Show that the common speed at H is about $7.8 \times 10^5\ \mathrm{m\,s^{-1}}$. [1]

(b) The atoms in (a) that have gone through H enter a new region of magnetic field as shown. The magnetic flux density is 0.50 T and is directed out of the plane of the page.



The atoms are bent into two circular paths of different radius.

(i) Show that the radius of the circular path of charged particle in a magnetic field is given by $R = \dfrac{mv}{eB}$. [1]

(ii) State what is meant by isotopes. [2]

(iii) Outline why the presence of more than one path is evidence for isotopes. [2]

(c) The beam consists of stable atoms of neon of charge +*e*. The path of least radius corresponds to ${}^{20}_{10}\mathrm{Ne}$.

(i) Show that this radius is about 0.3 m. [2]

(ii) Estimate the mass number of the isotope corresponding to a radius of 0.36 m. [1]

(d) ${}^{23}_{10}\mathrm{Ne}$ is an unstable isotope of neon. ${}^{23}_{10}\mathrm{Ne}$ decays into sodium (Na) by beta minus decay.

(i) Radioactive decay is described as random and spontaneous. State what this means. [2]

(ii) Write down the decay equation. [2]

(e) The **atomic** mass of ${}^{23}_{10}\mathrm{Ne}$ is M_{Ne} = 22.9945 u and the **atomic** mass for Na is M_{Na} = 22.9898 u.

Determine the energy released in the decay. [3]

Markscheme

		A	B	C	D	E
		SL	SL	SL	SL	SL
	Q1	5				
	Q2			9		
	Q3	7				
	Q4		9			
SL&HL	Q5				9	11
		12	9	9	9	11

1				
a	i	$P = Fv$ so engine force is $F = \frac{P}{v} = \frac{32\times10^3}{15} = 2.1\times10^3$ N ✓ Since speed is constant the drag force is equal to 2.1×10^3 N ✓		[2]
b	ii	The engine must provide an additional force $Mg\sin\theta$ ✓ $Mg\sin\theta = 9800\times\sin5.0^\circ = 854.1\text{ N}$ ✓ The additional power is then $854.1\times15 = 12.8\times10^3 \approx 13$ kW ✓		[3]

2				
a		The Sun warms the earth through EM waves/earthquake waves can destroy buildings/sound at the right frequency can shutter glass✓		[1]
b	i	According to Graph 1, the displacement after t = 0 becomes negative so the wave must be moving to the left ✓		[1]
b	ii	The wavelength is 2.0 m and the period is 1.2 ms ✓ The speed is $\frac{2.0}{1.2\times10^{-3}} = 1.67\times10^3$ m s^{-1} ✓		[2]
c		$\frac{\sin25^\circ}{1.67\times10^3} = \frac{\sin\theta}{340}$ ✓ $\sin\theta = \frac{340}{1.67\times10^3}\times\sin25^\circ = 8.604\times10^{-2} \Rightarrow \theta = 4.9^\circ$ ✓		[2]
d		A standing wave can be established in the pipe if the length satisfies $\lambda = \frac{4L}{n}$ and so the minimum length is then $L = \frac{\lambda}{4}$ ✓ The wavelength in air is $\frac{1.67\times10^3}{2.0} = \frac{340}{\lambda} \Rightarrow \lambda = 0.41\text{ m}$ ✓ Hence, $L = \frac{0.41}{4} = 0.10$ m ✓		[3]

3				
a		The falling droplet exerts a force on the fluid around it making it move ✓ By Newton's third law the fluid exerts a force opposite the velocity ✓		[2]
b		$[\eta]=\frac{[F]}{[rv]}=\frac{\mathrm{kg\,m\,s^{-2}}}{\mathrm{m\,m\,s^{-1}}}=\mathrm{kg\,m^{-1}\,s^{-1}}$ ✓		[1]
c	i	$mg=6\pi\eta rv$ ✓ $\frac{4\pi}{3}r^3\rho g=6\pi\eta rv$ ✓ $v=\frac{2\rho g}{9\eta}r^2$ ✓		[3]
c	ii	$v=\frac{2\times 1000\times 9.8}{9\times 1.8\times 10^{-5}}\times(5.0\times 10^{-5})^2=3.0\times 10^{-3}\ \mathrm{m\,s^{-1}}$ ✓		[1]

4				
a	i	At A: $P_1+\frac{mg}{A}=P_{atm}\Rightarrow P_1=P_{atm}-\frac{mg}{A}$ and at B: $P_2=P_{atm}+\frac{mg}{A}$ ✓ $P_2-P_1=\frac{2mg}{A}=1.50\times 10^4$ Pa ✓ $m=\frac{2.40\times 10^{-2}\times 1.50\times 10^4}{2\times 9.8}=18.4$ kg ✓		[3]
a	ii	$P_1=P_{atm}-\frac{mg}{A}=1.00\times 10^5-\frac{1.50\times 10^4}{2}=9.25\times 10^4$ Pa ✓ $V_1=\frac{nRT}{P_1}=\frac{0.500\times 8.31\times 300}{9.25\times 10^4}=1.348\times 10^{-2}\approx 1.35\times 10^{-2}\ \mathrm{m^3}$ ✓		[2]
a	iii	$P_2=P_{atm}+\frac{mg}{A}=1.00\times 10^5+\frac{1.50\times 10^4}{2}=1.075\times 10^5$ Pa ✓ $P_1V_1=P_2V_2\Rightarrow V_2=\frac{P_1V_1}{P_2}$ ✓ $=\frac{9.25\times 10^4}{1.075\times 10^5}\times 1.348\times 10^{-2}=1.160\times 10^{-2}\approx 1.16\times 10^{-2}\ \mathrm{m^3}$		[2]
b		$\frac{V_2}{T_2}=\frac{V_3}{T_3}\Rightarrow T_3=T_2\frac{V_1}{V_2}$ ✓		[2]

		$T_3 = 300 \times \frac{1.348 \times 10^{-2}}{1.160 \times 10^{-2}} = 348.6 \approx 349 \text{ K}$ ✓		

5			
a	i	$E = \frac{V}{d} = \frac{2.5 \times 10^3}{8.0 \times 10^{-3}} = 3.125 \times 10^5 \approx 3.1 \times 10^5 \text{ N C}^{-1}$ ✓	[1]
a	ii	The atoms that will go through H must be undeflected ✓ So $qE = qvB$ ✓ $v = \frac{E}{B}$ i.e. speed is unique ✓	[3]
a	iii	$v = \frac{3.125 \times 10^5}{0.40} = 7.813 \times 10^5 \approx 7.8 \times 10^5 \text{ m s}^{-1}$ ✓	[1]
b	i	$qvB = \frac{mv^2}{R}$ hence result ✓	[1]
b	ii	Atoms of the same element/same number of protons ✓ But different number of neutrons ✓	[2]
b	iii	Different paths are due to different mass since $R = \frac{mv}{eB}$ and v, q and B are the same ✓ Different mass can only be due to extra neutrons since the proton number is the same /same element ✓	[2]
c	i	$R = \frac{20 \times 1.66 \times 10^{-27} \times 7.813 \times 10^5}{1.6 \times 10^{-19} \times 0.50}$ ✓ $R = 0.324 \approx 0.3 \text{ m}$ ✓	[2]
c	ii	$\frac{0.36}{0.324} \times 20 = 22.2 \approx 22$ ✓	[1]
d	i	Random: it cannot be predicted which nucleus and when will decay✓ Spontaneous: the rate of decay cannot be influenced/changed✓	[2]
d	ii	${}^{23}_{10}\text{Ne} \rightarrow {}^{23}_{11}\text{Na} + e^- + \bar{\nu}$ Correct numbers for Na ✓ Presence of antineutrino ✓	[2]
e		$Q = \Delta mc^2 = (\bar{M}_{\text{Ne}} - \bar{M}_{\text{Na}} - m_e)c^2$ where the bar denotes **nuclear** masses ✓ $Q = (M_{\text{Ne}} - 10m_e)c^2 - \left((M_{\text{Na}} - 11m_e)c^2 + m_e c^2\right) = (M_{\text{Ne}} - M_{\text{Na}})c^2$ ✓ $Q = (22.9945 - 22.9898) \times 931.5 = 4.4 \text{ MeV}$ ✓ (use of MP3 alone gets [1])	[3]