Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Promotional Examination
Year 5

H2 PHYSICS

9749/02
6 October 2021
2 hours

Paper 2 Structured Questions

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 1	
MCQ	20
Paper 2	
1	10
2	11
3	9
4	10
5	10
6	10
7	20
s.f.	-1
Total	100

This document consists of **19** printed pages and **1** blank page.

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1}
		$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	T/°C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux denxity due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** the questions.

1 Two trains, P and Q, travel by the same route, from rest at station A to rest at station B.

Train P has a constant acceleration a for the first third of the **time**, constant velocity for the second third, and constant deceleration of magnitude a for the final third of the time.

Train Q has a constant acceleration a for the first third of the **distance**, constant velocity for the second third, and constant deceleration of magnitude a for the final third of the distance.

(a) On the axes of Fig. 1.1, complete the graph to show the variation with time t of the velocity v for train P. The first third of the journey has been drawn.

Fig. 1.1

[2]

(b) The first third of the journey for train Q has been drawn in Fig. 1.2.

Fig. 1.2

(i) Write down an expression for

1. the distance for each third of the journey in terms of *a* and t_Q,

distance = ... [1]

2. the duration for second third of the journey in terms of t_Q.

duration = ... [1]

(ii) On the axes of Fig. 1.2, complete the graph to show the variation with time of the velocity *v* for train Q. [2]

(c) Hence, determine the following ratio

$$\frac{\text{total time taken by train Q for the journey}}{\text{total time taken by train P for the journey}}.$$

ratio = ... [4]

2 A pile driver is used to drive cylindrical poles, called piles, into the ground so that they form the foundations of a building. Fig. 2.1 shows a possible arrangement for a pile driver. The hammer is held above the pile and then released so that it falls freely under gravity, until it strikes the top of the pile.

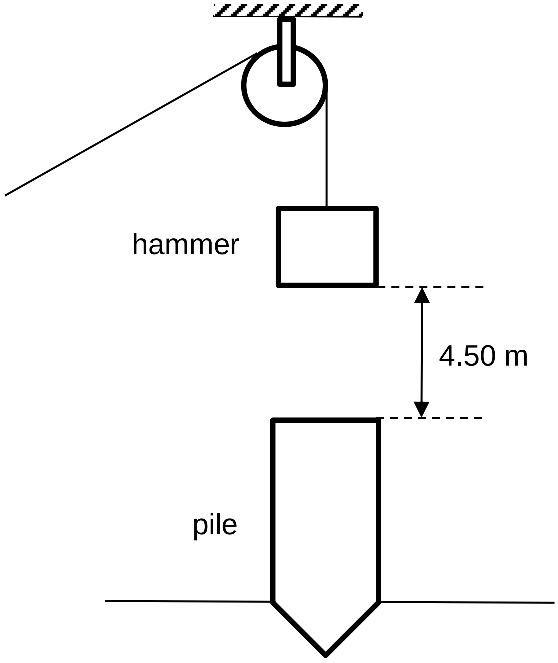

Fig. 2.1

(a) The hammer has a mass of 250 kg and falls 4.50 m before striking the pile. After impact, the hammer and pile move downwards together.

Calculate

(i) the speed of the hammer just before the impact,

speed of hammer = ………………………… $m\ s^{-1}$ [2]

(ii) the momentum of the hammer just before the impact,

momentum of hammer = ………………………… $kg\ m\ s^{-1}$ [1]

(iii) the speed of the hammer and pile immediately after impact, if the mass of the pile is 2000 kg.

speed of hammer and pile = ……..………………… m s^{-1} [2]

(b) After impact, the hammer and the pile move so that the pile sinks into the ground to a depth of 0.25 m.

Calculate

(i) the loss in kinetic energy of the hammer and pile,

loss in kinetic energy = ……..………………… J [2]

(ii) the average frictional force the ground exerts on the pile while bringing it to rest.

average frictional force = ……..………………… N [2]

(c) The process is repeated several times and each time the hammer is raised 4.5 m above the pile. Suggest why the extra depth of penetration is likely to decrease with each impact.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………….. [2]

3 **(a)** Explain what is meant by *centre of gravity*.

………

……… [1]

(b) Fig. 3.1 shows a supermarket trolley.

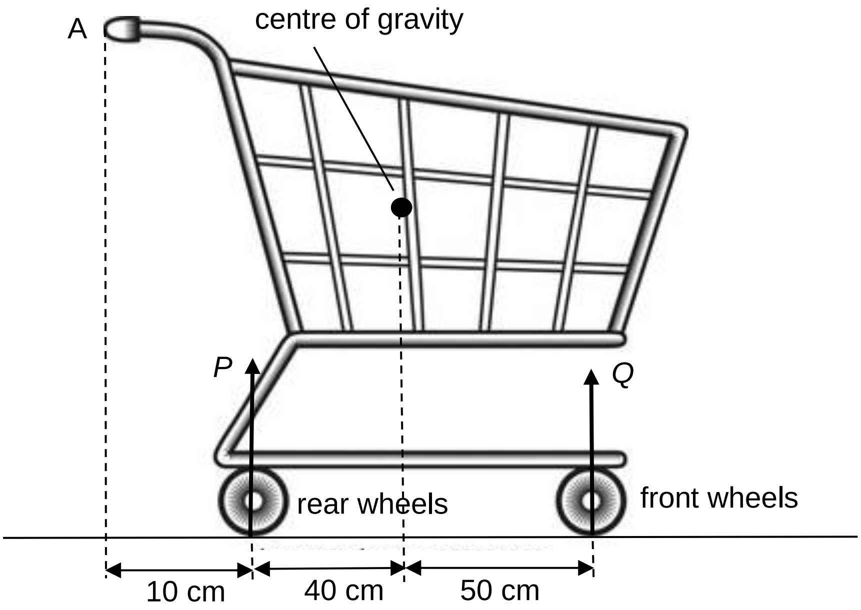

Fig. 3.1 (not to scale)

The weight of the trolley and its contents is 160 N.

P and *Q* are the resultant forces that the ground exerts on the rear wheels and front wheels respectively.

Calculate

(i) force *P*,

P = ……………………… N [2]

(ii) force *Q*,

Q = ……………………… N [2]

(iii) the minimum force that needs to be applied vertically at A to lift the front wheels off the ground.

minimum force = ……………………. N [2]

(c) State and explain, without calculation, how the minimum force that needs to be applied vertically at A to lift the rear wheels off the ground compares to the force you have calculated in **(b)(iii)**.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………[2]

4 **(a)** Explain what is meant by *gravitational field*.

....

.... [1]

(b) A binary star system consists of two stars S_1 and S_2, each in a circular orbit about a point P as shown in Fig. 4. The two stars rotate with the same angular velocity ω.

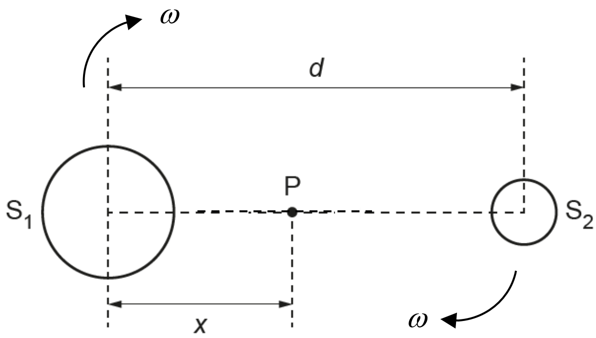

Fig. 4 (not to scale)

The separation d of the centres of S_1 and S_2 is 1.8 x 10^{12} m. Point P is at a distance x from the centre of star S_1. The period of rotation of the stars is 44.2 years.

(i) Calculate ω.

ω = ... rad s^{-1} [2]

(ii) Show that the ratio of the masses of the stars is given by

$$\frac{\text{mass of } S_1}{\text{mass of } S_2} = \frac{d - x}{x}$$

[2]

(iii) By considering circular motion of S_2 about P, show

$$GM_1 = d^2 (d - x)\, \omega^2$$

where G is the gravitational constant and M_1 is the mass of star S_1. [2]

(iv) The ratio in **(ii)** is found to be 1.5.

Use data from **(i)** and your answer in **(iii)** to determine the mass M_1.

M_1 = ……….………………… kg [3]

5 **(a)** Explain what is meant by the *internal energy* of an ideal gas.

………

…………………………………………………………………………………………………… [2]

(b) A cylinder of helium gas, at a temperature of 20 °C and pressure of 1.01×10^5 Pa, occupies a volume of 1000 cm^3.

The gas expands at constant pressure to a volume of 1500 cm^3.

Assuming that the helium gas is ideal, calculate

(i) the final temperature of the gas,

final temperature = ……………………… °C [2]

(ii) the number of particles in the gas,

number of particles = ……………………… [2]

(iii) the increase in internal energy of the gas,

increase in internal energy = ……………………… J [2]

(iv) the heat supplied to the gas.

heat supplied = ……………………… J [2]

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6 **(a)** Fig. 6 shows a cubical box of side *l* which contains *N* molecules, each of mass *m*, all moving horizontally with speed *u* at right angles to wall A.

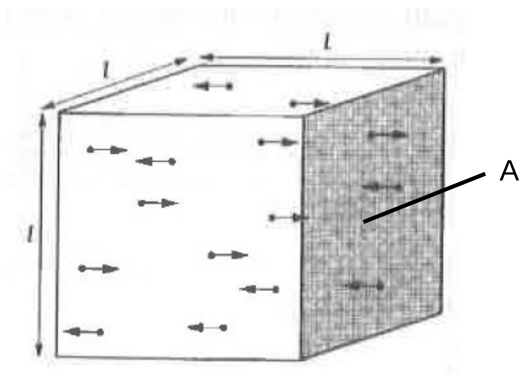

Fig. 6

When a molecule hits a wall, it bounces off with no loss of speed and travels in the opposite direction. Deduce

(i) the momentum of a molecule just before a collision with the wall,

momentum = ………………………… [1]

(ii) the change in momentum of a molecule when it collides with the wall,

change in momentum = ………………………… [2]

(iii) the time taken by one molecule between collisions with wall A,

time = ………………………… [1]

(iv) the total number of collisions per unit time made with wall A by all the molecules,

total number of collisions per unit time = ……….……………… [2]

(v) the rate of change of momentum for all the molecules colliding with wall A

rate of change of momentum = ……….……………… [1]

(vi) Use your answer in **(v)** to show that the pressure P on wall A is given by

$$P = \frac{Mu^2}{V}$$

where M is the total mass of all the molecules and V is the volume of the box. [1]

(b) The conditions considered in **(a)** are highly improbable. Explain briefly how the conditions may be altered to provide a better model of an ideal gas.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

7 **(a)** A tube, sealed at one end, has a total mass m and a uniform area of cross-section A. The tube floats upright in a liquid of density ρ with length L submerged, as shown in Fig. 7.1a.

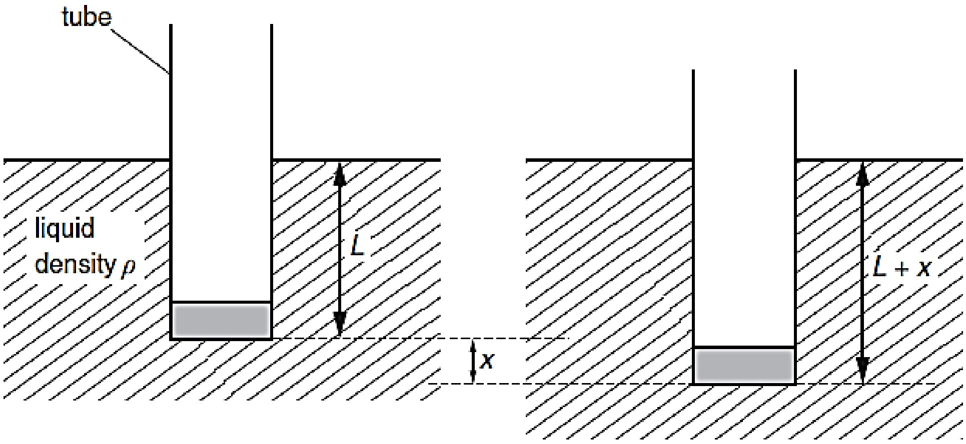

Fig. 7.1a **Fig. 7.1b**

The tube is displaced vertically and then released. The tube oscillates vertically in the liquid. At one time, the displacement is x, as shown in Fig. 7.1b.

Theory shows that the acceleration a of the tube is given by the expression

$$a = -\frac{A\rho g}{m}x$$

where g is the acceleration of free fall.

(i) Explain how it can be deduced from the expression that the tube is moving with simple harmonic motion.

....

....

.... [2]

(ii) Show that the tube is performing simple harmonic motion with a frequency *f* given by

$$f = \frac{1}{2\pi}\sqrt{\frac{A\rho g}{m}}\ .$$

[2]

(b) When the tube is at rest in water, the depth *L* of immersion of the base of the tube is 16 cm. The tube is displaced vertically and then released. The variation with time *t* of the depth *L* of the base of the tube is shown in Fig. 7.2.

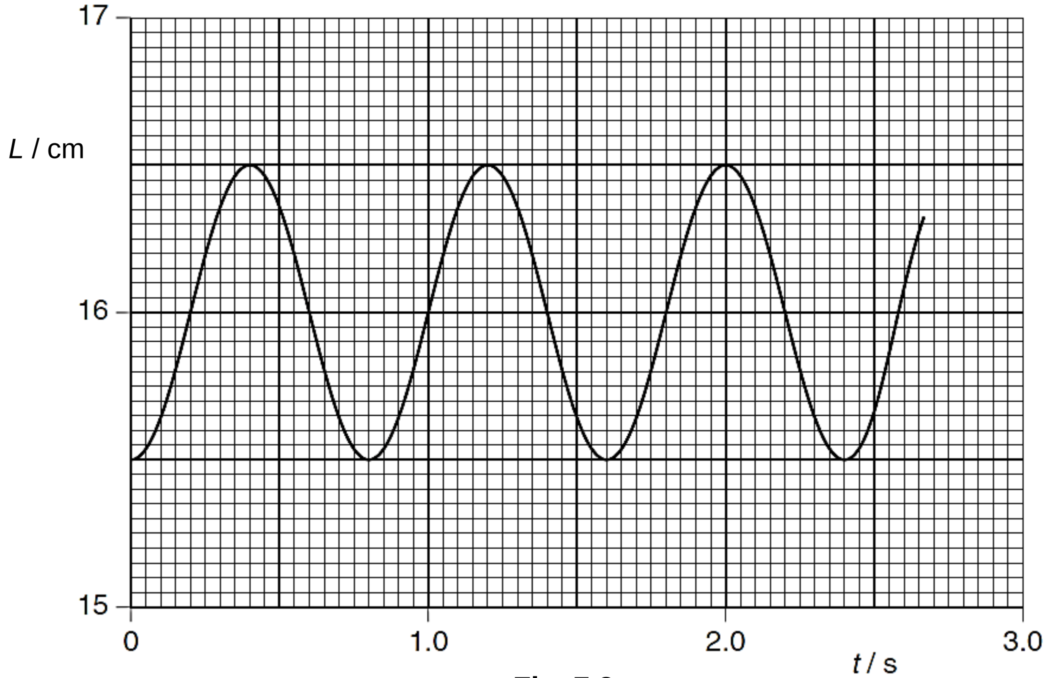

Fig. 7.2

(i) Use Fig. 7.2 to determine, for the oscillations of the tube,

1. the amplitude,

amplitude = …………………………… cm [1]

2. the period.

period = …………………………… s [1]

(ii) Calculate the vertical speed of the tube at a point where the depth L is 16.2 cm.

speed = ………………………………. cm s^{-1} [3]

(iii) The tube has a cross-sectional area of 4.2 cm^2 and is floating in water of density 1.0×10^3 kg m^{-3}. Calculate the total mass of the tube.

mass = ………………………………. kg [2]

(c) The tube is now placed in a different liquid. The tube oscillates vertically. The variation with time t of the vertical displacement x of the tube is shown in Fig. 7.3.

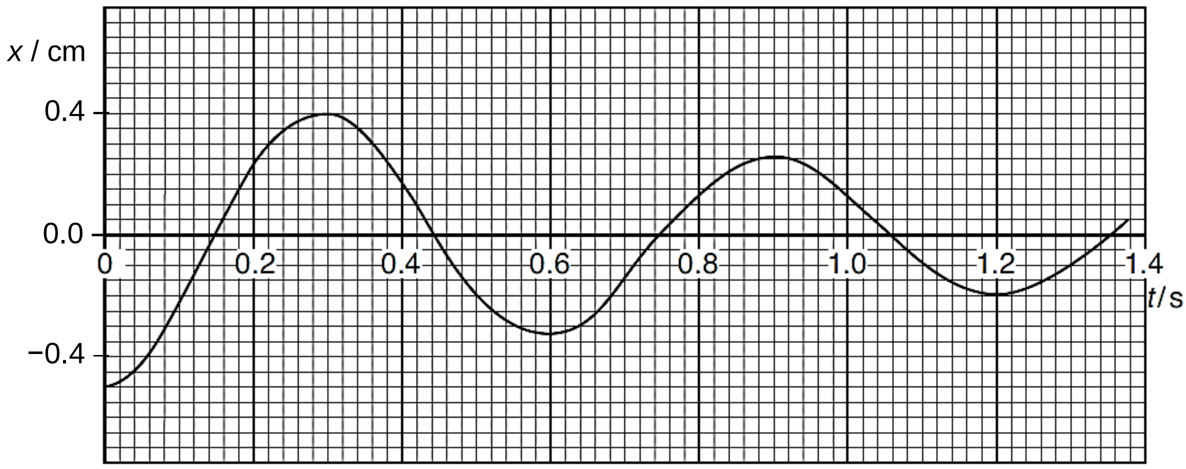

Fig. 7.3

(i) Assuming the equation in **(a) (ii)**, calculate the density of the liquid.

density = ………………………………. kg m^{-3} [3]

(ii) Suggest one reason why the amplitude of the oscillation decreases with time.

…..……………………………………………………..……………………………...

……………………………………………………………………………………...

……………………………………………………………………………...…… [1]

(iii) Calculate the energy of the oscillation at time t = 1.2 s.

energy = …………………………….. J [2]

(d) The tube is placed back into water which is now cooled so that, although the density of water is unchanged, it undergoes damped oscillatory motion after it is displaced vertically and released. A variable frequency water wave generator is used to produce surface water waves that incident on the tube and force it to oscillate vertically.

The amplitude of vibrations of the wave generator is constant. The frequency *f* of the wave generator is varied. When surface water waves of frequency 0.75 Hz are incident on the tube, they cause resonance in the vertical oscillation of the tube.

(i) Explain what is meant by *resonance*.

…………………………………………………………………………………………...

…………………………………………………………………………………………...

…………………………………………………………………………………..…… [1]

(ii) On Fig. 7.4, draw a line to show the variation with frequency of the amplitude of the forced oscillations of the tube. [2]

Fig. 7.4