Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Promotional Examination
Year 5

H2 PHYSICS — 9749/02

Paper 2 Structured Questions

1 October 2024

1 hour 55 minutes

Candidates answer on the Question Paper

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	**15**
Paper 2	
1	**8**
2	**11**
3	**7**
4	**10**
5	**10**
6	**9**
7	**20**
s.f.	**- 1**
Total	**90**

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

Data

speed of light in free space	c =	3.00×10^{8} m s^{-1}
permeability of free space	μ_o =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o =	8.85×10^{-12} F m^{-1}
	=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e =	1.60×10^{-19} C
the Planck constant	h =	6.63×10^{-34} J s
unified atomic mass constant	u =	1.66×10^{-27} kg
rest mass of electron	m_e =	9.11×10^{-31} kg
rest mass of proton	m_p =	1.67×10^{-27} kg
molar gas constant	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant	k =	1.38×10^{-23} J K^{-1}
gravitational constant	G =	6.67×10^{-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	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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.	$v = v_0 \cos \omega t$ $= \pm\ \omega \sqrt{\left(x_0^2 - x^2\right)}$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** the questions.

1 The rotational kinetic energy, $E_{Rotational}$, and the moment of inertia, I, of a solid metal sphere are given by the following equations:

$$E_{Rotational} = \frac{1}{2} I \omega^2$$
$$I = \frac{2}{5} MR^2$$

where M is the mass of the solid metal sphere, R is the radius of that sphere and ω is the angular velocity.

Hence, the rotational kinetic energy, $E_{Rotational}$, can be expressed as the following equation with the unit of Joules (J):

$$E_{Rotational} = \frac{1}{5} MR^2 \omega^2$$

The details of the solid metal sphere are given in Table 1.1. An electronic balance, a micrometer screw gauge and an electronic stopwatch were used to obtain the data.

Mass of sphere/ g	36.935 ± 0.001
Diameter of sphere/ mm	20.79 ± 0.01
Period of sphere/ s	1.2 ± 0.2

Table 1.1

(a) State the base SI units of the moment of inertia, I.

units of I = ... [1]

(b) The base unit of ω is given by s^{-1}. Show that the rotational kinetic energy, $E_{Rotational}$, shares the same base units with the translational kinetic energy given by $\frac{1}{2} mv^2$.

[1]

(c) Calculate the value of $E_{Rotational}$ and its uncertainty.

$E_{Rotational}$ = ……………..…………….. $\pm$ ……………..………………. J [4]

(d) State an example of a possible systematic and random error associated with the measurements to obtain $E_{Rotational}$.

systematic error: ……………………………………………….……….……………... [1]

random error: …..…………………………………………………………...….………… [1]

[Total: 8]

2 An aeroplane is stationary on a runway. It begins to accelerate in a straight line along the runway and successfully takes off after 55.0 s.

Fig. 2.1 shows the variation with time of the resultant force acting on the aeroplane while it is in contact with the runway.

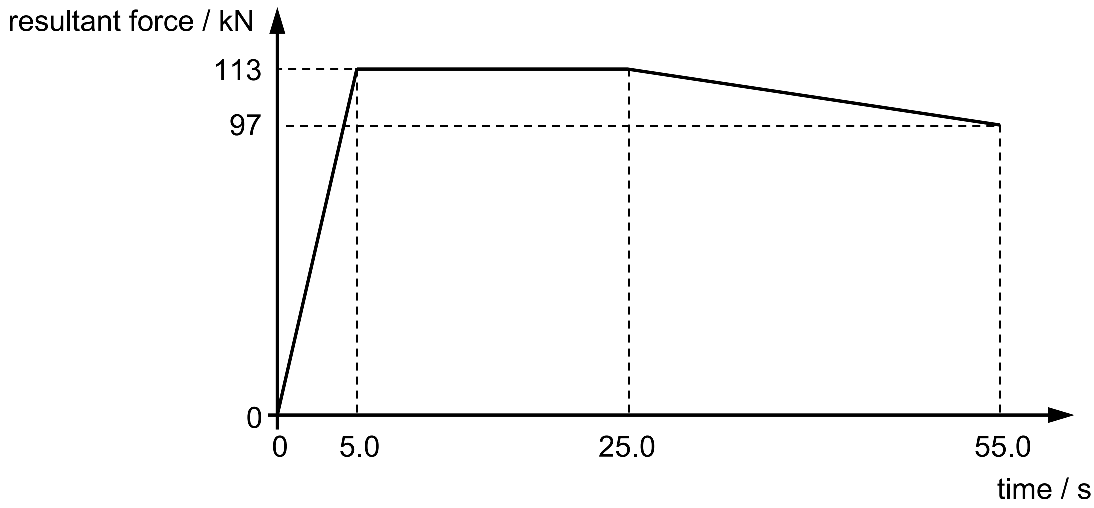

Fig. 2.1

(a) Suggest two reasons why the resultant force on the aeroplane varies rather than remaining constant as it accelerates along the runway.

1. ....

....

2. ....

.... [2]

(b) **(i)** State *Newton's second law of motion*.

....

....

....

.... [1]

(ii) Calculate the momentum of the aeroplane at take-off.

momentum = ……….………….…..... N s [3]

(c) The total mass of the aeroplane is 7.45×10^4 kg.

Calculate the velocity v_t of the aeroplane at take-off.

velocity = …………………………….. m s^{-1} [1]

(d) On Fig. 2.2, sketch a graph to show the variation with time of the velocity of the aeroplane as it travels along the runway. (Numerical values for the velocity are not required.)

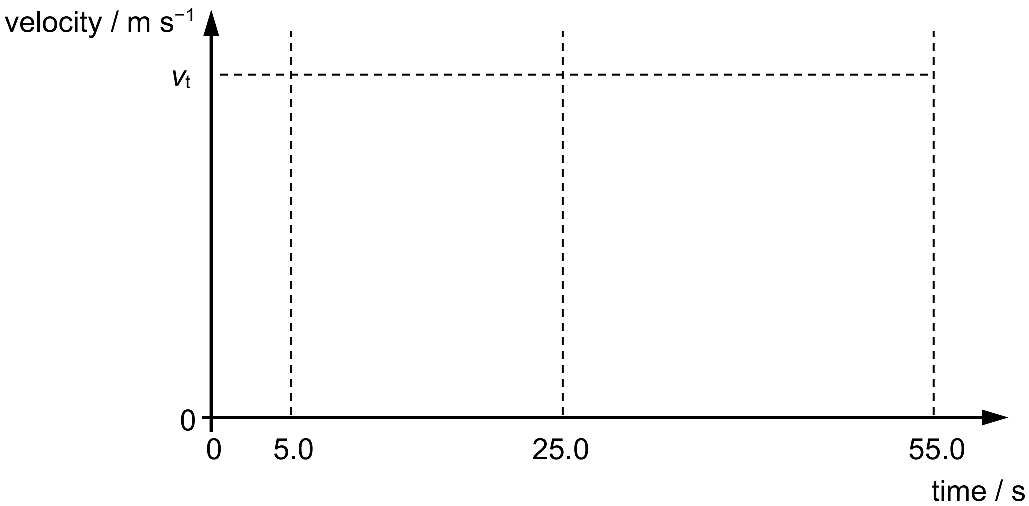

Fig. 2.2 [2]

(e) Estimate the distance travelled by the aeroplane along the runway.

distance = ……….………….……..... m [2]

[Total: 11]

3 A block of mass 0.20 kg has velocity 1.8 m s^{-1}. It collides with a stationary block of mass 0.30 kg. The two blocks stick together after the impact.

(a) Calculate the velocity of the two blocks after impact. Ignore the effects of friction.

velocity = ... m s^{-1} [2]

(b) Show that the collision is inelastic.

[2]

(c) The collision took place over a time interval of 0.20 s.

By calculating the change of momentum of each block, show how Newton's third law of motion applies to this collision.

[3]

[Total: 7]

4 (a) Explain what is meant by *upthrust*.

....

....

....

.... [1]

(b) Before a small balloon is inflated, its mass is 1.30 g as recorded on an electronic mass balance.

The balloon is inflated with air so that it is spherical in shape with a diameter of 22.0 cm.

(i) The density of air is 1.21 kg m^{-3}. Calculate the mass of air displaced by the balloon.

mass of air displaced = ……………….. g [2]

(ii) The inflated balloon gives a reading of 1.55 g when placed on the balance. Calculate the mass of air in the balloon.

mass of air in balloon = ………………… g [2]

(iii) Suggest why the value in **(b)(ii)** is larger than the value in **(b)(i).**

....

....

....

.... [1]

(c) A nut of mass 2.10 g is now tied to the balloon with a light cotton thread. The balloon is dropped from a height of 4.00 m.

(i) Calculate the acceleration of the balloon and nut at the start of their descent.

acceleration = ……………….. m s^{-2} [2]

(ii) Explain why the acceleration will approach zero as the balloon descends.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

[Total: 10]

5 A spring that has an unstretched length of 7.0 cm is attached to a fixed point. A mass M of 100 g is attached to the spring and gently lowered until equilibrium is reached, as shown in Fig. 5.1 (a). The length of the spring at equilibrium is 9.0 cm.

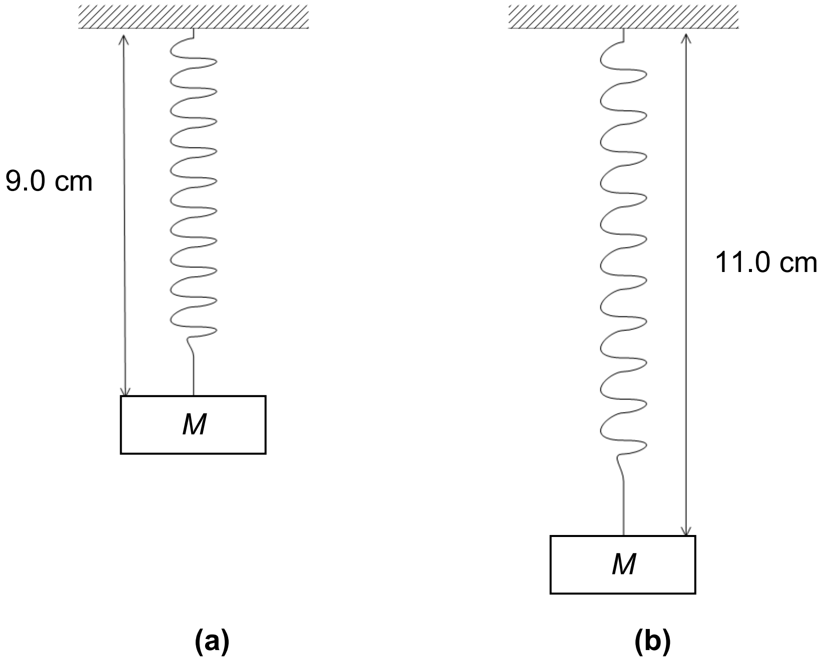

Fig. 5.1

The mass M is gently pulled downward, extending the spring to a length of 11.0 cm, as shown in Fig. 5.1 (b). It is then released and allowed to oscillate in simple harmonic motion with a frequency of 3.5 Hz.

Assume air resistance and other dissipative forces are negligible.

Consider the downward direction as positive.

(a) Calculate the angular frequency, ω, of the oscillation.

ω = …………………………………… rad s^{-1} [1]

(b) Write the equation that represents the displacement y as a function of time t for the motion of the mass.

equation is …………………………………… [1]

(c) Determine the magnitude and direction of the acceleration of mass M when $t = 2.0$ s.

magnitude = ………………………………. m s^{-2}

direction = ………………………………………

[3]

(d) Show that the force constant k of the spring is 49 N m^{-1}.

[1]

(e) Fig. 5.2 is a table of the energies of the simple harmonic motion of the spring.

Fill in the missing values in the table.

	gravitational potential energy / J	elastic potential energy / J	kinetic energy / J
lowest point	0		
equilibrium position			
highest point			

Fig. 5.2

[4]

[Total: 10]

6 Fig. 6.1 shows a potential divider circuit using cells of e.m.f. 6.1 V with negligible internal resistance.

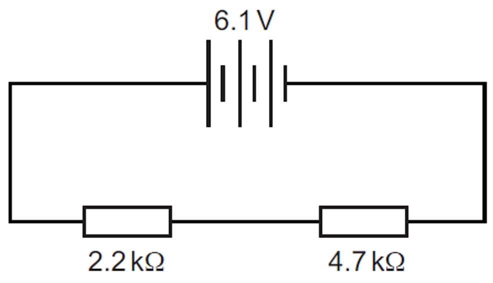

Fig. 6.1

(a) Determine the potential difference across the 4.7 kΩ resistor.

potential difference = ... V [2]

(b) An analogue voltmeter connected across the 4.7 kΩ resistor reads 3.2 V.

Determine the resistance of the analogue voltmeter.

resistance = ... Ω [3]

(c) A cell is made by inserting a zinc strip and a copper strip into a potato. When the same analogue voltmeter is connected to the cell as shown in Fig. 6.2, it registers a potential difference of 0.50 V.

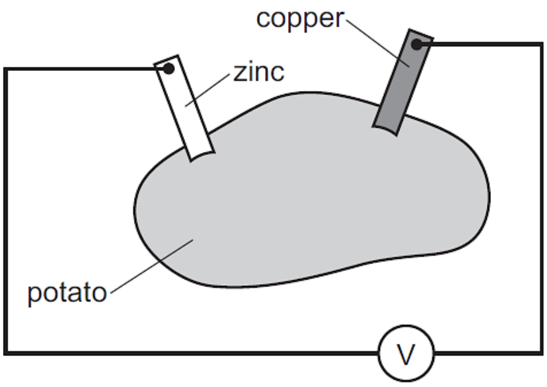

Fig. 6.2

(i) Using your answer to **(b)**, calculate the current in the circuit.

current = ... A [1]

(ii) When a digital voltmeter of resistance 1.0 MΩ replaces the analogue voltmeter in Fig. 6.2, it registers a potential difference of 0.93 V. Use the readings from the two meters to estimate the internal resistance of the potato.

internal resistance = ... Ω [2]

(iii) Determine the e.m.f. of the cell.

e.m.f. = ... V [1]

[Total: 9]

7 **(a)** State *Newton's law of gravitation*.

....

....

....

....

.... [1]

(b) Fig. 7.1 shows a satellite of mass m moving at speed v in a circular orbit of radius r about the Earth of mass M.

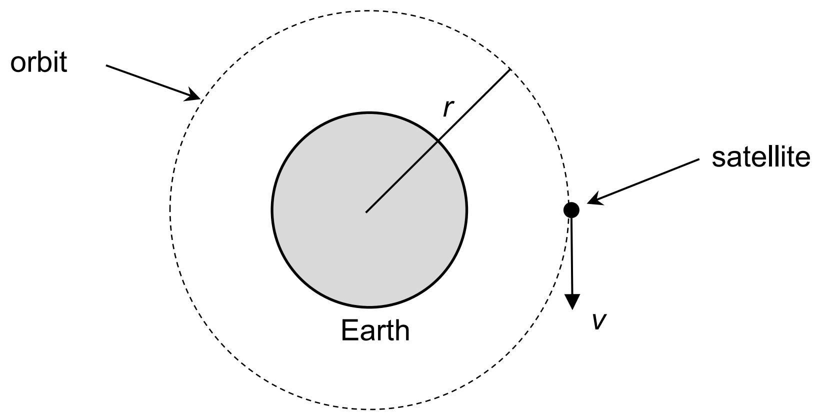

Fig. 7.1 (not drawn to scale)

(i) Show that the satellite's potential energy E_p and kinetic energy E_k are related by the expression $E_p = -2E_k$.

[3]

(ii) On Fig. 7.2, sketch the variation with orbital radius, r of the satellite's

1. gravitational potential energy E_p,
2. kinetic energy E_k,
3. total energy E_T.

Fig. 7.2

[3]

(c) It is given that $r = 6.70 \times 10^6$ m, $m = 1.80 \times 10^3$ kg and $M = 5.98 \times 10^{24}$ kg.

(i) Calculate the satellite's orbital speed v.

orbital speed v = ………………………… m s^{-1} [2]

(ii) For the satellite to be geostationary at this orbital radius, it must orbit at a speed of about 487 m s^{-1}. Explain, in terms of centripetal force, why the geostationary orbit is not possible at this orbital radius.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(d) As a result of atmospheric friction, the radius, r of the satellite's orbit about the Earth decreases by 0.20% in a week.

(i) State the energy conversion taking place during the decrease in orbital radius.

....

....

....

.... [2]

(ii) Assuming that the orbit remains circular, show that the percentage change in the satellite's total energy in a week is 0.20%. The total energy of the satellite is given by $E_T = -\dfrac{GMm}{2r}$.

[1]

(iii) By considering the satellite's rate of loss of energy and your answer to **(c)(i)**, show that the frictional force acting on the satellite is 0.023 N.

[3]

(e) To counter the decrease in orbital radius, the satellite carries a small booster motor. The force exerted by the motor is equal to *uz* where *z* is the rate at which fuel is burnt (mass per unit time), and *u* has a value of 2.00×10^{3} N s kg^{-1} .

(i) On Fig. 7.3, draw labelled arrows showing (at this particular instant)

1. the direction of the satellite's change in velocity (label X) and

2. the direction of the force exerted by the booster motor (label Y).

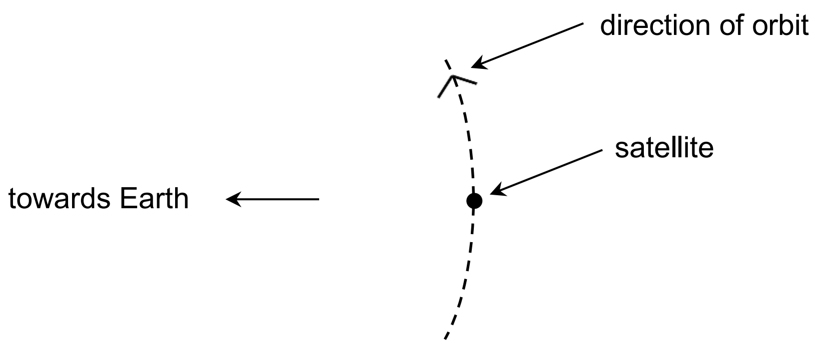

Fig. 7.3

[2]

(ii) Determine the amount of fuel necessary for the satellite to maintain its orbit for 24 hours.

amount of fuel = …………………………..kg [2]

[Total: 20]

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