Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Promotional Examination
Year 5

H2 PHYSICS 9749/02

29 September 2023

Paper 2 Structured Questions **1 hour 55 minutes**

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

This document consists of **19** printed pages and **3** blank pages.

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	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	T/°C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 n I$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** the questions.

1 An experiment to determine the acceleration of free fall g is conducted by projecting a stone with speed u at an angle θ to the horizontal. The horizontal distance R travelled by the stone when it returns to the level of projection is measured. Air resistance is negligible.

(a) In determining the speed of the stone, a student defines speed as “distance travelled per second”.

Explain why this definition is incorrect.

....

....

.... [2]

(b) By expressing the time of flight of the stone T in terms of g, u and θ, show that R is given by the expression

$$R = \frac{2u^2 \sin\theta \cos\theta}{g}.$$

[3]

(c) The expression in **(b)** can be written as

$$R = \frac{u^2 \sin 2\theta}{g}.$$

The experiment is conducted to obtain the maximum range R_0.

State and explain the value of θ to obtain R_0.

....

.... [2]

(d) The values of u and R_0 are 45.36 km h^{-1} and 16.3 m, with the respective percentage uncertainties of 3% and 4%.

Calculate the value of g and present the answer together with its uncertainty.

g = ... ± .... m s^{-2} [4]

[Total: 11]

2 Statistics for road traffic accidents are sometimes interpreted as showing that many occur because of speeding or tiredness of the driver. As a result, some countries have introduced laws to limit the speed at which vehicles may travel and the length of time a person may drive without rest.

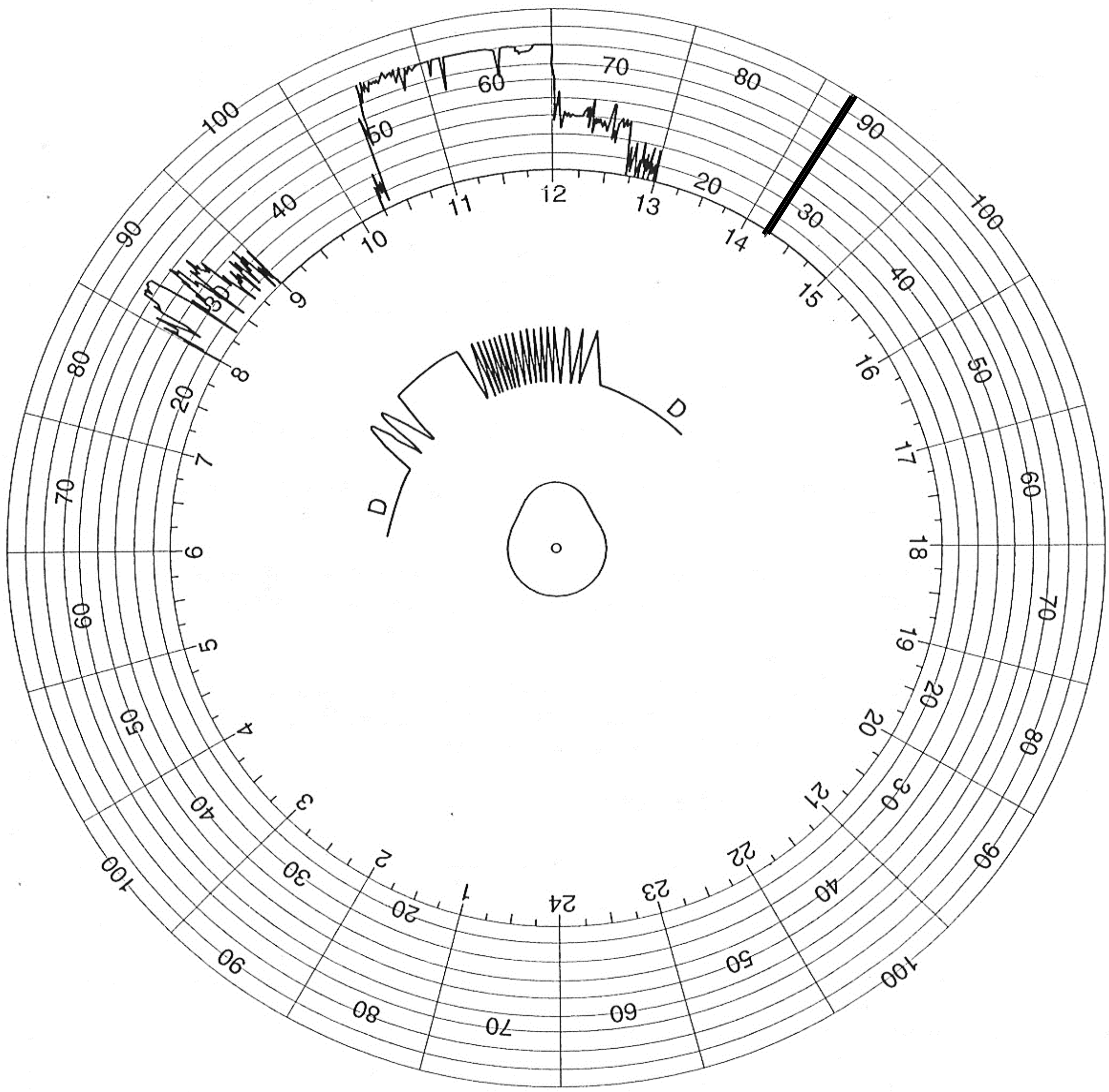

Fig. 2.1

To enforce these laws, some types of vehicles are fitted with tachographs. A tachograph records, on a circular chart, amongst other information, the times at which the vehicle is being driven, together with its speed. One such chart from a lorry tachograph is illustrated in Fig. 2.1.

The time of day, using the 24-hour clock, is shown on the inner scale. Each concentric circle represents a speed measured in kilometres per hour (km h^{-1}). For example, at time 12.15, the lorry was travelling at 40 km h^{-1}.

(a) Use Fig. 2.1 to determine

(i) the speed of the lorry at 11.30,

speed = ... km h^{-1} [1]

(ii) the length of time for which the lorry was not moving between 08.00 and mid-day (12.00).

length of time = ... hours [1]

(b) Suggest what evidence is provided between the times 08.00 and 13.00 on Fig. 2.1 for

(i) a device on the lorry which limits its maximum speed,

.... [1]

(ii) the lorry being in a congested area with heavy traffic between 12.45 and 13.00.

.... [1]

(c) Fig. 2.2 shows data for a particular journey.

time of day	activity
16.00 – 18.00	resting
18.00	accelerates to 40 km h^{-1}
18.00 – 18.30	continues at 40 km h^{-1}
18.30	accelerates to 65 km h^{-1}
18.30 – 19.10	continues at 65 km h^{-1}
19.10	stops

Fig. 2.2

On Fig. 2.1, draw the trace which would be produced for this journey. [2]

(d) The tachograph chart is one form of speed-time graph. Use Fig. 2.1 to estimate the distance travelled by the lorry between 12.00 and 13.00.

distance = ... km [2]

(e) When the tachograph is switched off, the chart stops rotating and the speed recorded is the maximum for the chart.

(i) Use Fig. 2.1 to determine the time at which the tachograph was switched off.

time = ... [1]

(ii) Suggest why, when the tachograph is switched off, it is desirable for the speed recorded to be the maximum, rather than zero.

....

.... [1]

[Total: 10]

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3 **(a)** Define the *moment of a force*.

……………………………………………………………………………………………………

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

(b) Fig. 3.1 shows a type of balance that is used for measuring mass.

A rigid rod is pivoted about a point 6.2 cm from the centre of a pan which is attached to one end. The object being measured is placed on the centre of this pan.

A spring, attached to the rod 1.8 cm from the pivot, is hung at its other end from a fixed point P. The spring obeys Hooke's law over the full range of operation of the balance.

A pointer, on the other side of the pivot, is set against a millimeter scale which is a distance 52.6 cm from the pivot.

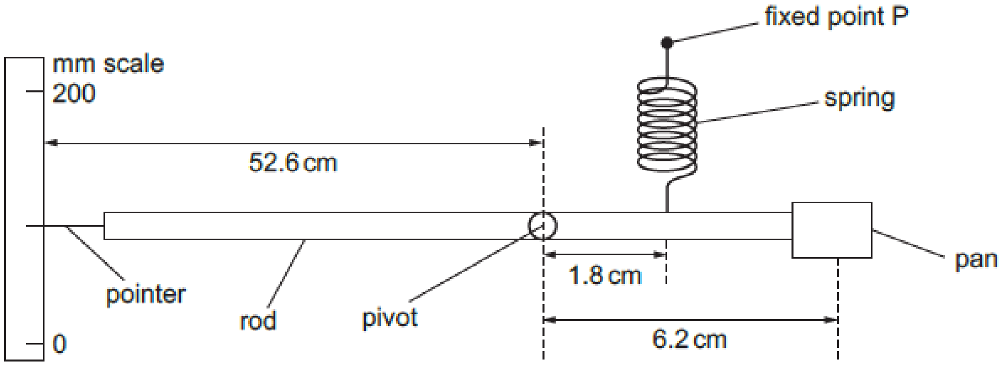

Fig. 3.1 (not to scale)

When the system is in equilibrium with no mass on the pan, the rod is horizontal and the pointer indicates a reading on the scale of 86 mm.

An object of mass 0.472 kg is now placed on the pan. As a result, the pointer moves through a small angle θ to indicate a reading of 123 mm on the scale when the system is again in equilibrium, as shown in Fig. 3.2.

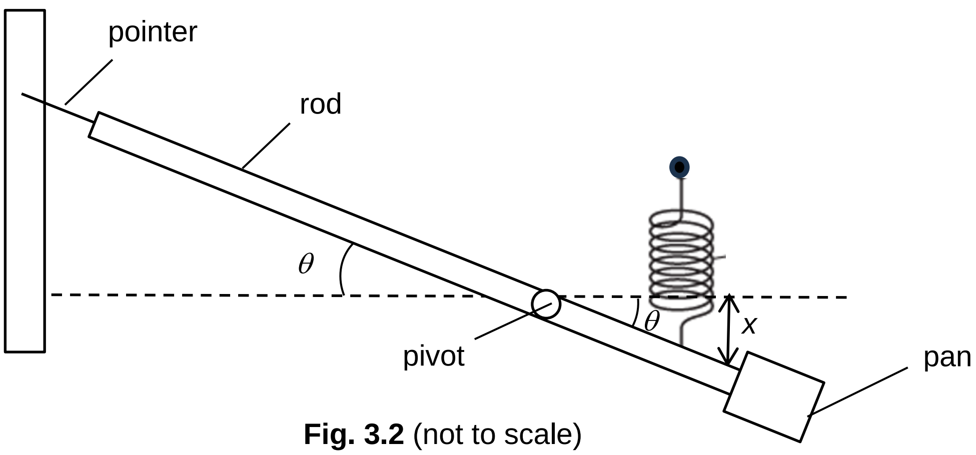

Fig. 3.2 (not to scale)

(i) Show that the increase in the length of the spring, *x*, is approximately 1.3 mm.

[2]

(ii) Calculate the magnitude of the moment about the pivot of the weight of the object.

moment = ……………………… N m [2]

(iii) Use your answer in **(b)(ii)** to determine the increase in the tension in the spring due to the 0.472 kg mass.

increase in tension = ……………………. N [2]

(iv) Use the information in **(b)(i)** and your answer in **(b)(iii)** to determine the spring constant *k* of the spring.

k = ……………………… N m^{-1} [2]

[Total: 9]

4 **(a)** Define *gravitational field strength*.

……………………………………………………………………………………………………

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

(b) An isolated planet is a uniform sphere of radius 3.39×10^6 m. Its mass of 6.42×10^{23} kg may be considered as a point mass concentrated at its centre. The planet rotates about its axis with a period of 24.6 hours.

For an object resting on the surface of the planet at the equator, calculate, to three significant figures,

(i) the gravitational field strength,

gravitational field strength = ……………………… N kg^{-1} [2]

(ii) the centripetal acceleration,

centripetal acceleration = ……………………… m s^{-2} [2]

(iii) the force per unit mass exerted on the object by the surface of the planet.

force per unit mass = ……………………… N kg^{-1} [2]

[Total: 7]

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5 **(a)** Explain what is meant by *simple harmonic motion*.

....

....

.... [2]

(b) A trolley of mass m is held on a horizontal surface by means of two springs. One spring is attached to a fixed point P. The other spring is connected to an oscillator, as shown in Fig. 5.1.

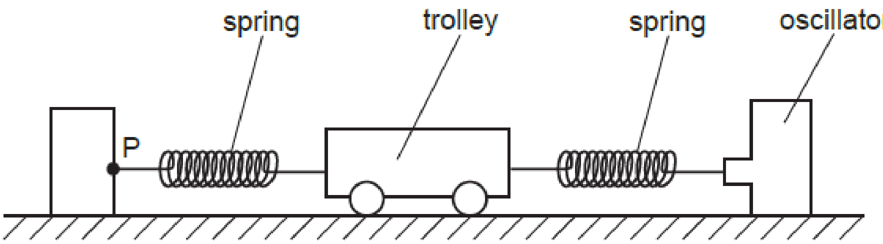

Fig. 5.1

The springs, each having spring constant k of 130 N m^{-1}, are always extended.

The oscillator is switched off. The trolley is displaced along the line of the springs and then released. The resulting oscillations of the trolley are simple harmonic.

The acceleration a of the trolley is given by the expression

$$a = -\left(\frac{2k}{m}\right)x$$

where x is the displacement of the trolley from its equilibrium position.

The mass of the trolley is 840 g.

Calculate the frequency f of oscillation of the trolley.

frequency = ... Hz [3]

(c) The oscillator in **(b)** is switched on. The frequency of oscillation of the oscillator is varied, keeping its amplitude of oscillation constant.

The amplitude of oscillation of the trolley is seen to vary. The amplitude is a maximum at the frequency calculated in **(b)**.

(i) State the name of the effect giving rise to this maximum.

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

(ii) At any given frequency, the amplitude of oscillation of the trolley is constant.

Explain how this indicates that there are resistive forces opposing the motion of the trolley.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

[Total: 8]

6 The variation with the potential difference V across a filament wire of current I is shown in Fig. 6.1.

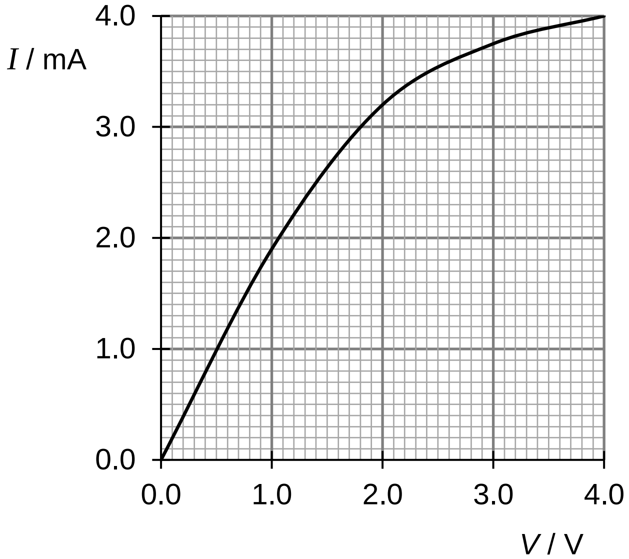

Fig. 6.1

(a) Explain how Fig. 6.1 shows that the resistance of the filament wire increases with potential difference.

....

....

.... [2]

(b) Hence, or otherwise, use Fig. 6.1 to determine the minimum value of the resistance of the filament wire.

minimum resistance = ... Ω [3]

(c) The filament wire is 2.0 m long and has a diameter of 0.046 mm.

Determine the resistivity of the wire when *V* is 4.0 V.

resistivity = ... Ω m [3]

(d) When the filament wire is connected in series with an ideal ammeter and a cell with internal resistance 0.50 Ω, the ammeter reads 1.0 mA.

Determine the e.m.f. of the cell. Give your answers to 4 significant figures.

e.m.f. = ... V [2]

[Total: 10]

7 A Rube Goldberg machine, is a chain-reaction type contraption consisting of a series of unrelated of simple unrelated devices in which the action of each triggers the initiation of the next, until it eventually achieves a stated goal.

A student designs a three-stage Rube Goldberg machine with the end goal of having a toy car stop over a light switch. In the first stage, a toy car X of mass 20.0 g is launched horizontally by a compressed spring through a vertical circular loop such that it is just able to go over the loop of radius 0.183 m as shown in Fig. 7.1.

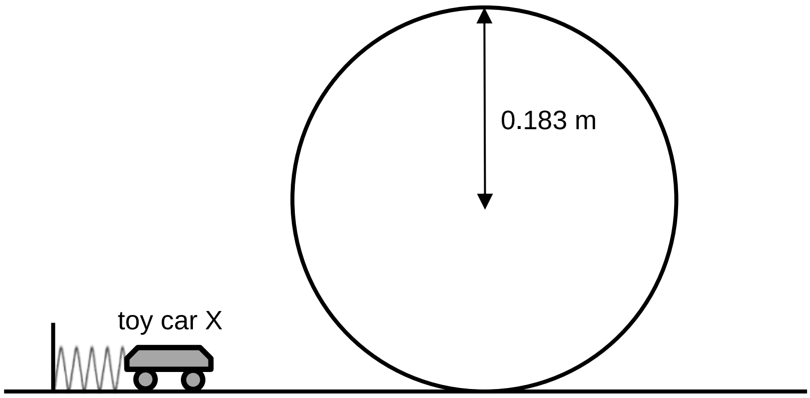

Fig. 7.1

(a) With reference to the magnitude and direction of velocity and acceleration, explain why the marble is *not* undergoing uniform circular motion.

……

……

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

(b) **(i)** Calculate the speed of toy car X when it is at the top of the loop.

speed of toy car X = …………………………………… m s^{-1} [2]

(ii) Hence or otherwise, show that the speed of toy car X when it enters the loop is $3.00\ \text{m s}^{-1}$.

[2]

(iii) Determine the magnitude of the normal contact force acting on toy car X at the bottom of the loop.

magnitude of normal contact force = ……………………………… N [2]

(iv) Calculate the minimum compression in the spring for toy car X to execute a complete loop given that the force constant of the spring is $80.0\ \text{N m}^{-1}$.

compression in spring = ……………………………… m [2]

(c) In the second stage after completing the circular loop, the toy car X will collide into another stationary toy car Y. The variation with time of the velocity of both cars are shown in Fig. 7.2.

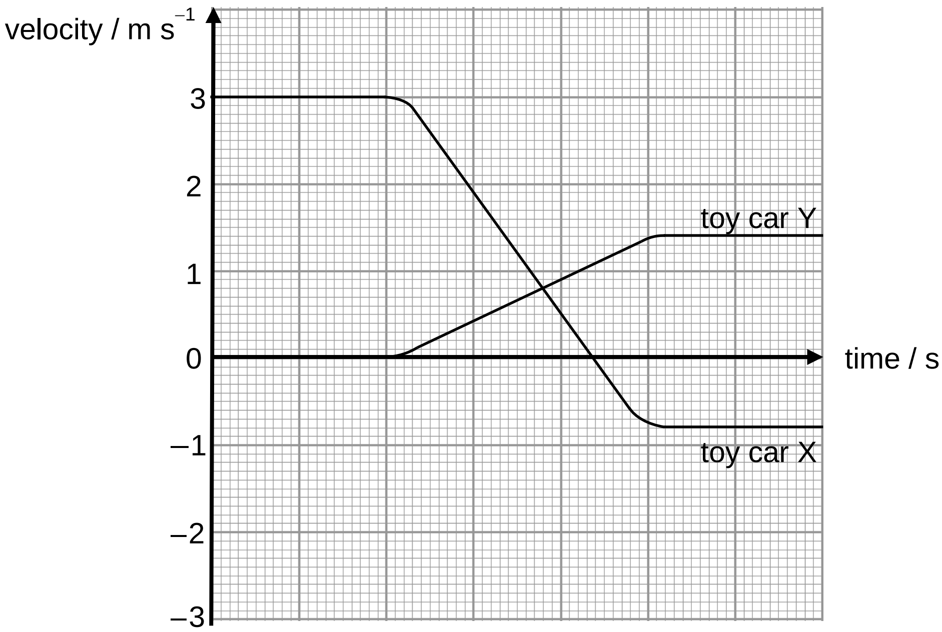

Fig. 7.2

(i) State the *principle of conservation of momentum*.

……………………………………………………………………………………………

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

(ii) Using the information from Fig. 7.2, state and explain whether the collision is elastic or inelastic.

……………………………………………………………………………………………

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

(iii) Determine the mass of toy car Y.

mass of toy car Y = …………………………………… kg [2]

(d) The variation with time of the force that toy car X exerts on toy car Y is shown in Fig. 7.3.

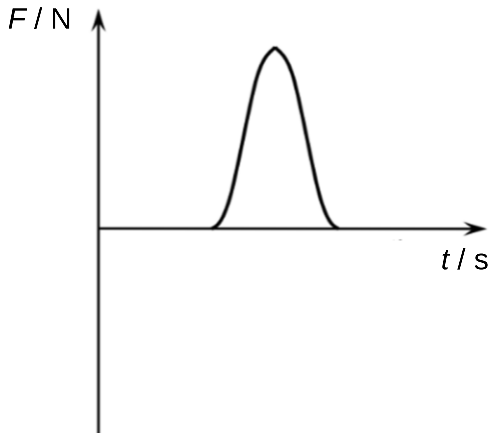

Fig. 7.3

(i) On Fig. 7.3, sketch a graph of the force exerted by toy car Y on toy car X. [1]

(ii) Explain how your answer to **(d)(i)** is consistent with the principle of conservation of momentum.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

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

In the final stage after the collision, toy car Y travels through a 25.0 cm long rough horizontal surface before eventually stopping over the light switch.

(e) **(i)** Calculate the initial kinetic energy possessed by toy car Y.

initial kinetic energy = …………………………………… J [1]

(ii) Determine the magnitude of the frictional force exerted by the rough surface on toy car Y.

magnitude of frictional force = …………………………………… N [1]

[Total: 20]

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