Catholic Junior College

JC1 Promotional Examinations

Higher 2

CANDIDATE NAME	
CLASS	**1T**

PHYSICS **9749/2**

Paper 2: Structured Questions **30 September 2022**

2 hours

Candidates answer on the Question Paper
No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

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

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 11			
Q2	/ 10			
Q3	/ 10			
Q4	/ 12			
Q5	/ 9			
Q6	/ 15			
Q7	/ 13			
PAPER 2	/ 80			

DATA

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	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} mol^{-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	=	$u\,t + \frac{1}{2}a\,t^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/{}^{\circ}C + 273.15$
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	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_0^{\,2} - x^2}$
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	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** A ball of mass 0.50 kg leaves the edge of a table with a horizontal velocity v, as shown in Fig. 1.1.

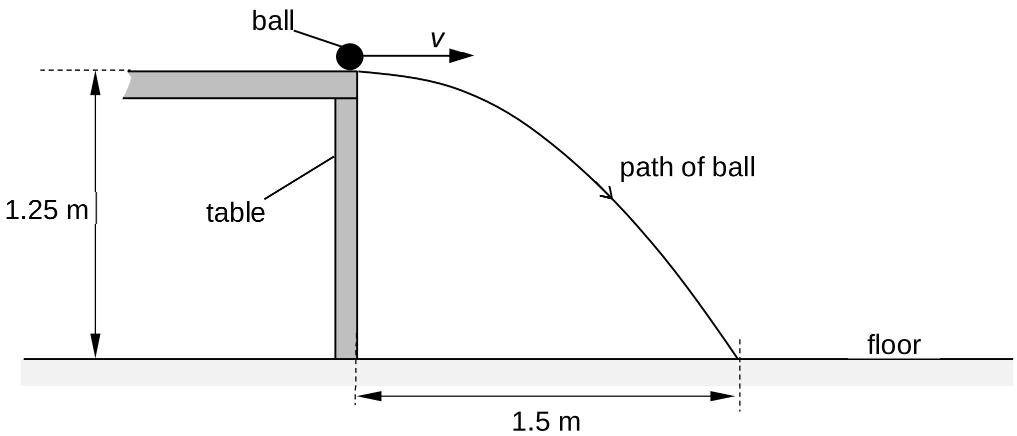

Fig. 1.1

The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

For the ball,

(i) show that the horizontal velocity v is 3.0 m s^{-1},

[2]

(ii) calculate the velocity just as it hits the floor.

magnitude of velocity = ……….......…….......…………. m s^{-1}

direction of velocity = ………………………………………. [3]

(iii) Using the floor as reference where the potential energy of the ball is zero, calculate the kinetic energy and potential energy of the ball at the top of the table.

kinetic energy = ……….......…….......…………. …J

potential energy = ……….......…….......…………. …J [2]

(b) The horizontal distance, along the floor, from the bottom of the table is *x.* Fig. 1.2 shows the variation with *x* of the potential energy E_p of the ball.

On Fig 1.2, sketch the variation with *x* of the kinetic energy E_k of the ball.

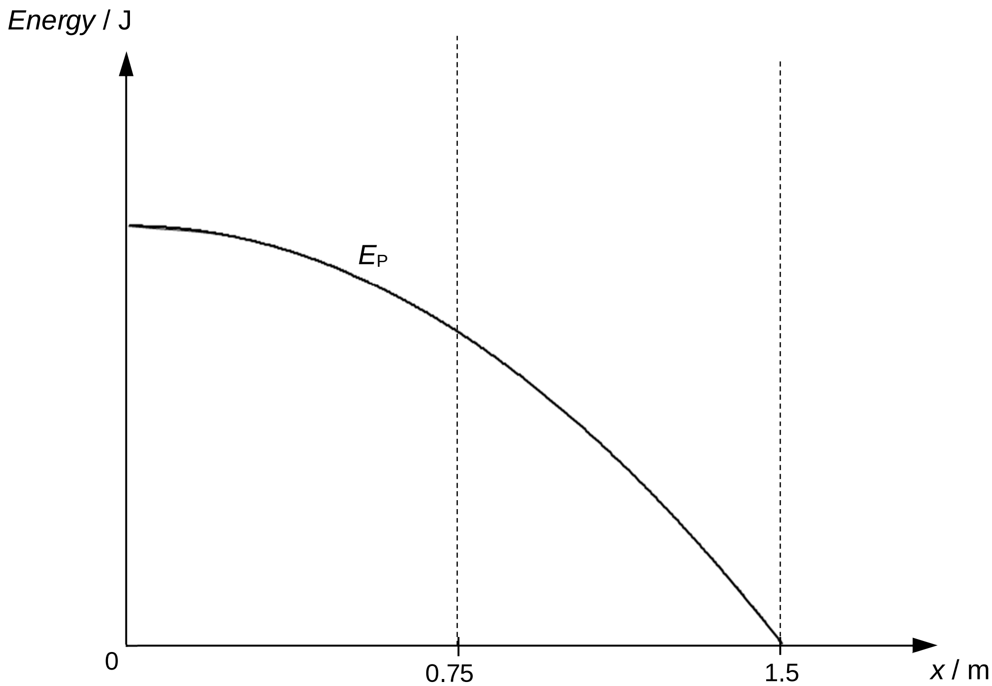

Fig. 1.2 [2]

(c) On Fig 1.1, draw the path of the ball if air resistance was not negligible. [2]

2 **(a)** State the principle of moments.

……………………………………………………………………………………………….

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

(b) In a bicycle shop, two wheels hang from a horizontal uniform rod AC, as shown in Fig. 2.1.

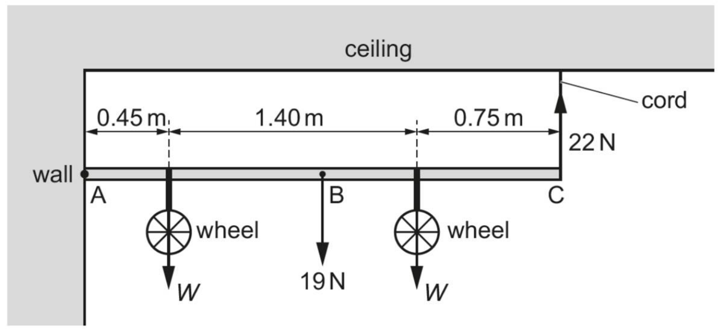

Fig. 2.1 (not to scale)

The rod has weight 19 N and is freely hinged to a wall at end A. The other end C of the rod is attached by a vertical elastic cord to the ceiling. The centre of gravity of the rod is at point B.

The weight of each wheel is *W* and the tension in the cord is 22 N.

(i) By taking moments about end A, show that the weight *W* of each wheel is 14 N.

[2]

(ii) Determine the magnitude and the direction of the force acting on the rod at end A.

magnitude = ………..……………… N

direction = …………..……………… [2]

(c) The unstretched length of the cord in **(b)** is 0.25 m. The variation with length *L* of the tension *F* in the cord is shown in Fig. 2.2.

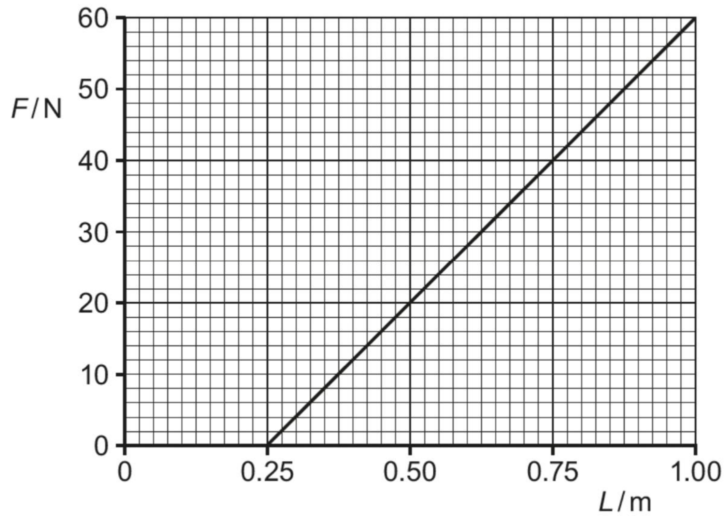

Fig. 2.2

(i) State and explain whether Fig. 2.2 suggests that the cord obeys Hooke's law.

....

.... [2]

(ii) Calculate the spring constant *k* of the cord.

k = ... N m^{-1} [2]

(iii) On Fig. 2.2, shade the area that represents the work done to extend the cord when the tension is increased from *F* = 0 to *F* = 40 N. [1]

3 **(a)** **(i)** Define gravitational potential at a point.

....

....

.... [2]

(ii) Use your answer in **(i)** to explain why the gravitational potential near an isolated mass is always negative.

....

....

....

.... [2]

(b) A rocket is launched from the surface of a planet and moves along a radial path, as shown in Fig. 3.1.

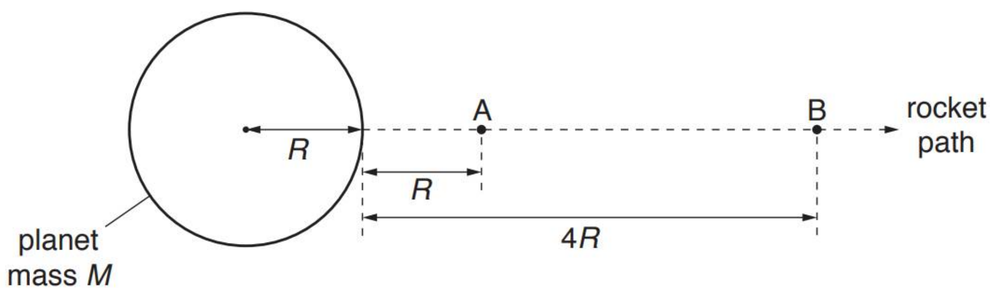

Fig.3.1

The planet may be considered to be an isolated sphere of radius *R* with all of its mass *M* concentrated at its centre. Point A is a distance *R* from the surface of the planet. Point B is a distance 4*R* from the surface.

(i) Show that the difference in gravitational potential $\Delta\phi$ between points A and B is given by the expression

$$\Delta\phi = \frac{3GM}{10R}$$

where *G* is the gravitational constant.

[1]

(ii) The rocket motor is switched off at point A. During the journey from A to B, the rocket has a constant mass of 4.7×10^4 kg and its kinetic energy changes from 1.70 TJ to 0.88 TJ.

For the planet, the product GM is 4.0×10^{14} N m^2 kg^{-1}. It may be assumed that resistive forces to the motion of the rocket are negligible.

Use the expression in **(b)(i)** to determine the distance from A to B.

distance = ………………………. m [3]

(c) A spherical planet has mass 6.00×10^{24} kg and radius 6.40×10^6 m. The planet may be assumed to be isolated in space with its mass concentrated at its centre.

A satellite of mass 340 kg is in a circular orbit about the planet at a height 9.00×10^5 m above its surface.

Determine the satellite's orbital speed.

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

4 **(a)** Define *simple harmonic motion.*

....

....

.... [2]

(b) A mass is hung from a vertical spring attached to the ceiling. d is the distance between the ceiling and the centre of the mass as shown in Fig. 4.1.

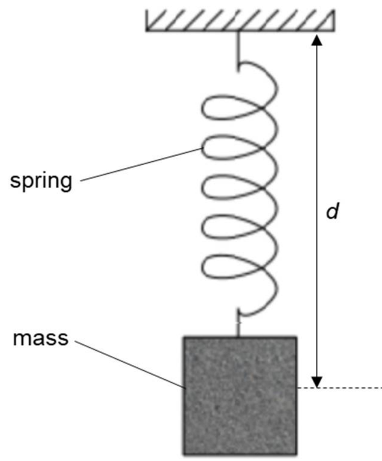

Fig. 4.1

At time $t = 0$, the mass is displaced a small distance downwards and released. It moves with simple harmonic motion, and the variation with time t of the distance d is shown in Fig. 4.2

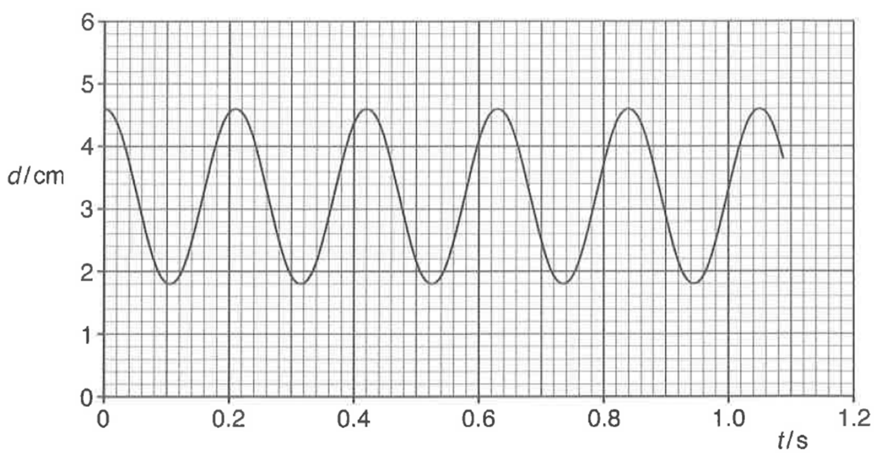

Fig. 4.2

(i) Use Fig. 4.2 to state two times at which the mass is

1. at the lowest point of its oscillation,

time ………… s and time ………… s [1]

2. moving upwards with maximum speed.

time ………… s and time ………… s [1]

(ii) Determine, for the mass,

1. the angular frequency *ω*,

angular frequency = …………….. rad s^{-1} [2]

2. the maximum speed.

maximum speed = ………………….. m s^{-1} [2]

(iii) Use your answer to **(b)(ii)2** to sketch, on the axes of Fig. 4.3, a graph of how the velocity of the mass varies with the displacement from the equilibrium position.

Label the axes with the appropriate scale and values.

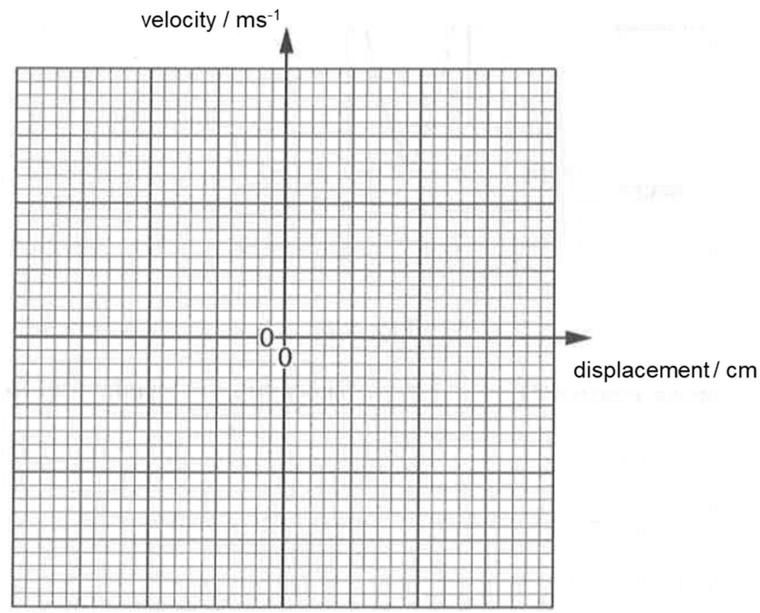

Fig 4.3 [3]

(iv) A periodic external force is applied to the spring-mass system in the vertical direction.

State the frequency of the periodic external force when the system oscillates with maximum amplitude.

frequency = ………… Hz [1]

5 **(a)** A wave of frequency *f* and wavelength *λ* has speed *v*.

Using the definition of speed, deduce the equation $v = f\lambda$.

[1]

(b) A car horn emits a sound wave of frequency 800 Hz. A microphone and a cathode-ray oscilloscope (c.r.o.) are used to analyse the sound wave. The waveform displayed on the c.r.o. screen is shown in Fig. 5.1.

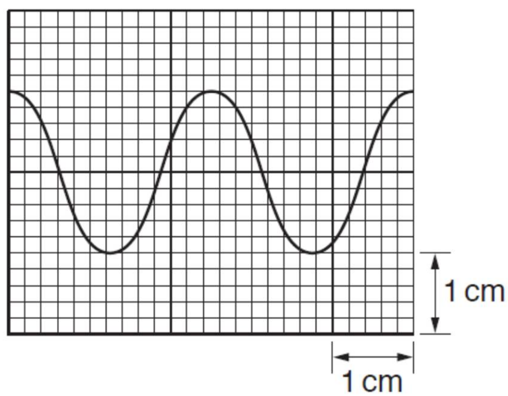

Fig. 5.1

Determine the time-base setting, in s cm^{-1}, of the c.r.o.

time-base setting = ... s cm^{-1} [3]

(c) The intensity I of the sound at a distance r from the car horn in (b) is given by the expression

$$I = \frac{k}{r^2}$$

where k is a constant.

Fig. 5.2 shows the car in **(b)** on a road.

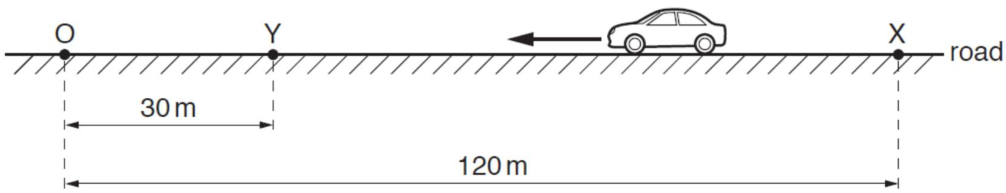

Fig. 5.2

An observer stands at point O. Initially the car is parked at point X which is 120 m away from point O. The car then moves directly towards the observer and stops at point Y, a distance of 30 m away from O.

The car horn continuously emits sound when the car is moving between points X and Y.

The sound wave at point O has amplitude A_X when the car is at X and has amplitude A_Y when the car is at Y.

Calculate the ratio $\frac{A_Y}{A_X}$.

ratio = ... [2]

(d) **(i)** Describe what is meant by a polarized wave.

....

....

.... [2]

(ii) State why a sound wave **cannot** be polarized.

....

.... [1]

6 **(a)** State the conditions required for the formation of a stationary wave.

…………………………………………………………………………………………….

…………………………………………………………………………………………….

…………………………………………………………………………………………….

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

(b) A horizontal string is stretched between two fixed points X and Y. The string is made to vibrate vertically so that a stationary wave is formed. At one instant, each particle of the string is at its maximum displacement, as shown in Fig. 6.1.

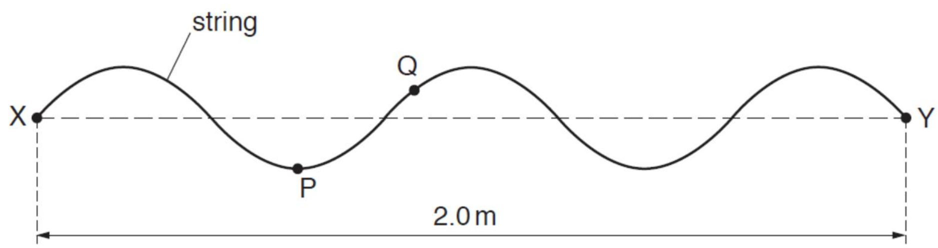

Fig.6.1.

P and Q are two particles of the string. The string vibrates with a frequency of 40 Hz. Distance XY is 2.0 m.

(i) State what is meant by an antinode of the stationary wave.

…………………………………………………………………………………………

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

(ii) State the number of antinodes in the stationary wave.

number = ... [1]

(iii) Determine the minimum time taken for the particle P to travel from its lowest point to its highest point.

time taken = ... s [2]

(iv) State the phase difference, with its unit, between the vibrations of particle P and of particle Q.

phase difference = ... [1]

(v) Determine the speed of a progressive wave along the string.

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

(c) A tube is open at both ends. A loudspeaker, emitting sound of a single frequency, is placed near one end of the tube, as shown in Fig. 6.2.

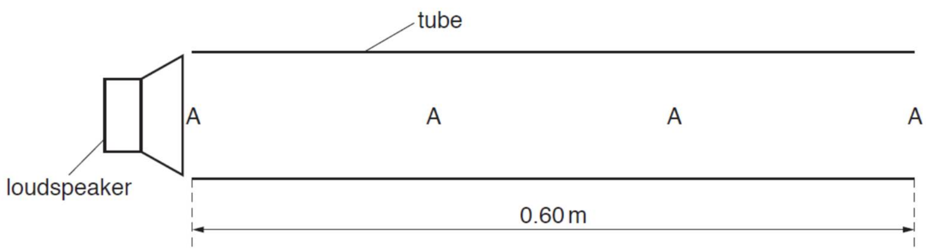

Fig. 6.2

The speed of the sound in the tube is 340 m s^{-1}. The length of the tube is 0.60 m. A stationary wave is formed with an antinode A at each end of the tube and two antinodes inside the tube.

(i) State the distance between a node and an adjacent antinode.

distance = ... m [1]

(ii) Determine, for the sound in the tube,

1. the wavelength,

wavelength = ... m [1]

2. the frequency.

frequency = ... Hz [2]

(iii) Determine the minimum frequency of the sound from the loudspeaker that produces a stationary wave in the tube.

minimum frequency = ... Hz [2]

7 Read the passage below and answer the questions that follow.

Resistive Forces and Fuel Consumption in Vehicles

With the increasing cost of fuel, increasing the efficiency of fuel use in vehicles has become more pertinent to manufacturers and drivers. While some of the energy generated by the fuel in the engine goes into accelerating the vehicle from rest, a larger percentage of the energy is lost to the resistive forces acting against the motion of the vehicle.

There are two main types of resistive forces acting on a moving vehicle: the rolling resistance acting against the tires as they turn and the air resistance acting against the vehicle as it moves. Overcoming both forces use up some of the energy provided by the fuel in the engine, but to different extents depending on the speed of the vehicle.

For a certain vehicle of unladen mass 1000 kg, the variation of the energy consumed per 100 kilometres of travel due to these resistive forces with its speed is shown in Fig. 7.1.

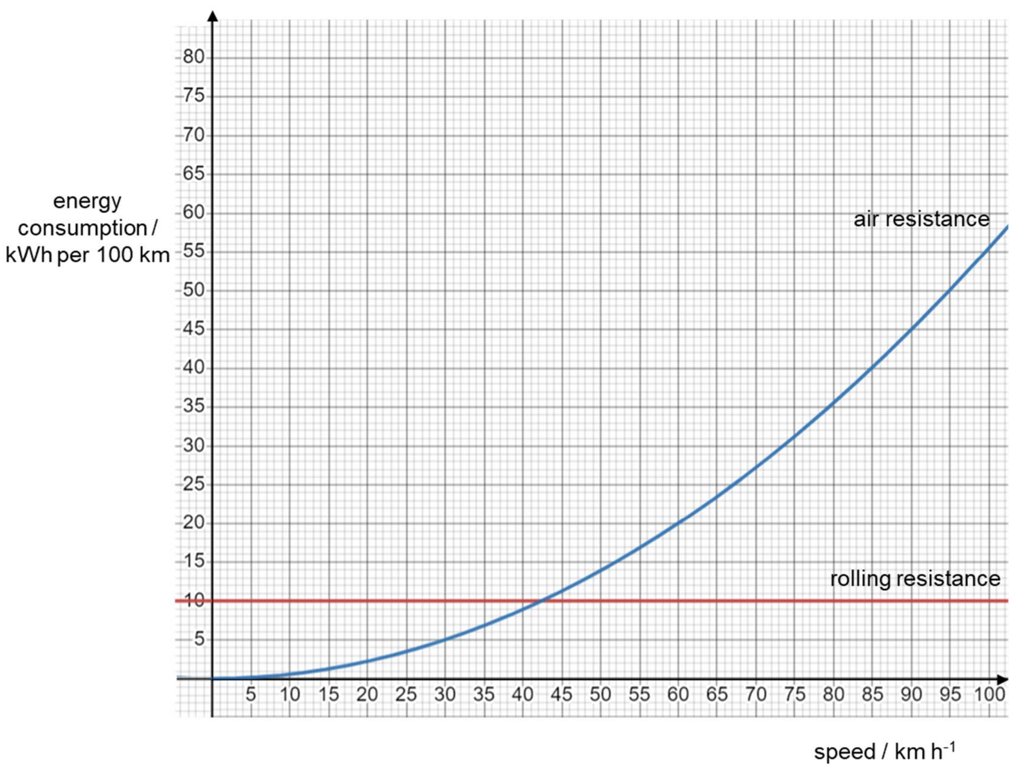

Fig. 7.1

The magnitude of the rolling resistance F_{rr} is given by

$$F_{rr} = C_{rr} N$$

where N is the normal contact force between the surface and the vehicle, and C_{rr} is coefficient of rolling friction, which is a quantity dependent on the types of material of the road and the tires.

(a) On Fig 7.1, sketch the graph representing the variation of the **total** energy consumed per 100 km due to rolling resistance and air resistance with speed. [2]

(b) Using the expression of the rolling resistance, explain why the energy consumed due to the rolling resistance is independent of the vehicle's speed.

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(c) **(i)** Show that 1.0 kW h is equivalent to 3.6×10^6 J of energy.

[1]

(ii) Using the definition of work done and data from Fig 7.1, calculate the magnitude of the rolling resistance F_{rr} acting on the vehicle.

F_{rr} = …………………. N [2]

(iii) Hence, determine the coefficient of rolling resistance C_{rr} for this vehicle

C_{rr} = ……………………… [2]

(d) Based on the information provided in the passage, explain why energy consumption per 100 km is higher

(i) when the vehicle is driven at a constant high speed,

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

……………………………………………………………………………………

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

(ii) when the vehicle is fully laden with passengers.

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

-- END OF PAPER 2 –