Catholic Junior College

JC2 Preliminary Examinations

Higher 2

CANDIDATE NAME	
CLASS	**2T**

PHYSICS **9749/2**

Paper 2: Structured Questions

25 August 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	/ 8			
Q3	/ 11			
Q4	/ 9			
Q5	/ 7			
Q6	/ 5			
Q7	/ 7			
Q8	/ 22			
PAPER 2	/ 80			

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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	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\,\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T / K = T / {}^\circ C + 273.15$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A cliff train cabin is used to carry passengers up a slope as shown in Fig.1.1.

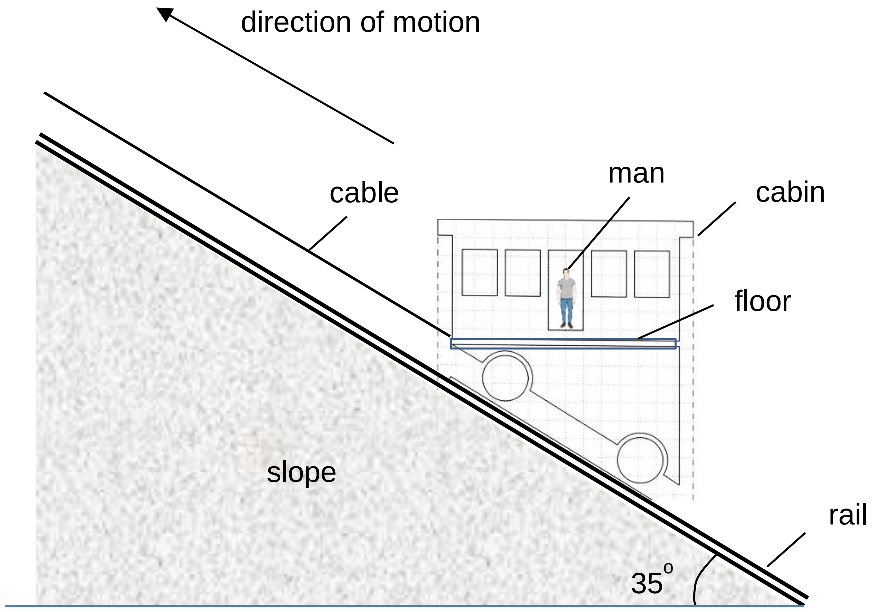

Fig. 1.1

The cable attached to the cabin pulls the cabin up the slope along the rail line which is inclined at 35° to the horizontal.

Initially, the cabin starts from rest and accelerates at 1.0 m s^{-2} for a time of 3.0 s. The cabin then moves at constant speed of 3.0 m s^{-1} for 100 s. Finally, the cabin decelerates to rest in 3.0 s.

The floor of the cabin is horizontal all the times. A man of mass 95 kg is standing upright on the floor of the cabin.

(a) Calculate the vertical height moved by the man during the initial acceleration of the cabin.

height = ... m [3]

(b) **(i)** Calculate the normal reaction force acting on the man from the floor of the cabin when the cabin is moving at constant speed.

normal reaction = ... N [1]

(ii) Explain your working in **(b)(i)**.

....

.... [1]

(c) Forces act on the man by the floor of the cabin.

(i) State the forces for the man as the cabin accelerates.

.... [1]

(ii) Explain how these forces produce the acceleration of the man.

....

.... [2]

(d) The vertical height *h* of the man varies with time *t*. On the axes below, show qualitatively the variation with time *t* of height *h* for the motion of the man during

(i) the acceleration,

[1]

(ii) the constant speed,

[1]

(iii) the deceleration.

[1]

[Total: 11]

2 A stationary electron is in a uniform field of force.

(a) Describe the direction of the force on the electron relative to the direction of the field if the field is

(i) a gravitational field,

.... [1]

(ii) an electric field,

.... [1]

(iii) a magnetic field.

.... [1]

(b) Describe and explain the path the electron will take when it moves at right angles to each field.

....

....

....

....

....

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....

....

.... [5]

[Total: 8]

3 **(a)** **(i)** Explain what is meant by an *ideal gas*.

....

.... [2]

(ii) Use the kinetic theory of gases to explain why when the volume of an ideal gas decreases at constant temperature, the pressure of the gas increases.

....

....

....

....

....

....

.... [4]

(b) A fixed amount of an ideal gas undergoes a cycle of changes A→B→C→A as shown in Fig. 3.1.

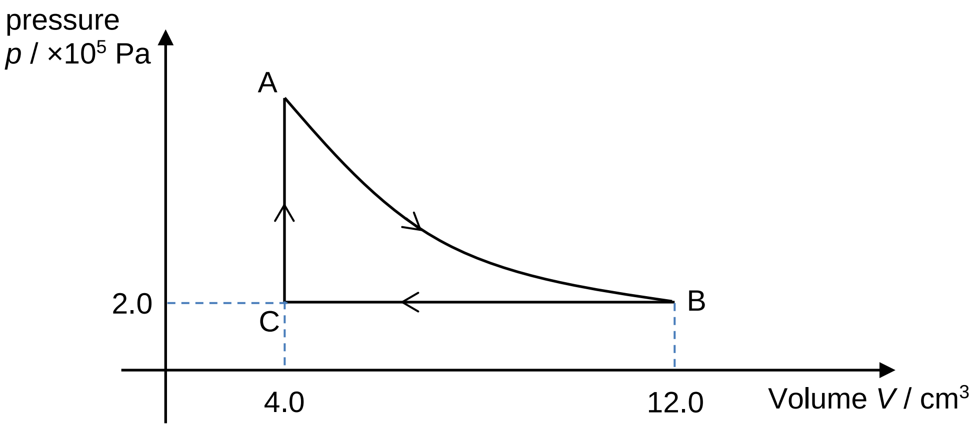

Fig. 3.1

(i) Determine the work done on the ideal gas during the process B→C.

work done on gas = ... J [2]

(ii) Explain why there is a net thermal energy absorbed by the ideal gas when it undergoes a cycle of changes A→B→C→A.

[3]

[Total: 11]

4 The variation with potential difference V *of* current I in a resistor X is shown in Fig. 4.1.

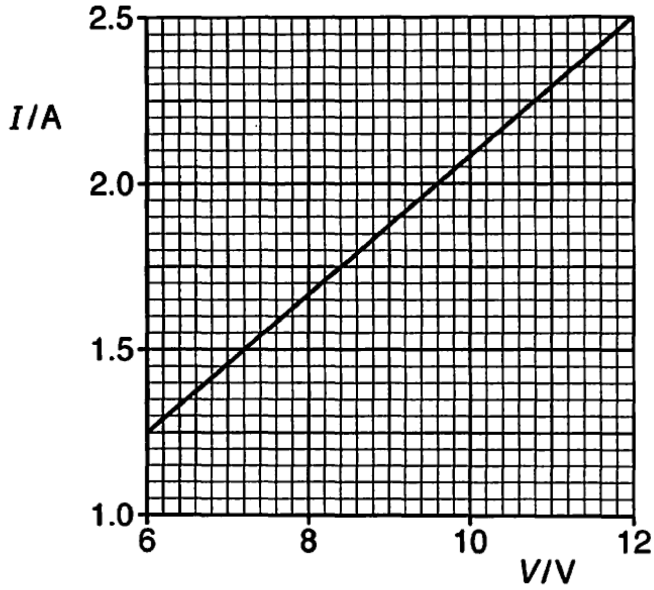

Fig. 4.1

(a) Use Fig. 4.1 to show that the resistance of X remains constant.

[2]

(b) In an attempt to obtain the graph of Fig. 4.1 for resistor X, a student sets up a circuit as shown in Fig. 4.2.

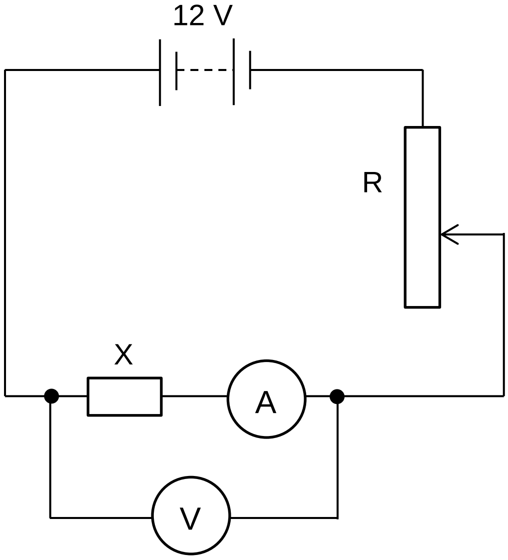

Fig. 4.2

The battery has an e.m.f. of 12 V and negligible internal resistance. The resistor R has a resistance that can be varied between 0 Ω and 2.0 Ω. The voltmeter and ammeter are both ideal.

State and explain why the circuit shown in Fig. 4.2 is inappropriate for obtaining data from V = 6 V to V = 12 V for the graph in Fig. 4.1.

____

____

____

____

____ [2]

(c) In the space below, draw a circuit diagram using the same components as shown in Fig. 4.2 from which the graph of Fig. 4.1 may be determined.

[1]

(d) Calculate the difference in the power dissipated in resistor X when *V* is increased from 7.2 V to 9.6 V.

difference in power = ... W [2]

(f) Suppose the battery has an internal resistance of 0.50 Ω, and R in Fig. 4.2 is adjusted to 0 Ω.

Calculate the terminal potential difference across the battery.

terminal potential difference = ... V [2]

[Total: 9]

5 **(a)** When white light is incident on a single slit, a diffraction pattern is formed on a screen.

The central fringe of the diffraction pattern is coloured at the edges and has a white central region. Explain this observation.

--- [2]

(b) **(i)** Explain what is meant by the *Rayleigh criterion* for the resolution of the images of two objects.

--- [2]

(ii) The Griffith Observatory in Los Angeles includes an astronomical refracting telescope (Griffith telescope) with an objective lens of diameter 0.305 m.

Calculate the wavelength of light for which the Griffith telescope has a minimum angular resolution of 1.8×10^{-6} rad.

wavelength = ______ m [1]

(iii) The asteroid Apophis has a diameter of 325 m. It has been calculated that in the year 2029, its distance of closest approach to the Earth's surface will be 3.0×10^{4} km.

Supporting your answer with calculations, explain whether the Griffith telescope can resolve Apophis.

--- [2]

[Total: 7]

6 In an X-ray tube, electrons are produced from a filament heated by an electric current as shown in Fig. 6.1. A large accelerating potential difference is set up between the filament and the target material. The electrons are accelerated from the filament and hit the target material to emit X-ray photons.

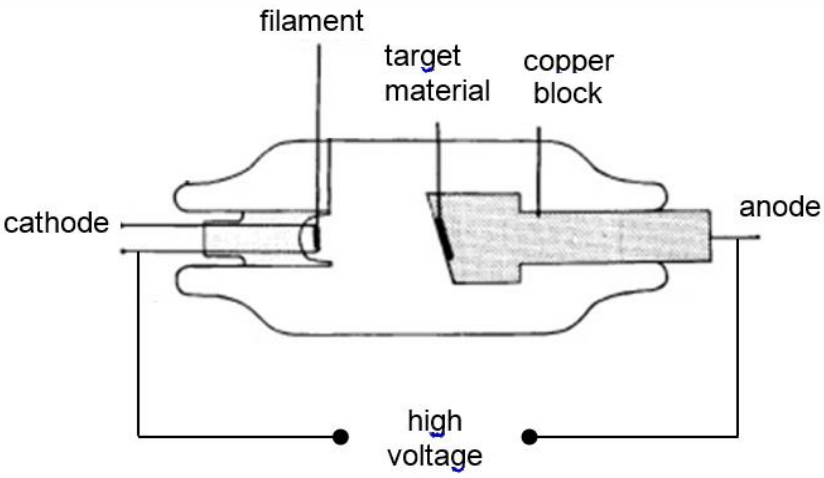

Fig. 6.1

A graph of intensity against wavelength of the emitted radiation is plotted as shown in Fig. 6.2 when the X-ray tube is operated at a voltage of 50 kV.

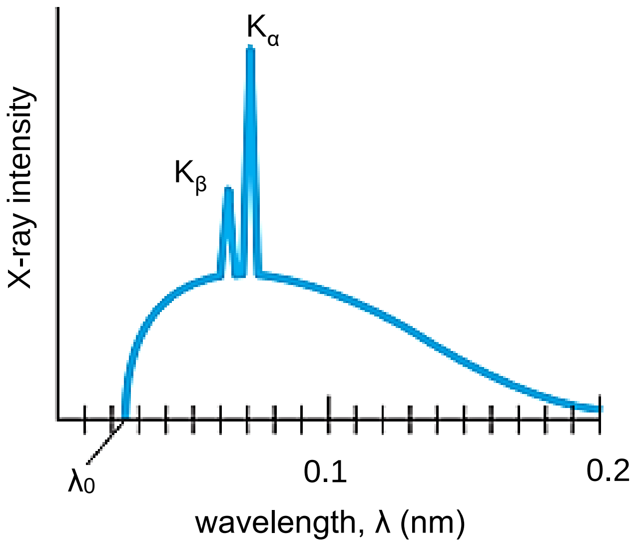

Fig. 6.2

(a) Explain why there is a minimum wavelength λ_0 for the emitted X-rays.

....

....

....

....

....

.... [2]

(b) Show that λ_0 equals to 0.024 nm.

[1]

(c) Sketch on Fig. 6.2 a graph to show the intensity variation with wavelength if the accelerating potential difference is reduced to one-quarter of its original value. [2]

[Total: 5]

7 An induced nuclear fission reaction may be represented by the equation

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{141}_{56}\text{Ba} + ^{92}_{36}\text{Kr} + 3^{1}_{0}\text{n}$$

The variation with nucleon number *A* of the binding energy per nucleon B_E is illustrated in Fig. 7.1.

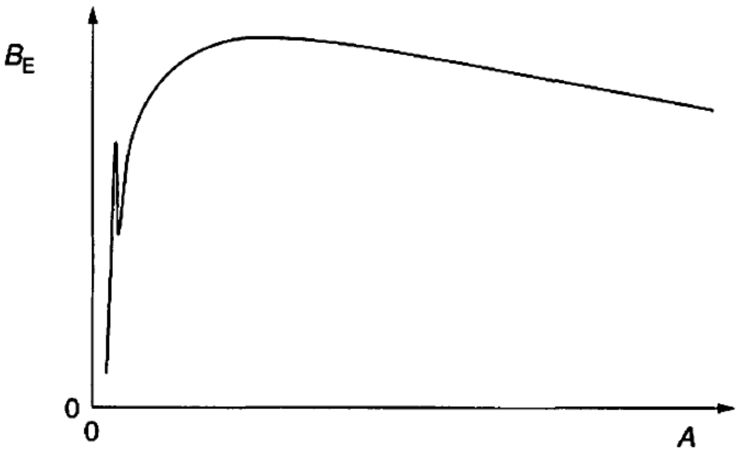

Fig. 7.1

(a) State an approximate value, in MeV, for the maximum binding energy per nucleon.

maximum binding energy per nucleon = ... MeV [1]

(b) On Fig. 7.1, mark approximate positions for the nuclei of

(i) uranium-235 (label the position U),

(ii) barium-141 (label the position Ba),

(iii) Krypton-92 (label the position Kr).

[3]

(c) By reference to binding energy per nucleon, explain why energy is released in this fission reaction.

....

....

....

....

....

....

....

.... [3]

[Total: 7]

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

Torque from a Vehicle Engine

An internal combustion engine used on a vehicle operates over a limited rotational speed which can be controlled by the driver. As the driver increases the depression on the accelerator pedal, the input power to the engine will increase to a maximum when the throttle is fully opened. The power delivered to the wheels of the vehicle will also reach a maximum value.

The output torque of the engine is transmitted to the forward driving force on the vehicle's wheels. The transmission of the output torque of the engine is done through a gearbox which consists of several gear ratios capable of providing the required driving force to suit the different driving speeds and accelerations.

The gear ratio is the ratio of the rotational speed of the vehicle's engine to the rotational speed of the vehicle's wheel. A high gear ratio is required at low vehicle's speeds to provide a higher torque.

A vehicle starts to move off with the highest gear ratio, namely gear 1. As the vehicle's speed increases, the gear ratio changes from gear 1 to gear 4, with gear 4 being the lowest gear ratio. The lowest gear ratio is to provide for the maximum speed achievable. Thus, the forward driving force on the vehicle's wheels will change with the speed of the vehicle for different gears.

As the vehicle moves, it encounters a total resistive force that opposes its motion.

Fig. 8.1 shows how the speed of the vehicle affects the available force F at the wheels for different gears and the total resistive force on a 1200 kg vehicle when the input power to the engine is maintained at the maximum value. The available force is the maximum forward driving force that can be transmitted to the wheels.

To stop the vehicle quickly from a certain speed, the driver steps on the brake pedal to produce a braking force on the wheels, and at the same time, the power of the engine is removed completely. The maximum braking force of the car is 9300 N.

When a vehicle moves up an inclined slope, it encounters a climbing resistance that depends on the gradient of the slope. The gradient of the slope is defined as the ratio of the increase in height to the horizontal distance moved in percentage value.

The chart in Fig. 8.2 shows how the climbing resistance is affected by the gradient of the slope.

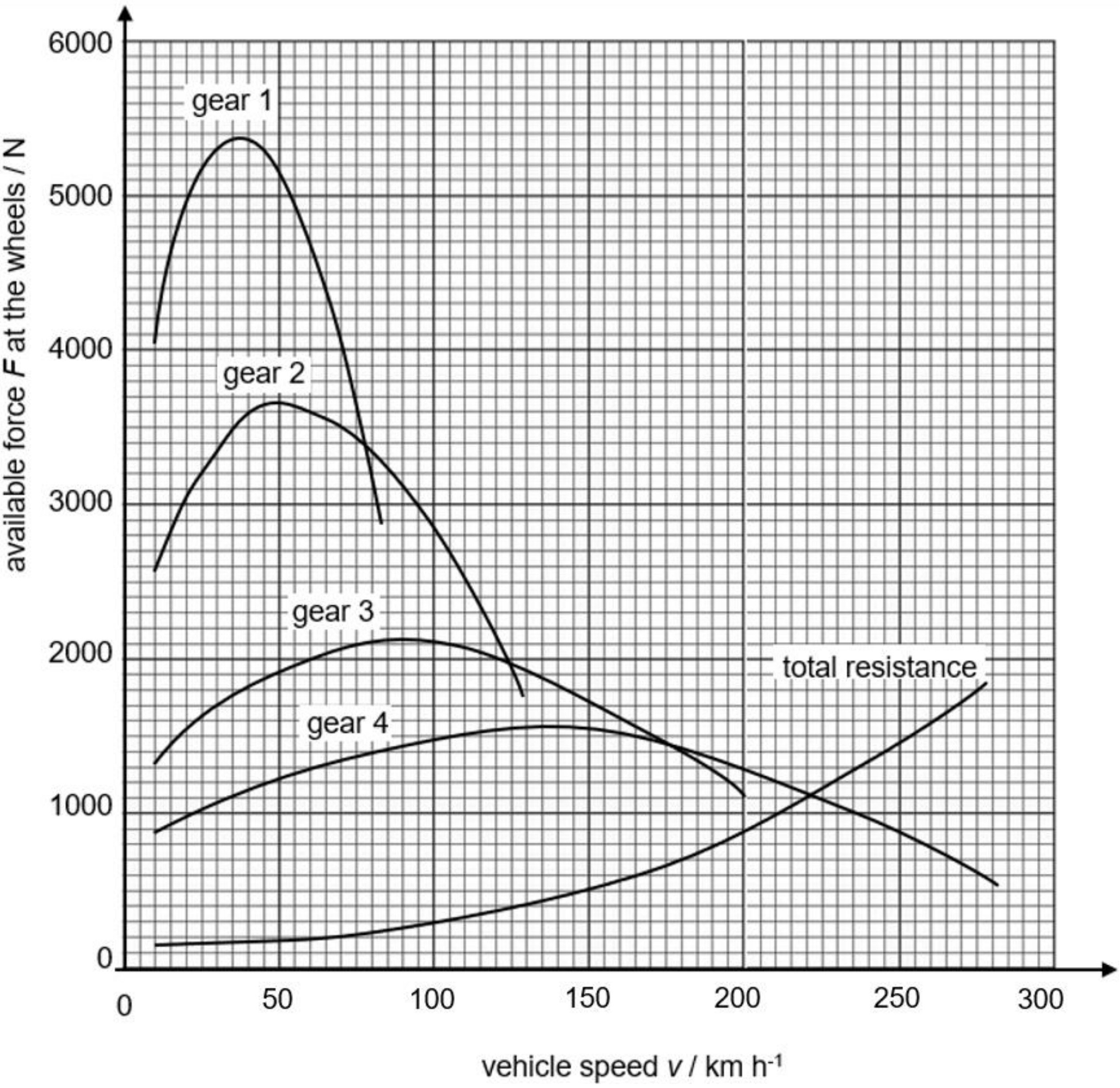
6000
5000
4000
3000
2000
1000
0
available force F at the wheels / N
gear 1
gear 2
gear 3
gear 4
total resistance
0
50
100
150
200
250
300
vehicle speed v / km h-1

Fig. 8.1

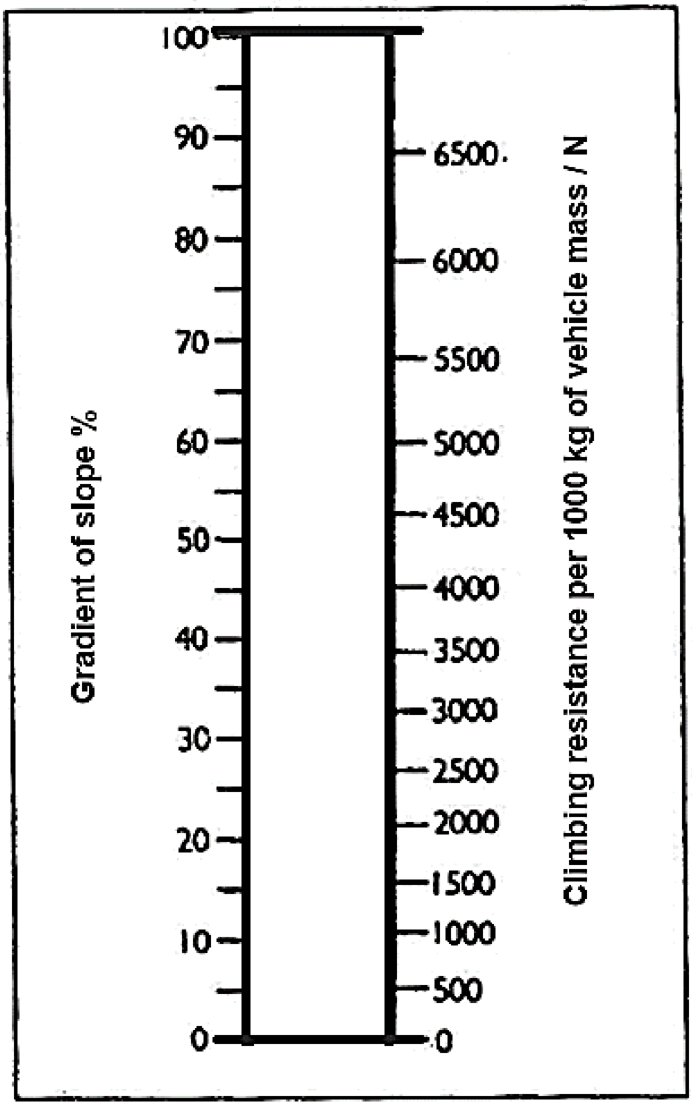

Fig. 8.2

(a) Explain why gear 1 is used to accelerate the vehicle from rest.

....

.... [1]

(b) Explain what is meant by the term *available force* at the wheels.

....

.... [1]

(c) The vehicle is travelling at 100 km h^{-1} on a horizontal road and gear 3 is engaged by a driver.

(i) State the available force at the wheels and the resistive force.

available force = ... N

resistive force = ... N [2]

(ii) Calculate the maximum acceleration.

maximum acceleration = ... $m\ s^{-2}$ [2]

(iii) Explain why gear 3 is the optimum gear for maximum power output at a speed of $100\ km\ h^{-1}$.

....

.... [1]

(iv) The driver wishes to overtake another vehicle which is also travelling at $100\ km\ h^{-1}$. Explain whether he needs to change gear.

....

.... [2]

(d) **(i)** Starting from the definition of work done, show that the power output of the vehicle is given by the expression

power output = driving force x speed

[2]

(ii) Explain why for a given power delivered to the engine, the available force at the wheels for gear 3 is smaller than that for gear 2.

....

....

....

.... [2]

(e) State the maximum possible speed of the vehicle.

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

(f) The vehicle is moving up a slope inclined at 20° to the horizontal.

(i) Show that the gradient of the slope, in percentage, is 36%.

[1]

(ii) Use Fig. 8.2 to determine the climbing resistance on the car.

climbing resistance = ... N [2]

(iii) Using the answer to **(f)(ii)** and **Fig. 8.1**, estimate and explain the maximum speed at which the vehicle can move up the slope.

....

.... [2]

(g) The vehicle is travelling up the slope with a speed of 40 km h^{-1}. The driver intends to stop the car by applying the maximum braking force.

Estimate the distance moved along the slope before the car stop.

distance moved = ... m [3]

[Total: 22]

END OF PAPER 2