NANYANG JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CLASS		TUTOR'S NAME	

PHYSICS **9646/02**

Paper 2 Structured Questions **19 September 2014**

1 hour 45 minutes

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	72

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} Fm^{-1}
			$(1 / (36\pi)) \times 10^{-9}$ Fm^{-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	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	=	exp(-2kd)
	where k	=	$\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{0.693}{t_{\frac{1}{2}}}$

1 Astronauts plan a space expedition to Planet Newtonia to determine its acceleration of free fall.

(a) As part of the preliminary investigations conducted on Earth, a tennis ball is released from the top of a 12 storey building. Estimate the momentum of the tennis ball just before it hits the ground.

momentum = ………………………………… kg m s^{-1} [2]

(b) Upon reaching Planet Newtonia, a scientist takes measurements to determine a value for the acceleration of free fall on Planet Newtonia. A stroboscopic photograph (shown to scale) shows the motion of a free falling tennis ball released from rest. The strobe rate is 10 flashes per second.

Fig. 1.1

(i) Draw a graph on Fig. 1.2 showing how the displacement of the tennis ball varies with the square of time.

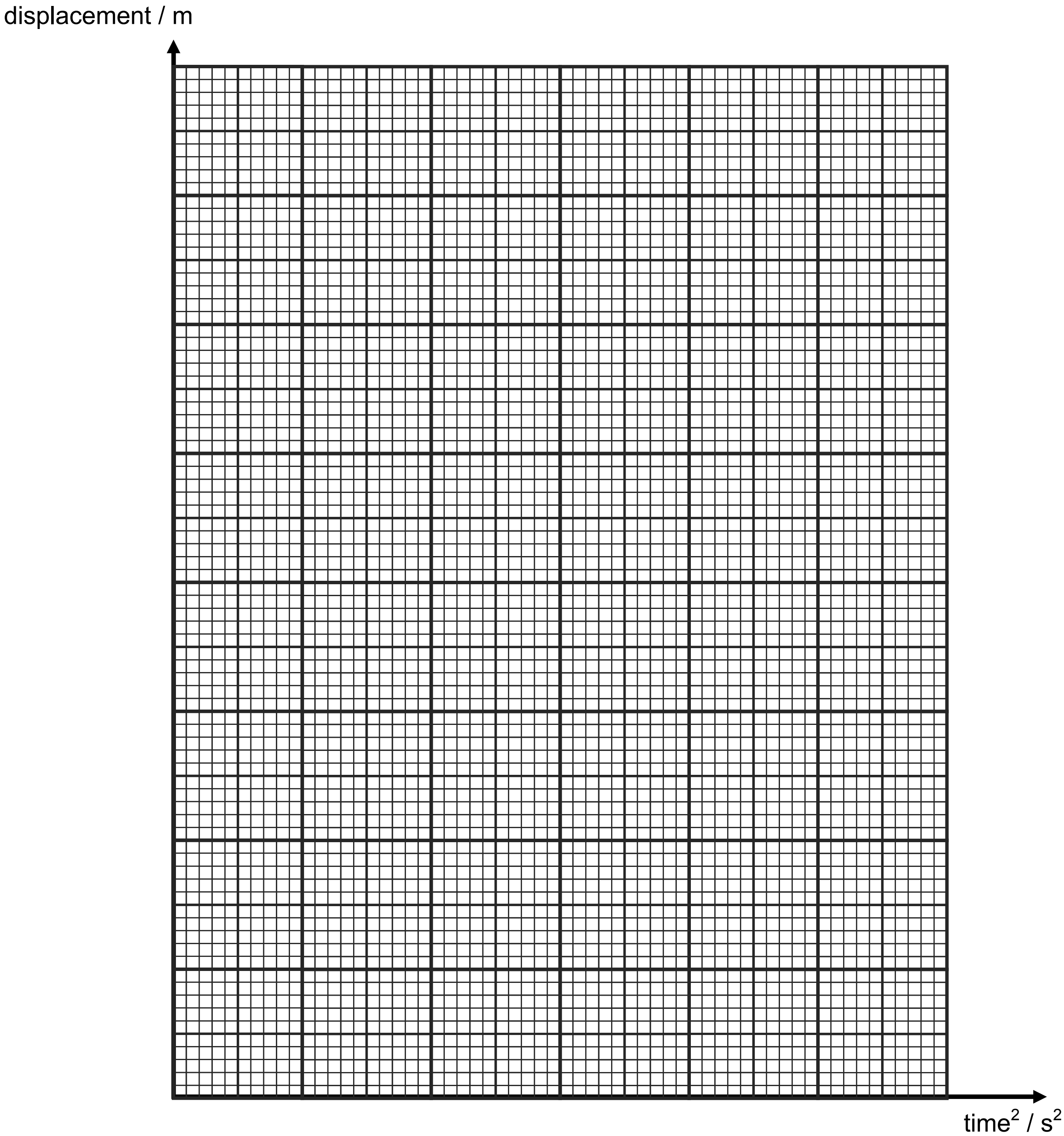


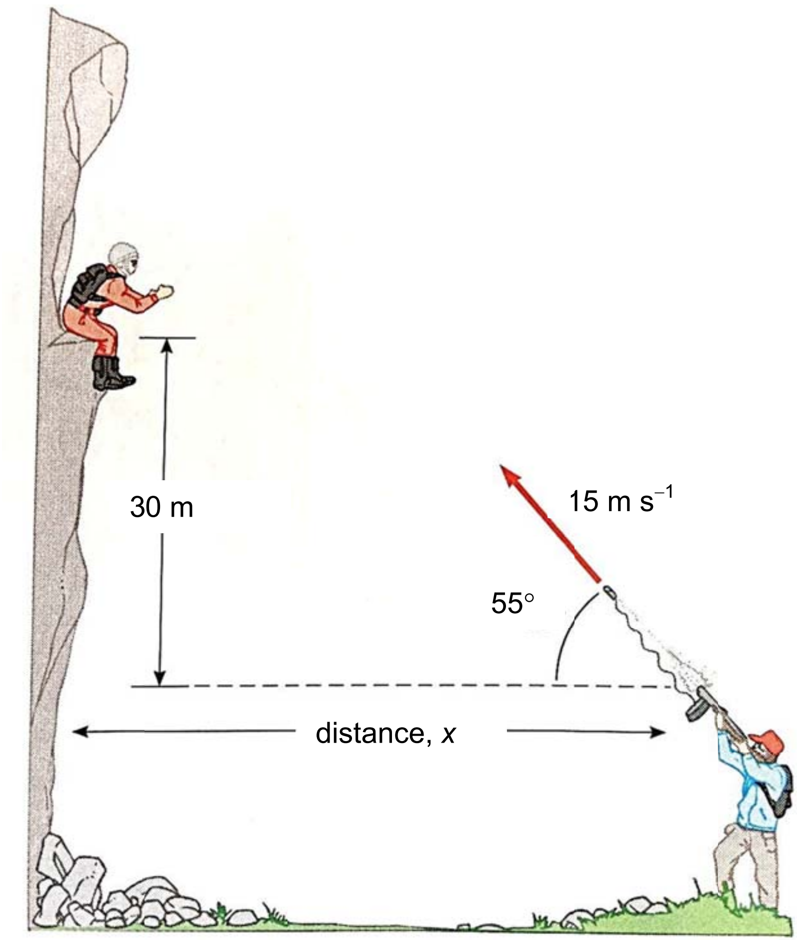
Fig. 1.2

[2]

(ii) Hence determine the acceleration of free fall on Planet Newtonia.

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

(c) During the space expedition on the Moon of Planet Newtonia, an astronaut is stranded on a ledge. The rescuer on the ground wants to shoot a projectile to him with a light rope attached to it. The projectile is directed at an initial angle of 55° and speed 15 m s^{-1}. The acceleration due to free fall on the Moon is 1.2 m s^{-2}.



(i) Determine the shortest possible time the rescuer needs to take to send the projectile to the astronaut.

time = …………………………………. s [2]

(ii) Hence, calculate how far the rescuer should stand in order for the projectile to land on the ledge.

distance = …………………………………. m [1]

(iii) Suggest how would your answer in **(c)(i)** change if the situation occurred on Planet Newtonia instead.

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

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

2 **(a)** State the principle of conservation of momentum.

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

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

(b) A 0.150 kg toy helicopter is moving at a constant altitude of 75.0 m with a speed of 1.50 m s^{-1} when a shooter fires vertically up and hits it as shown in Fig. 2.1 Given that the mass of the bullet is 1.00 g and the initial speed of the bullet is 100 m s^{-1}. Assume negligible air resistance and ignore height of shooter, determine

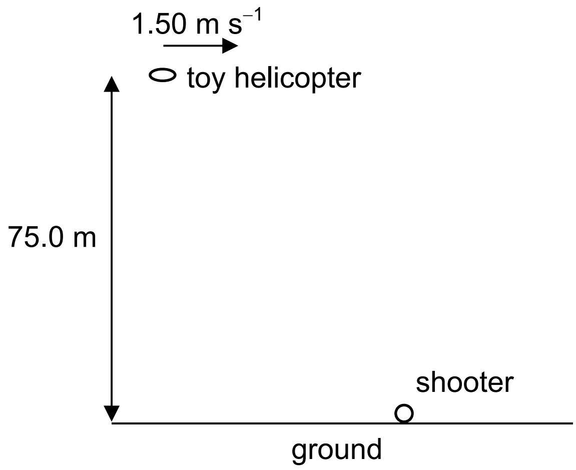


Fig. 2.1

(i) the distance of the toy helicopter from the shooter when he shoots

distance = ………………………………… m [3]

(ii) the momentum of the toy helicopter and bullet immediately after the hit. Assume that the bullet is embedded in the toy helicopter after the hit.

magnitude of momentum = ………………………………………. kg m s^{-1} [2]

(c) State and explain whether principle of conservation of momentum is violated for the toy helicopter in **(b)** considering its motion immediately after the hit and just before it hits the ground.

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

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

3 A uniform sheet of steel weighing 800 N is supported by a bolt at its lower-left hand corner and by a cable tied to a point on its left-edge as shown in Fig. 3.1 below. The pull by the cable on the sheet is *T*.

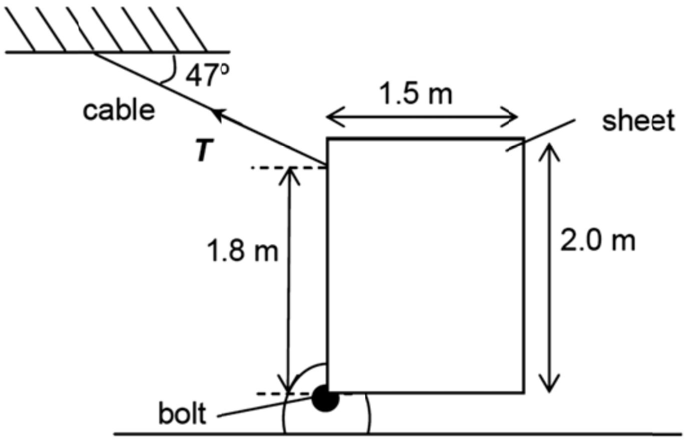

Fig. 3.1

(a) Show that *T* is 489 N.

[2]

(b) Determine the magnitude of force acting on the bolt by the sheet.

magnitude of force = …………………………………. N [3]

4 Fig. 4.1 shows a simple electric motor made up of an armature placed in between 2 permanent magnets. The region of space between the 2 magnets has a uniform magnetic flux density of 40 mT. The armature consists of a single square coil of copper wire with each side of length of 20 cm.

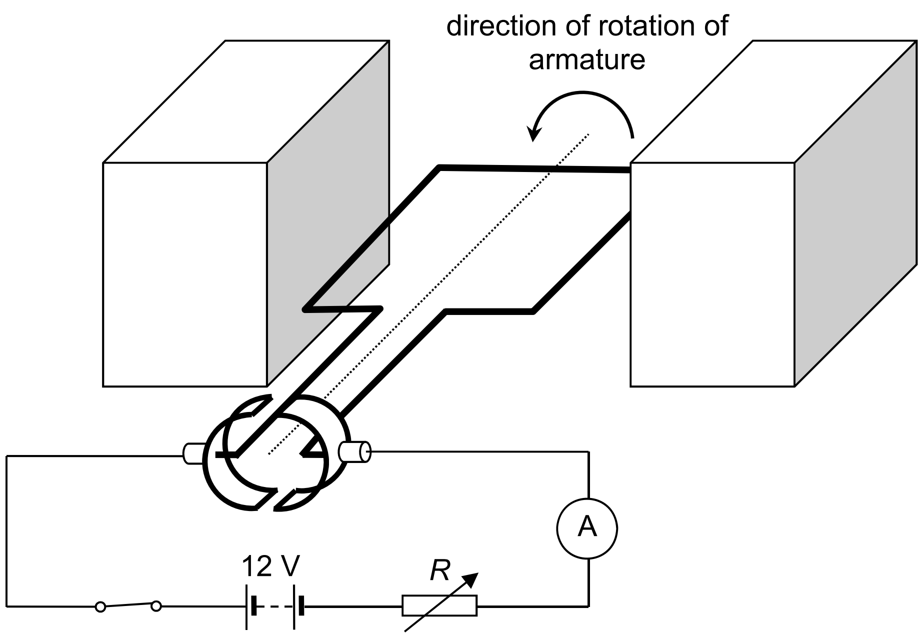

Fig. 4.1

(a) Explain what is meant by a *magnetic flux density of 40 mT*.

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

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

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

(b) On Fig. 4.1, indicate with an arrow the direction of the magnetic field in the region between the 2 permanent magnets. [1]

(c) The armature carries a current of 0.55 A just before it starts to move from the instant as shown in Fig 4.1. Determine the magnitude of the torque acting on the armature due to the magnetic force at this instant.

torque = …………………………………. N m [3]

5 A metal disc is swinging freely between the poles of an electromagnet, as shown in Fig. 5.1.

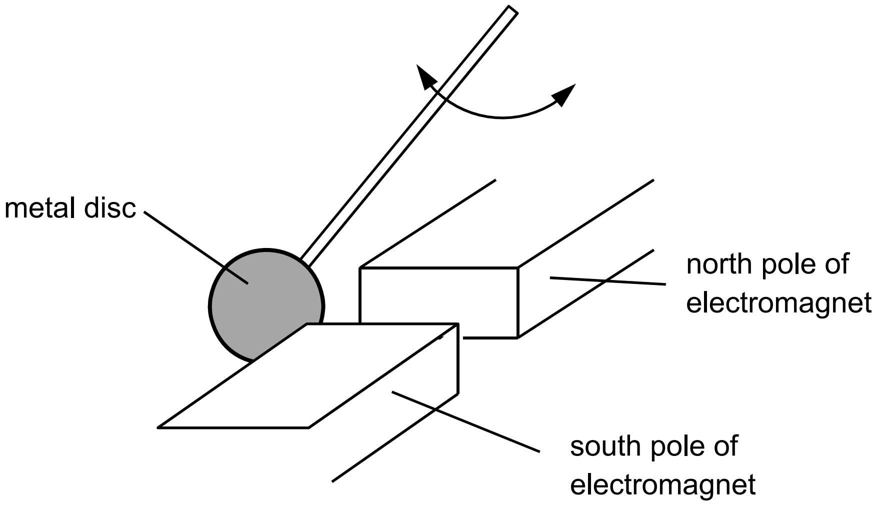

Fig. 5.1

When the electromagnet is switched on, the disc comes to rest after 12 s.

(a) State Faraday's law of electromagnetic induction and use the law to explain why an e.m.f. is induced in the disc.

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

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

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

(b) An enlarged diagram of the disc as it is leaving the magnetic field is shown in Fig. 5.2. The direction of the magnetic field is shown in the diagram. The dotted circle indicates one possible path of the eddy current generated.

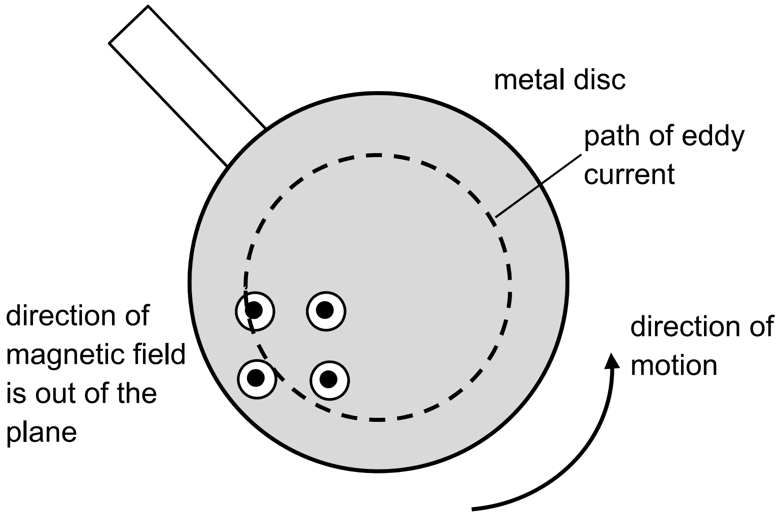

Fig. 5.2

(i) State Lenz's law of electromagnetic induction.

…………………………………………………………………………………………

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

(ii) Indicate on the dotted path in Fig. 5.2 the direction of the eddy current as the disc is leaving the electromagnet. [1]

(iii) Use Lenz's law to explain why eddy currents induced in the metal disc are in the direction as indicated in **(b)(ii)**.

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…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(c) State and explain how the time taken for the disc to come to rest will change if a metal of higher resistivity is used for the disc.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

6 A helium-neon laser tube consists of a 1:4 mixture of helium and neon gases, neon being the medium in which laser action occurs. Fig. 6.1 shows the few important energy levels involved in the actions.

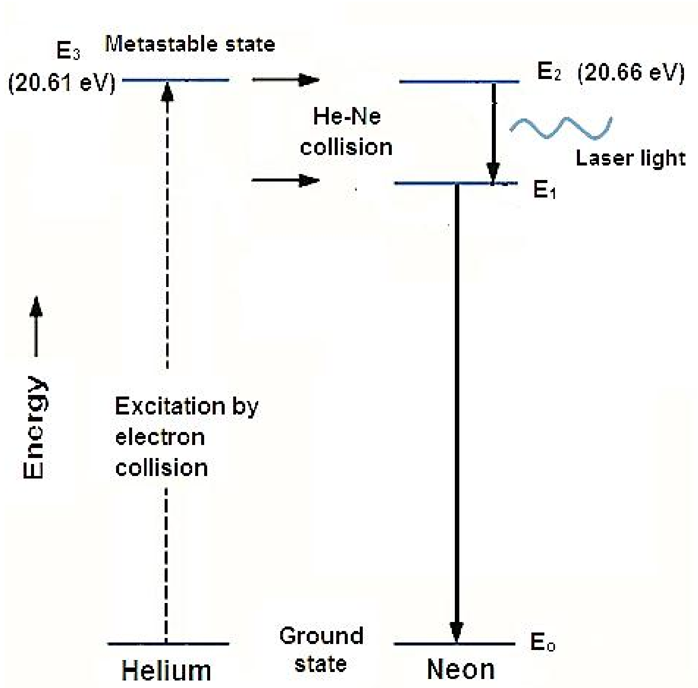

Fig. 6.1

Helium atoms are excited to a metastable state E_3 from ground state by collisions with high speed electrons. The energy in E_3 is then transferred to energy level E_2 by collisions between the helium and neon atoms. Laser light is then released when the electrons in E_2 state fall to E_1 state.

(a) Estimate the order of the time an electron will stay in the following states before falling to lower states

(i) metastable state E_3,

time = ………………………………… s

(ii) energy state E_2 or E_1.

time = ………………………………… s
[1]

(b) Electrons in E_3 have energy of 20.61 eV. This is not enough to raise the electrons from the ground state to E_2 which requires 20.66 eV. Suggest why this excitation is possible.

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

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

(c) Lasing occurs when electrons fall from E_2 state to E_1 state. Give a brief explanation of how population inversion is achieved between these two levels.

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

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

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

7 A series of data on the performance of one particular modern car are extracted from the manufacturer's handbook. The mass of car under test is 1400 kg. Study the following information in Fig. 7.1 to Fig 7.3 and answer the questions that follow.

Speed, v / m s^{-1}	13.0	18.0	22.0	27.0	31.0	35.0	36.5
Time to reach the speed from rest, t / s	3.5	5.0	7.0	10.0	13.5	19.5	28.0

Fig. 7.1 Time to reach the speed from rest

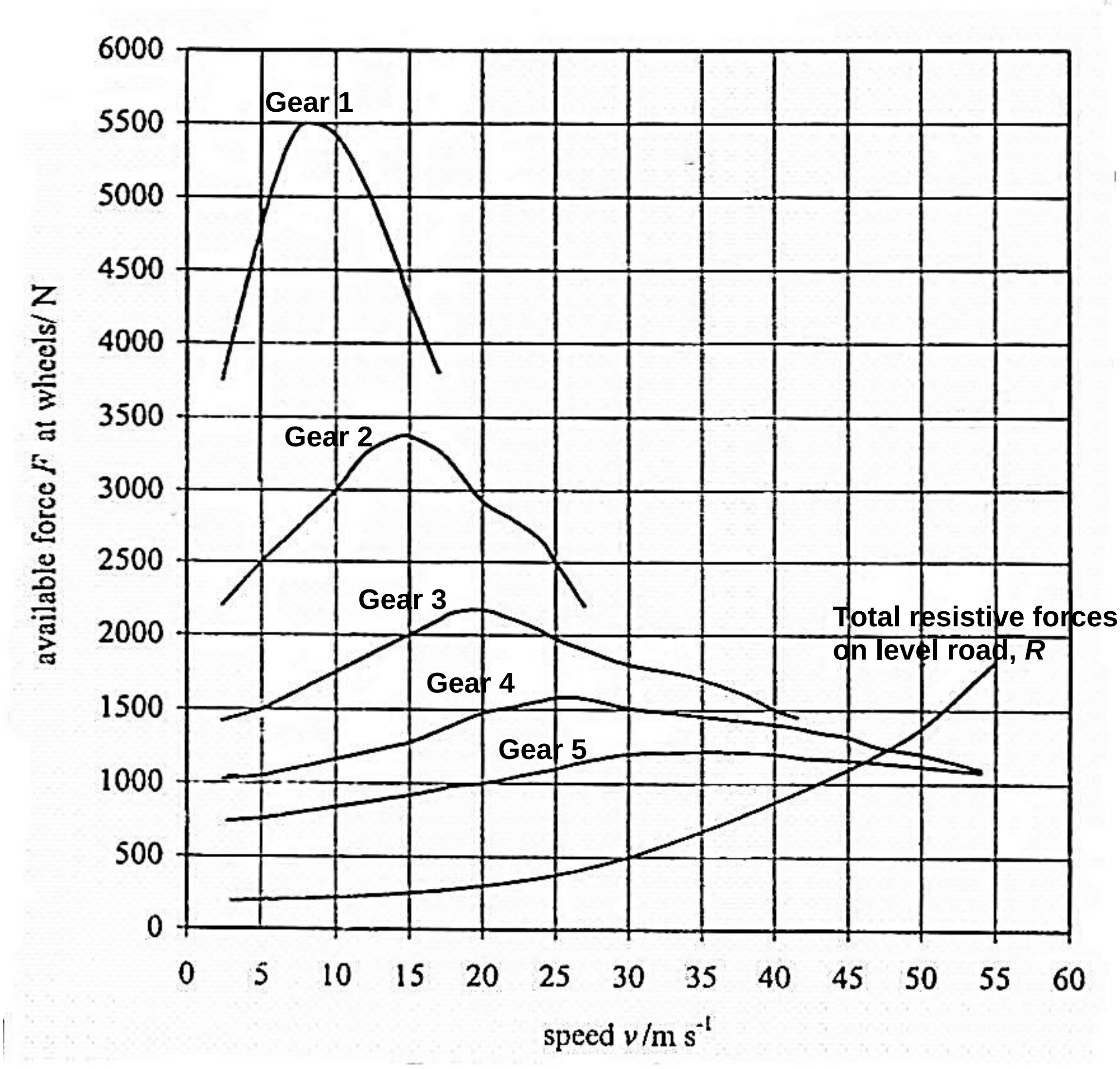

Fig. 7.2 Graphs of available force at the wheels (for different gears) and total resistive forces plotted against speed

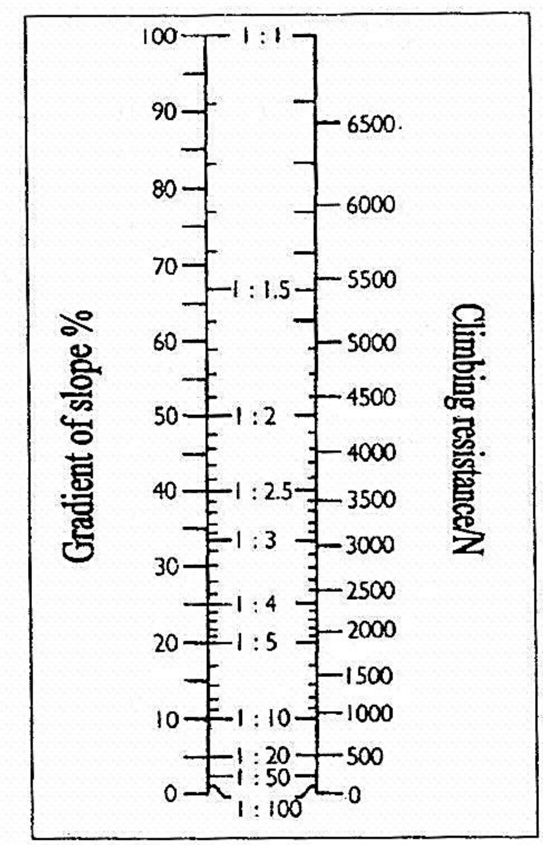

Fig. 7.3 Climbing resistance of the car on a particular slope

Note: A 10 % gradient means the slope rises 10 metres vertically for every 100 metres of horizontal distance.

(a) **(i)** On Fig. 7.4, plot a graph of speed *v* against time *t* for the car as it accelerates through the gears. [2]

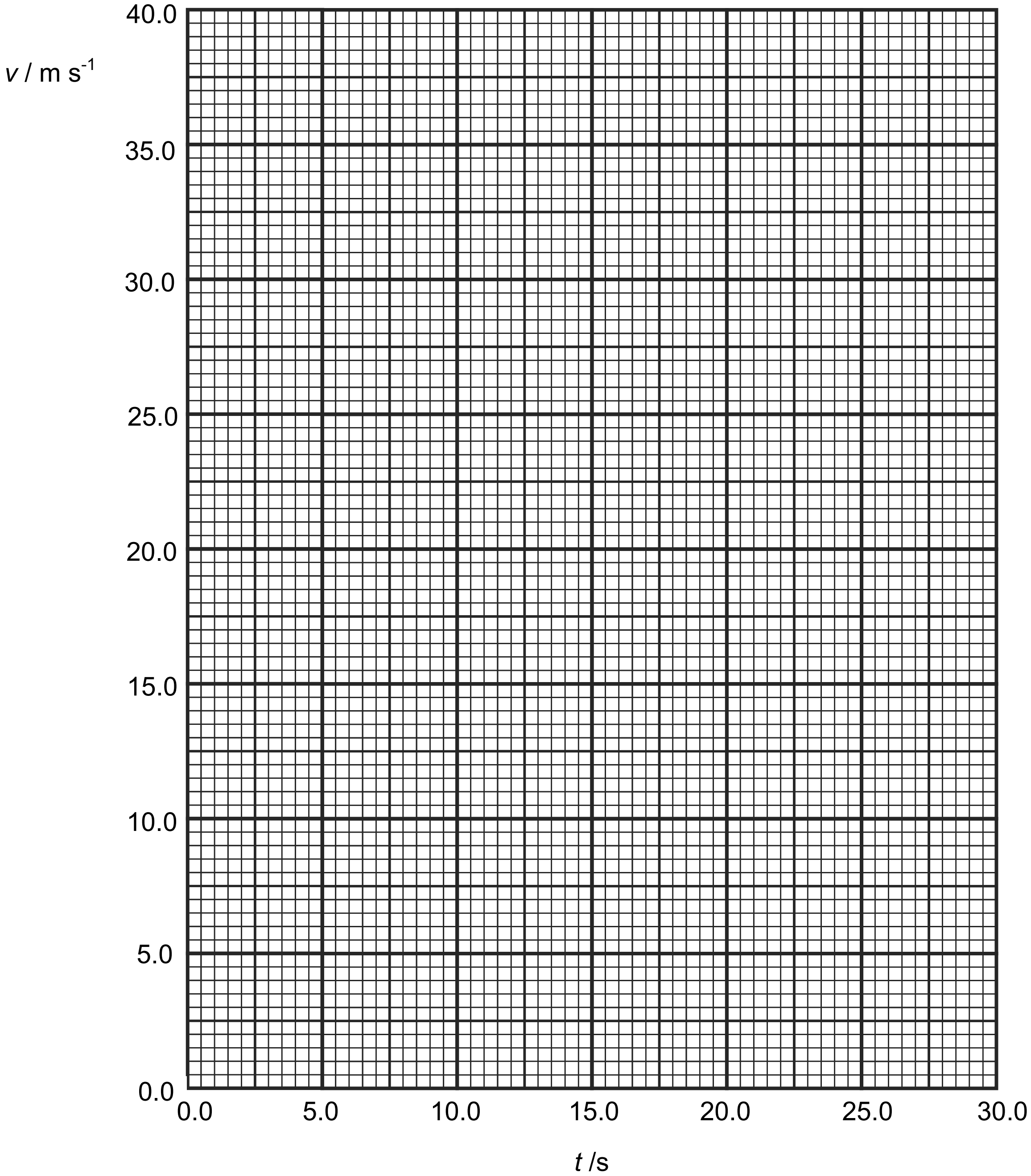

Fig. 7.4

(ii) From the above plot, determine the acceleration when the car is travelling at 25 m s^{-1}.

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

(b) Consider Fig. 7.2, which presents graphs of available force F at the wheels and the resistive forces R against speed v of the car travelling on a level road.

(i) Determine the optimum gear for maximum acceleration at 25 m s^{-1}. Justify your choice.

....

....

.... [2]

(ii) Calculate the maximum theoretical acceleration at 25 m s^{-1}.

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

(iii) Hence, comment on whether the information provided by the manufacturer is consistent.

....

....

.... [1]

(c) The total resistive force F_T to the car's motion on a slope is given by

$$F_T = R + F_S$$

where F_S is a constant climbing resistance on a particular slope.

By referring to Fig. 7.2 and Fig. 7.3, determine the maximum possible acceleration of the car on a 5 % slope at 15 m s^{-1}.

maximum acceleration = ………………………………… m s^{-2} [3]

(d) **(i)** By referring to Fig. 7.2, determine the power required from the engine if this car is to be maintained at a constant speed of 30 m s^{-1} on a level road.

power = ………………………………… W [2]

(ii) Determine the fuel consumption in the car's engine to provide this amount of power if the car travels for 1 hour. Assume that burning one litre of petrol releases 3.5×10^7 J, and the maximum energy conversion efficiency from the petrol combustion is 20 %.

fuel consumption = ………………………………… *l* [2]

(iii) From the answer in **(d)(ii)**, calculate the distance that the car can travel on 1 litre of petrol.

distance travelled per litre of petrol = ………………………………… m l^{-1} [2]

(e) Fig. 7.5 shows the hydraulic braking system of the car.

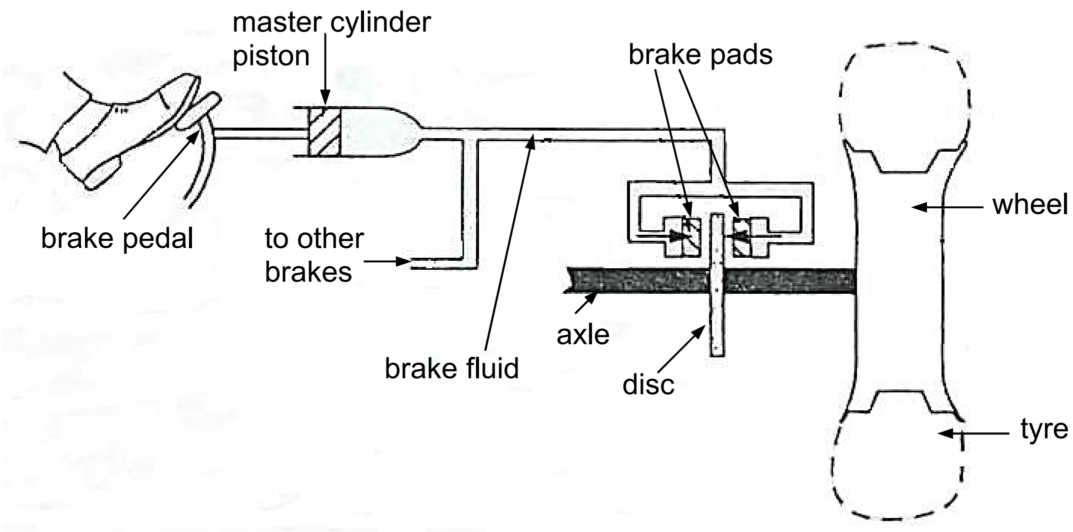

Fig. 7.5

Explain how a braking force is produced when the driver depresses the brake pedal with his foot.

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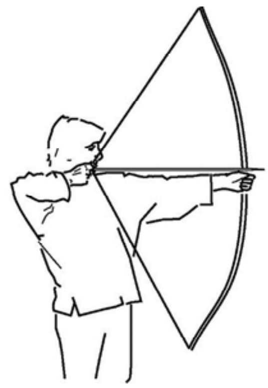
.... [2]

8 The **bow and arrow** is a projectile weapon system that predates recorded history and is common to most cultures.



A bow is a flexible arc which shoots aerodynamic projectiles called arrows. A string joins the two ends of the bow and when the string is drawn back, the ends of the bow are flexed. (Refer to the diagram on the right; the archer is drawing the string before releasing it.)

When the archer draws its string, elastic potential energy is stored in the **bow and string.** This stored energy gives the arrow its initial kinetic energy as the string is released.

The efficiency of the bow affects arrow flight, bow sound and vibration.

Somewhere during the action of drawing, then letting down, energy is lost. In this case, most of the energy is lost to friction in the system; this phenomenon is referred to as "hysteresis" and is common in all mechanical functions that have a return path. The friction comes from the parts of the bow turning on the bearings/axels, bending and relaxing of the limbs as that material shifts and moves, the flex of the riser, losses in the archer's bones and joints, along with various other minor losses.

Design an experiment to investigate how the efficiency of the bow is affected by the distance drawn by the archer. Earlier experiments indicate that x, the length drawn by the archer, is not proportional to F, the force applied by the archer.

The following equipment is available: A simple bow and arrows, various weights, a spring balance, light gates with a datalogger, and any other equipment normally available in a school laboratory.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how to measure the potential energy of the bow before the arrow is released,
(d) how to measure the kinetic energy of the arrow after the string is released,
(e) the control of variables.

Diagram

[12]