H

NANYANG JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS 8866/02

Paper 2 Structured Questions

19 September 2014

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

Section A
Answer **all** questions.

Section A
Answer any **two** 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	
Section A	
1	
2	
3	
4	
5	
6	
Section B	
7	
8	
9	
Total	

This document consists of **25** printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
acceleration of free fall.	$g = 9.81\ \text{m s}^{-2}$

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,	$p = \rho gh$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$

Section A

Answer **all** questions in this section.

1 **(a)** 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 the target as shown in Fig. 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

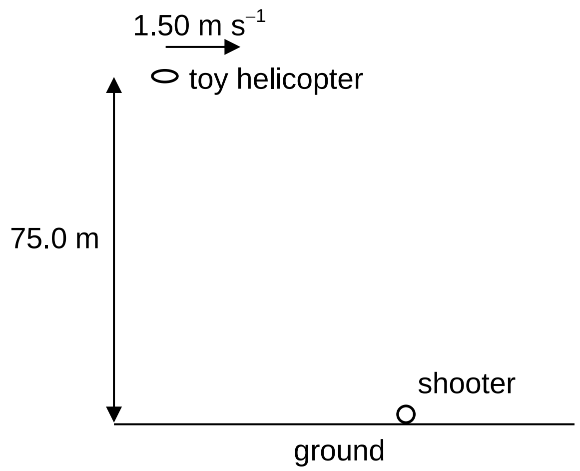


Fig. 1

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

Considering bullet, taking up as positive,

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

$$75.0 = 100t + \frac{1}{2}(-9.81)t^2$$

$$t = 0.780 \text{ s} \quad \text{or} \quad t = 19.6 \text{ s}$$

Considering toy, taking right as positive,

$$s_x = u_x t$$
$$= 1.50(0.780)$$
$$= 1.17 \text{ m}$$

$$\text{Distance} = \sqrt{s_x{}^2 + s_y{}^2}$$
$$= \sqrt{(1.17)^2 + (75.0)^2}$$
$$= 75.0 \text{ m}$$

distance = ………………………………… m [3]

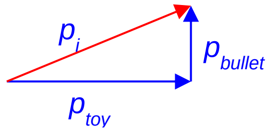
(ii) the momentum of the toy helicopter and bullet immediately after the hit. Assume that the bullet is embedded in the toy helicopter after the hit.

Considering bullet, taking up as positive,

$$v_y = u_y + a_y t$$
$$= 100 + (-9.81)(0.780)$$
$$= 92.3 \text{ m s}^{-1}$$

By Conservation of Momentum,

$$p_f = p_i$$
$$= \overrightarrow{p_{toy}} + \uparrow p_{bullet}$$



$$p_f = \sqrt{p_{toy}{}^2 + p_{bullet}{}^2}$$
$$= \sqrt{(m_{toy}u_{toy})^2 + (m_{bullet}u_{bullet})^2}$$
$$= \sqrt{[(0.150)(1.50)]^2 + [(1.0\times10^{-3})(92.3)]^2}$$
$$= 0.243 \text{ kg m s}^{-1}$$

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

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

No the principle of conservation of momentum is not violated.

As there is external force i.e. gravitational force acting on the toy-bullet system after the hit, principle of conservation of momentum is not applicable.

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

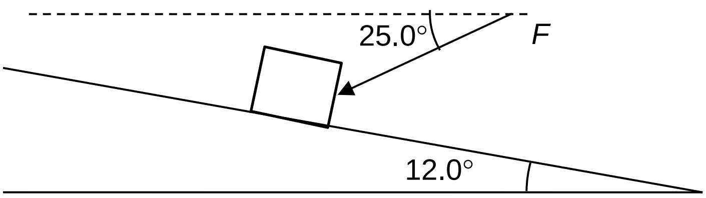
2 **(a)** State Newton's second law of motion.

The rate of change of momentum of a body is directly proportional to the net force acting on it and the change occurs in the direction of the net force.

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

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

(b) An initially stationary box of weight 15.0 N is being pushed by a force, *F*, of 32.0 N up a frictionless surface inclined at an angle of 12.0°. Given that the force is directed at an angle of 25.0° below the horizontal,



(i) calculate the acceleration of the box.

By Newton's Second Law,

$$F_{net} = ma$$

$$F\cos(\theta + \alpha) - mg\sin\theta = ma$$

$$32.0\cos(12.0° + 25.0°) - 15.0\sin 12.0° = \frac{15.0}{9.81}a$$

$$a = 14.7 \text{ m s}^{-2}$$

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

(ii) determine the time needed for the box's speed to increase to 2.50 m s^{-1}.

$$v = u + at$$

$$t = \frac{v-u}{a}$$

$$= \frac{2.50-0}{14.7}$$

$$= 0.170 \text{ s}$$

time taken = ... s [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*.

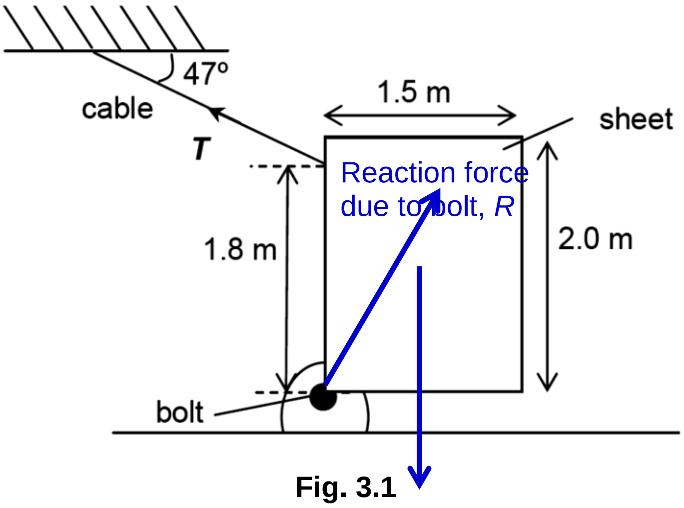


Fig. 3.1

Weight of sheet, *W*

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

Taking moment about the bolt,

$$Wd_1 = T_x d_2$$

$$800(1.5/2) = (T\cos 47)(1.8)$$

$$T = 489 \text{ N}$$

[2]

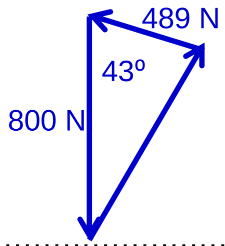
(b) Determine the magnitude of force acting on the bolt by the sheet.

Using Cosine Rule,

$R = \sqrt{W^2 + T^2 - 2WT\cos\theta}$

$R = \sqrt{800^2 + 489^2 - 2(800)(489)\cos 43}$

$R = 554$ N



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 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.

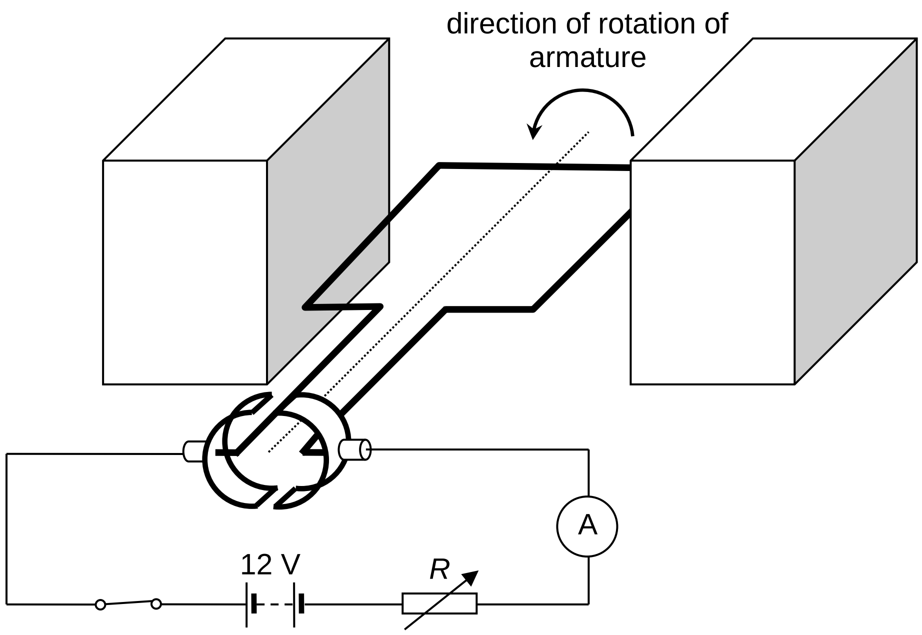


Fig. 4.1

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

40 mT is the magnetic flux density of a magnetic field in which a force per unit length of 40 mili-newton per metre acts on a conductor carrying a current of 1 ampere which is placed perpendicularly to the magnetic field.

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

Left to right

(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.

$F_B = BIL$

$= (40 \times 10^{-3})(0.55)(0.20)$

$= 0.0044$ N

$\tau = 0.0044 \times 0.20$

$= 0.00088$ Nm

torque = ………………………………….. N m [3]

5 **(a)** In classical wave theory, light is an electromagnetic wave and the intensity of the wave is proportional to the square of the amplitude of the wave.

But according to Einstein's photon theory, light comes in quanta of electromagnetic energy and each quantum is proportional to the frequency.

In a photoelectric experiment, the intensity or the frequency of the incident light changes accordingly as shown in table below. Fill in the blanks in the table correctly with the following descriptions:

1. Remains the same **2.** increases or **3.** decreases.

	Energy of each photon	Total energy of the light	Number of photons
If the frequency of the light is constant, as the intensity of the light increases….	Remains the same	Increases	Increases
If the intensity of the light is constant, as the frequency of the light increases….	Increases	Remains the same	Decreases

[2]

(b) Electromagnetic radiation is incident normally on the surface of a metal. Electrons are emitted from the surface and these electrons are attracted to a positively charged electrode, as shown in Fig. 5.1.

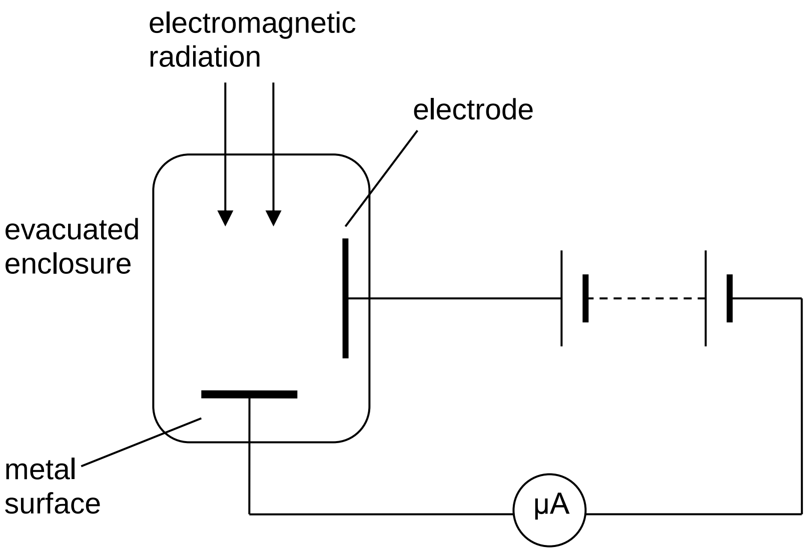


Fig. 5.1

The incident radiation has a wavelength of 240 nm. When the wavelength of the radiation is gradually increased to 310 nm, the reading in the microammeter just drops to zero.

Calculate the maximum kinetic energy of the electrons emitted from the metal surface when the wavelength of the radiation remains at 240 nm.

$$hf = hf_o + \tfrac{1}{2}mv_{max}^2$$

$$mv_{max}^2 = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_o}\right]$$

$$= 6.63 \times 10^{-34} \times 3.00 \times 10^{8}\left[\frac{1}{240 \times 10^{-9}} - \frac{1}{310 \times 10^{-9}}\right]$$

$$= 8.28 \times 10^{-19} - 6.40 \times 10^{-19}$$

$$= 1.87 \times 10^{-19}\ J$$

maximum kinetic energy = ………………………………… J [2]

(c) In the above experiment it was found that the ratio

$$\frac{\text{number of electrons emitted per second}}{\text{number of photons incident per second}}$$

is in the order of 10^{-6}.

Suggest why is the number ratio so small.

1. The photon is neutral, the chance of a photon hitting an electron directly is very small.
2. The chance of hitting a free electron near the surface is very slim. Electrons below the surface after absorbing a photon may lose most of its kinetic energy during collisions with other particles in the metal until its kinetic energy is below the work function energy.
3. By the law of conservation of momentum, the initial momentum of the photon is downwards, the final momentum of the electron after absorbing a photon is also downwards. So most of these electrons will travel into the body.

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

(d) **(i)** Calculate the momentum of the photon with a wavelength of 240 nm.

$p = h / \lambda = 6.63 \times 10^{-34} / 240 \times 10^{-9} = 2.76 \times 10^{-27}$ N s

momentum = ………………………………… N s [1]

(ii) Hence explain why there is a radiation pressure on the metal surface.

Light can be considered as particles (photons) which possess momentum. They will change momentum when they are reflected or absorbed by the surface. By Newton's second law and third law, there is a force on the photons and on the surface. Hence there is a pressure on the surface as pressure is the force acting perpendicularly on unit area of the surface.

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

6 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.

Mass of ball = 0.050 kg
Floor-to-ceiling height = 3 m

Height at the top of building = 12 x 3 = 36 m
Using $v^2 = u^2 + 2as$, velocity before ball reaches ground = 26.6 m/s
Momentum = mv = 1.3 Ns

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. 6.1

(i) Draw a graph on Fig. 6.2 showing how the displacement of the tennis ball varies with the square of time.

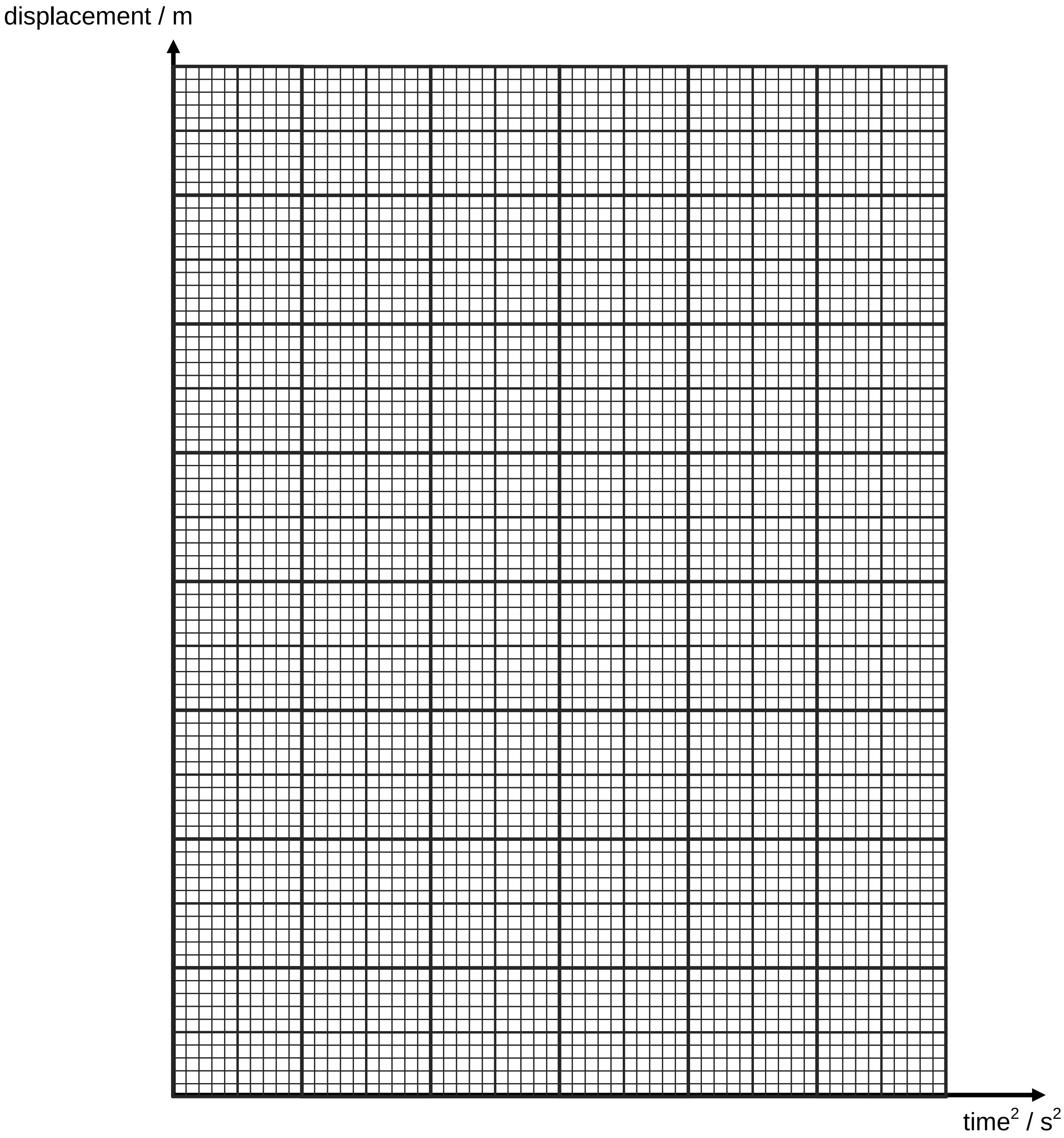


Fig. 6.2 [2]

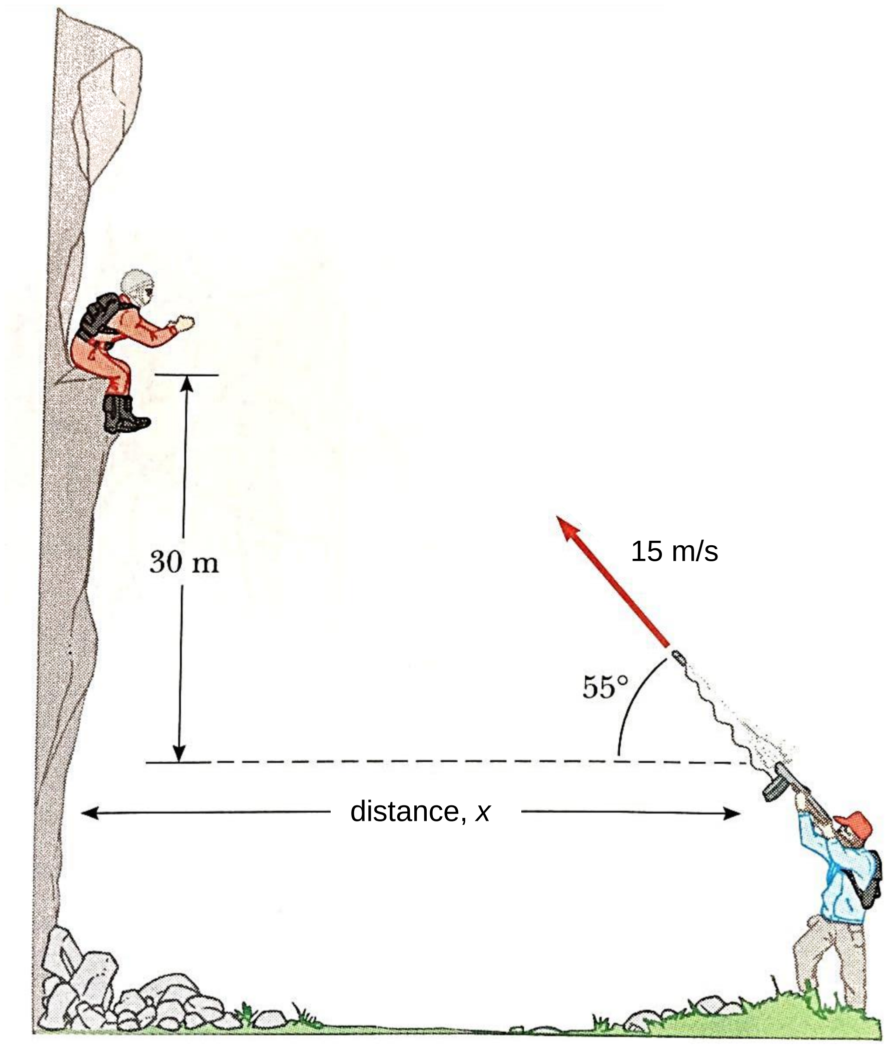
All points plotted correctly
Best Fit Line drawn

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

Gradient
= (0.016 - 0.094) / (0.02 – 0.13)
= 0.7 m/s^2
Acceleration = 2 x gradient = 1.4 m/s^2

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.

$s = ut + ½ at^2$

$30 = 15 \sin 55 – ½ (1.2t^2)$

t = 2.83 s or 17.6 s (NA)

time = …………………………………. s [2]

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

s = ut = 15 cos 55 (2.83) = 24.4 m

distance = …………………………………. m [1]

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

The acceleration of free fall on Planet Newtonia (1.4 m/s2) is larger than that on the moon. It would take longer for the projectile to reach a height of 30 m.

………………………………………………………………………………………..

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

Section B

Answer **two** questions in this section.

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 that 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

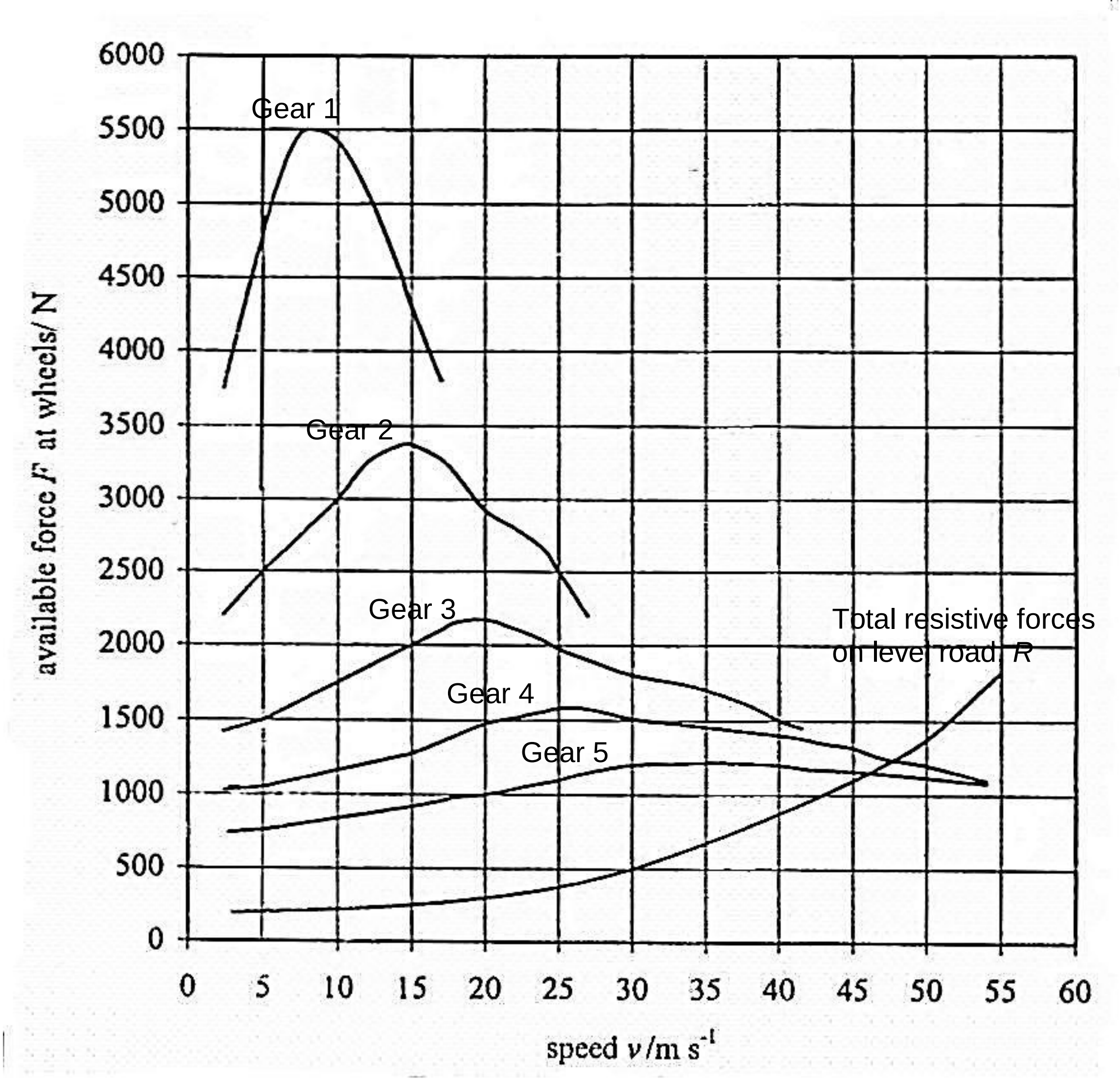


Fig. 7.2 Graphs of available force at the wheels (for different gears) and total resistive forces plotted against speed

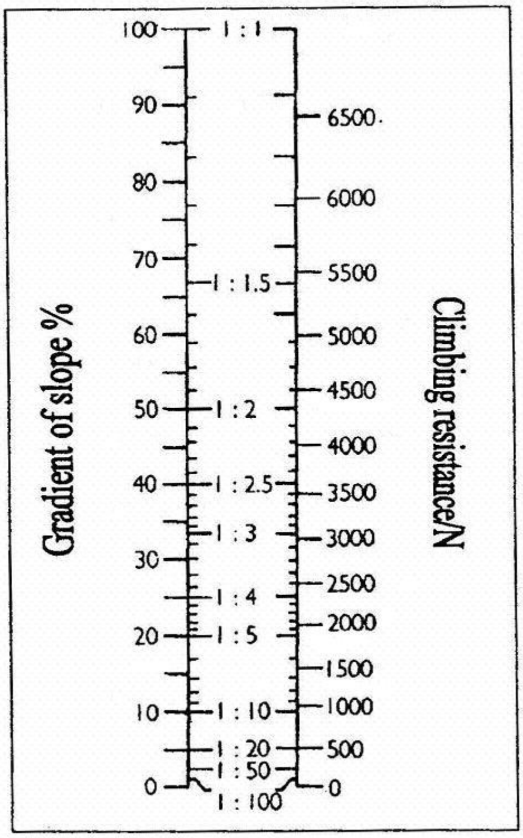


Fig. 7.3 Climbing resistance of the car on a particular slope

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]

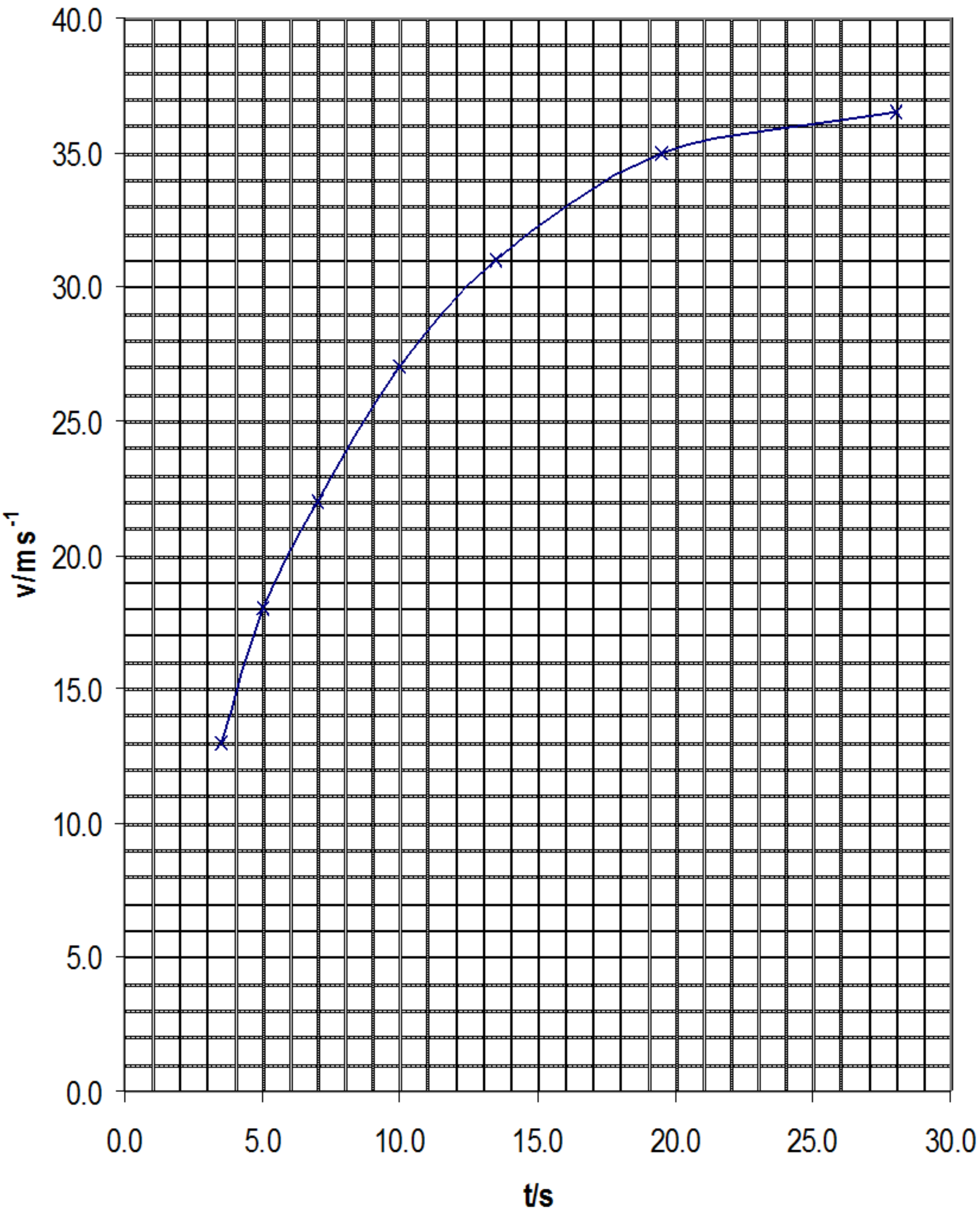


Fig. 7.4

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

Acceleration = $\dfrac{33.0-11.5}{14.0-0.0}$ = 1.536

= 1.54 ms^{-2}

for drawing tangent at v = 25 ms^{-1}
for correct calculation. (acceptable range: 1.39 – 1.69)

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.

Gear 2

Available force for forward motion, F, is the greatest at this gear.

.... [2]

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

From Fig. 7.2, F = 2500 N and R = 375 N

Newton's 2nd law, $F - R = ma$

$2500 - 375 = (1400)\,a$

$a = 1.52\ ms^{-2}$

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

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

It is almost equal to the **acceleration found in (a)(ii)**, and hence the information provided by the manufacturer had been 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}.

From Fig. 7.2, F = 4300 N and R = 250 N

From Fig. 7.3, F_S = 500 N

Newton's 2nd law, $F - F_T = ma$

$4300 - (250 + 500) = (1400)a$

$a = 2.54\ ms^{-2}$

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

(d) **(i)** By referring to Fig. 7.2, calculate 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.

From Fig. 7.2, R = 500 N

$P = Fv = (500)(30)$

$= 15000$ W or 15 kW

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 %.

Power input required = $\frac{15000}{0.20}$ = 75 000 W

Fuel consumption = $\frac{75000 \times 3600}{3.5 \times 10^7}$ = 7.71 litres

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

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

Distance travelled on 1 litre = $\frac{30 \times 3600}{7.71}$

= 14007 metres per litre

= 14.0 × 10^3 metres per litre

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

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

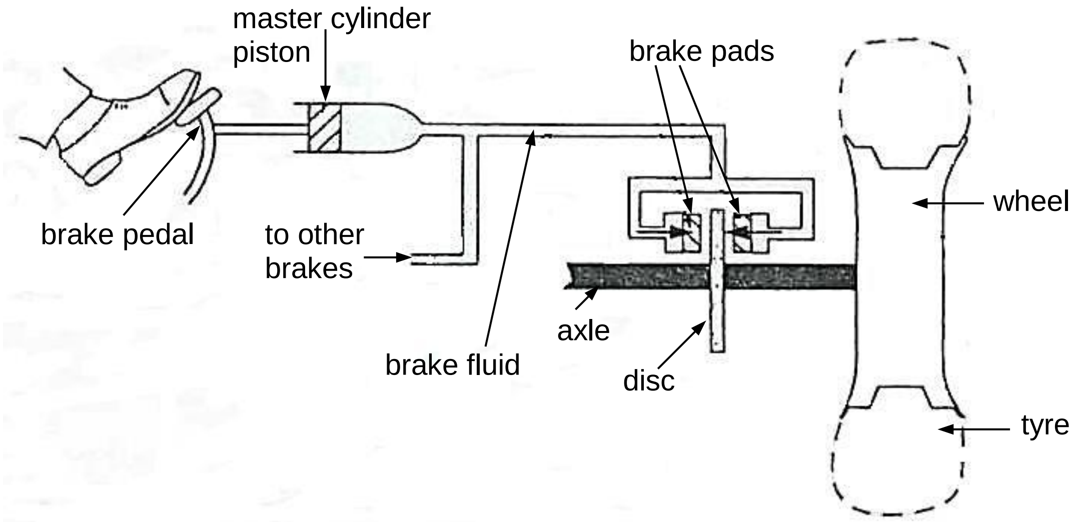


Fig. 7.5

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

Force exerted on the piston (through depression of the brake pedal) creates a pressure in the brake fluid. **Assuming that the fluid is incompressible, the fluid in turn exerts a force on brake pads**, which pushes them towards the disc.
Friction between the disc and brake pads creates the braking force.

.... [2]

8 An electric lamp is rated as 3.0 V, 0.60 W. The filament of the lamp is made from tungsten and is a wire of constant radius 4.0×10^{-5} m. The resistivity of tungsten at the normal operating temperature of the lamp is $7.9 \times 10^{-7}\ \Omega$ m.

(a) **(i)** Explain what information the rating "3.0 V, 0.60 W" provides about the normal operation of the lamp.

It means that when the lamp is connected to a 3.0 V supply, the lamp will produce energy at a rate of 6.0 W

.... [1]

(ii) Show that the resistance of the filament is 15 Ω at normal operating temperature. [1]

$$\text{Resistance} = \frac{V^2}{P} = \frac{3.0^2}{0.60} = 15\ \Omega$$

(iii) Calculate the length of the filament.

$$R = \frac{\rho l}{A}$$

$$l = \frac{RA}{\rho} = \frac{15\pi(4.0 \times 10^{-5})^2}{7.9 \times 10^{-7}} = 9.5 \text{ cm}$$

length = ... m [3]

(iv) Comment on your answer to (a)(iii).

The filament must be coiled up inside the lamp

.... [1]

(b) The electric lamp is used in a circuit to measure its current-voltage (I-V) characteristics as shown in Fig. 8.1.

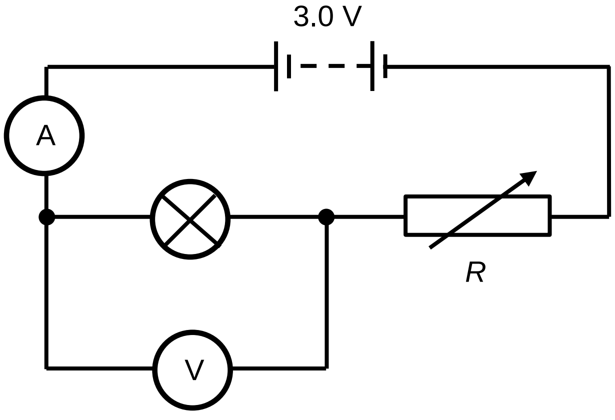


Fig. 8.1

When the variable resistor R is set to maximum value and zero value, the following ammeter and voltmeter readings were obtained:

Variable resistor setting	Ammeter reading	Voltmeter reading
Maximum	0.18 A	0.60 V
Zero	0.20 A	2.6 V

(i) Explain why, by changing the value of the resistance of the variable resistor, the potential difference across the lamp cannot be varied from 0 to 3.0 V.

Some potential difference will be lost across the internal resistance of the battery , therefore the lamp will have a potential difference less than 3.0 V even if we set the variable resistor to zero resistance.
The lamp is not of zero resistance, so it will have a finite potential difference across it even if the variable resistor is set to maximum resistance.
………..…………………………………………………………………………………………. [2]

(ii) Determine the internal resistance of the battery.

Using the data when variable resistor is set to zero,

$E = Ir + V_{lamp}$

$3.0 = 0.20r + 2.6$

$r = 2.0\ \Omega$

resistance = ………………………………… Ω [3]

(iii) Calculate the resistance of the filament when the reading on the voltmeter is

1. 0.60 V

$R = \frac{V}{I}$

$= \frac{0.60}{0.18}$

$= 3.3\ \Omega$

resistance = ………………………………… Ω [1]

2. 2.6 V

$R = \frac{V}{I}$

$= \frac{2.6}{0.20}$

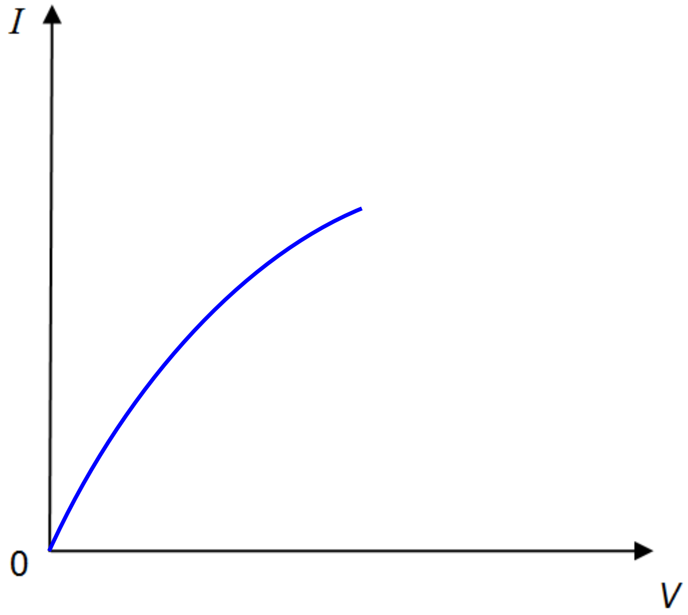
$= 13\ \Omega$

resistance = ………………………………… Ω [1]

(iv) Explain why there is a difference between your answers to **(b)(iii)1** and **(b)(iii)2**.

At higher potential difference, there is a greater current and the temperature of the filament will increase. This will increase the resistance of the metallic filament due to the vibration of the lattice structure
………..…………………………………………………………………………………………. [2]

(v) Using the axes below sketch the I-V characteristic of the filament of the lamp.



[1]

(vi) Fig. 8.2 below shows an alternative circuit for varying the potential difference across the lamp. A fixed resistor of 12 Ω is added to the circuit.

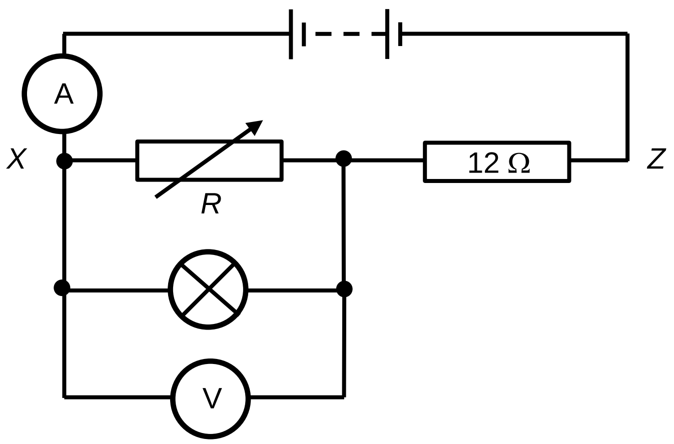


Fig. 8.2

The potential difference across XZ is 3.0 V. The variable resistor R is set to have resistance of 12 Ω, equivalent to the resistance of the fixed resistor. The resistance of the lamp is 4.0 Ω.

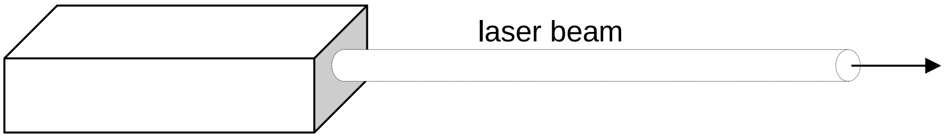
.

Calculate the potential difference across the lamp.

$$R_{eff} \text{ across lamp and XY} = \left(\frac{1}{4.0}+\frac{1}{12}\right)^{-1}$$
$$= 3.0\ \Omega$$
$$\text{Current } I = \frac{E}{R_{total}}$$
$$= \frac{3.0}{3.0+12}$$
$$= 0.20\ \text{A}$$
$$V_{lamp} = IR_{eff}$$
$$= 0.20(3.0)$$
$$= 0.60\ \text{V}$$

potential difference = ... V [4]

9 **(a)** Waves from a monochromatic **laser** source are confined to a circular beam of diameter d.



If the laser radiates a total energy E in a time interval t, write an expression for the intensity of light at a distance of x from the source.

$$I = \frac{\text{energy}}{(\text{time})(\text{area})} = \frac{E}{t(\pi \frac{d^2}{4})} = \frac{4E}{\pi t d^2}$$

. [2]

(b) **(i)** Suggest two conditions for observable interference pattern.

- The wave sources must be coherent sources; i.e. they must oscillate at a constant phase difference.
- The amplitude of the waves when they meet must be approximately equal.

[2]

(ii) The photograph shows the interference pattern produced when monochromatic light falls on a pair of slits 0.5 mm apart. The pattern was produced on a screen 1.5 m from the slits.

(i) Explain why there is a bright fringe at the centre of the pattern.

The path difference from the sources to the <u>centre of the pattern</u> is <u>zero</u>. Thus the waves <u>meet in phase</u>; superposition results in <u>constructive interference</u> and a maximum is observed.

[3]

(ii) The photograph as been magnified by a factor of X3. Use the photograph of obtain a value for the fringe spacing.

In the photo six fringes occupy 4.0 cm

Fringe spacing in photo = $\dfrac{4.0 \times 10^{-2}}{6} = 6.67 \times 10^{-3}$ **m**

Actual spacing = $\dfrac{6.67 \times 10^{-3}}{3} = 2.22 \times 10^{-3}$ **m**

[2]

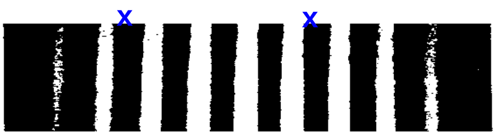
(iii) Calculate the frequency of the light used.

$$\lambda = \frac{a\,x}{D} = \frac{(0.50 \times 10^{-3})(2.22 \times 10^{-3})}{1.5} = 7.40 \times 10^{-7}\ \text{m}$$

$$f = \frac{v}{\lambda} = \frac{3.0 \times 10^{8}}{7.4 \times 10^{-7}} = 4.1 \times 10^{14}\ \text{Hz}$$

[3]

(iv) Mark with and X on the photograph the fringe or fringes where light from one slit has traveled a distance of two wavelengths further than the light from the other slit.



[1]

(v) From the list below circle the possible values of the phase difference between the two waves arriving at the centre of a dark region.

$\dfrac{\pi}{2}$ (π) $\dfrac{3\pi}{2}$ 2π $\dfrac{5\pi}{2}$ (3π)   4π   (5π)

[1]

(vi) Explain why the fringes nearer the centre of the photograph are clearer than those nearer the edges of the photograph.

Light diffracts (spreads) from each slit ,
such that the greatest intensity is at the centre of the spread and the least at the edges.
Thus the highest intensity of the superposition is also at the centre of the region of superposition.
The contrast is greatest at the centre thus they are clearer.

[2]

(vii) Explain how the pattern would be affected if (changes made separately)

1. Light of longer wavelength were used.

$$\lambda = \frac{a\,x}{D}$$

If the wavelength used were to be longer, the fringe separation would be greater.

[2]

2. One of the slits were covered completely.

There would no longer be any more interference as there is only one source of waves.
The pattern on the screen would be one showing the spread of light from the one slit.

[2]