YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CG

INDEX NO

PHYSICS

9749/02

Paper 2 Structured Questions

30 August 2023

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
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, highlighters, glue or correction fluid/tape.

The use of an approved scientific calculator is expected, where appropriate.

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	
Paper 2	
1	**/8**
2	**/8**
3	**/10**
4	**/14**
5	**/6**
6	**/11**
7	**/10**
8	**/13**
Penalty	
Paper 2 Total	
	/80

This document consists of **21** 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_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} 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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
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	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
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	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Answer **all** questions.

1 A ball is thrown with a velocity of 25 $m\,s^{-1}$ vertically upwards from ground level. Air resistance is not negligible.

The variation with time t of the vertical velocity v of the ball is shown in Fig. 1.1.

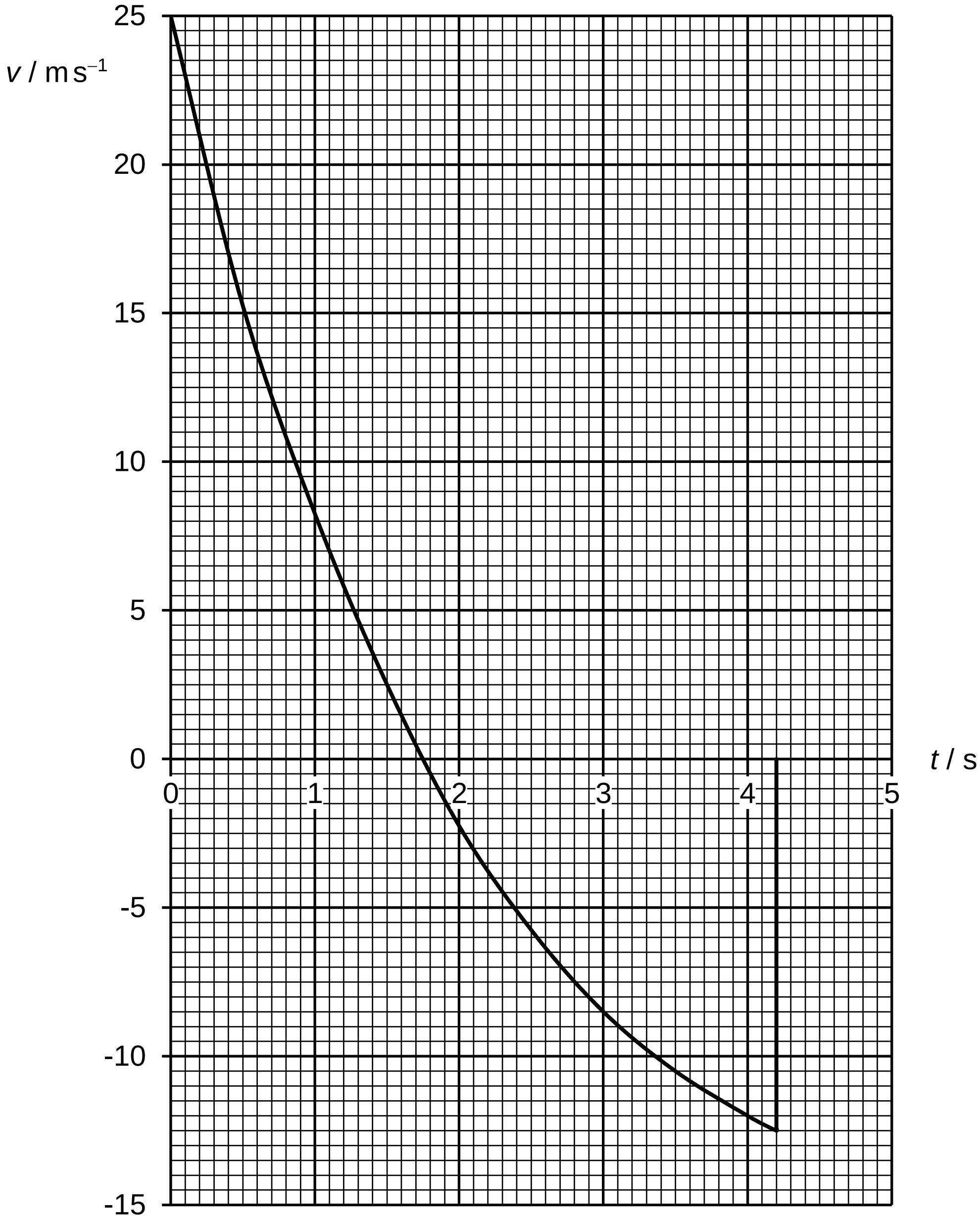

Fig. 1.1

(a) Use Fig. 1.1 to explain how it may be deduced that air resistance varies with speed.

……

……

……

…… [2]

(b) **(i)** State the time at which the acceleration of the ball is *g*.

time = ………………….. s [1]

(ii) On Fig. 1.1, sketch the graph to show the variation with time *t* of the velocity *v* of the ball if air resistance is negligible.

[2]

(c) The mass of the ball is 350 g and that the maximum height reached by the ball is 19 m.

Use Fig. 1.1 to determine the ratio,

$$\frac{\text{energy lost from the ball due to air resistance during the ball's upward motion}}{\text{energy lost from the ball due to air resistance during the ball's downward motion}}.$$

ratio = ………………….. [3]

[Total: 8]

2 **(a)** Define *moment of a force*.

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

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

(b) An arrangement for lifting heavy loads is shown in Fig. 2.1.

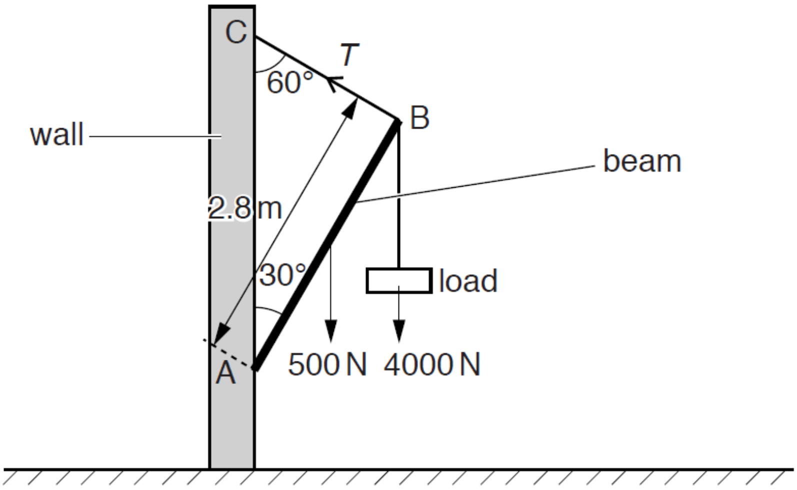

Fig. 2.1

A uniform metal beam AB is pivoted on a vertical wall at A. The beam is supported by a wire joining end B to the wall at C. The beam makes an angle of 30° with the wall and the wire makes an angle of 60° with the wall.

The beam has length 2.8 m and weight of 500 N. A load of 4000 N is supported from B. The tension in the wire is *T.* The beam is in equilibrium.

(i) By taking moments about an appropriate point, show that *T* is 2.1 kN.

[1]

(ii) Calculate the vertical component T_v of the tension *T.*

T_v = ………………….. N [1]

(iii) Explain why T_V does not equal the sum of the load and the weight of the beam although the beam is in equilibrium.

……..

……

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

(iv) Determine the magnitude and direction of the reaction force on the beam at A.

force magnitude = ……………………………. N

direction = ………………………………… [4]

[Total: 8]

3 **(a)** State what is meant by *work done*.

………..

……. [1]

(b) A lift of weight 13.0 kN is connected by a cable to a motor, as shown in Fig 3.1.

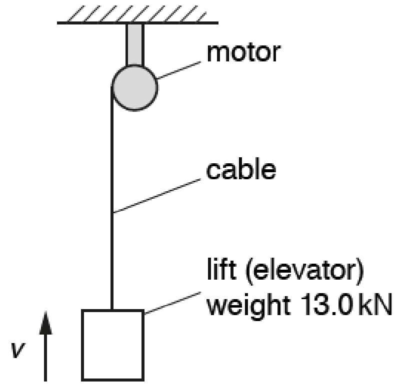

Fig. 3.1

The lift is pulled up by the cable. A constant frictional force of 2.0 kN acts on the cable by the motor when the lift is moving. The variation with time t of the speed v of the lift is shown in Fig. 3.2.

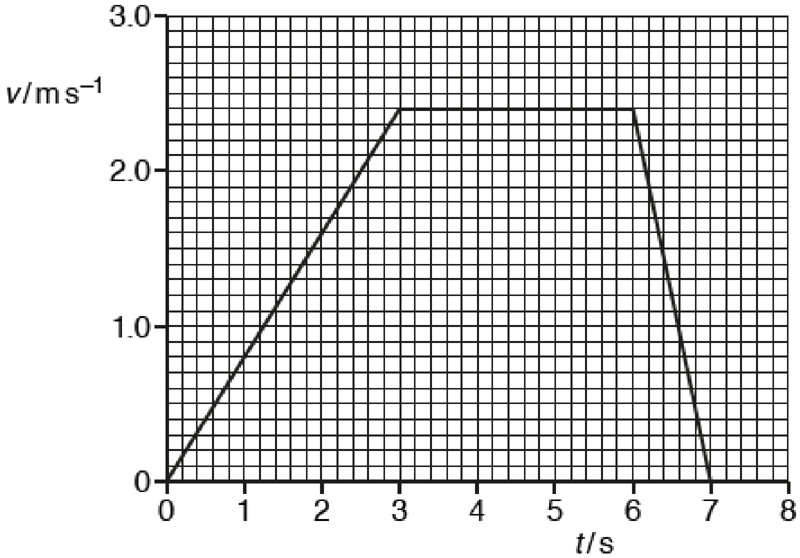

Fig. 3.2

(i) Use Fig. 3.2 to determine the displacement of the lift between time t = 0 and t = 4.0 s

displacement = ………………….. m [2]

(ii) Determine the work done by the motor to raise the lift between time $t = 0$ and $t = 4.0$ s.

work done = ………………….. J [4]

(iii) The motor has an efficiency of 67%. The tension in the cable is 1.6×10^4 N at time $t = 2.5$ s.

Determine the input power to the motor at this time.

power = ………………….. W [3]

[Total: 10]

4 **(a)** **(i)** State, in terms of force, the condition necessary for an object to move in a circular path at constant speed.

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

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

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

(ii) Explain why this object is accelerating. State the direction of the acceleration.

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

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

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

(b) A satellite moves in a circular orbit around the Earth at a constant speed of 3700 m s^{-1}.

The mass of the Earth is 6.0×10^{24} kg.

(i) Calculate the radius of this orbit. Show your working clearly.

radius = ………………….. m [3]

(ii) State and explain if the satellite is a geostationary satellite.

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

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

(iii) The mass of the satellite is 2.0 kg. Determine the total energy of this satellite.

Show your working clearly.

total energy = ………………….. J [3]

(c) In order to move the satellite in **(b)** into a new smaller orbit, a decelerating force is applied for a brief period of time.

(i) Suggest how the decelerating force could be applied.

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

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

(ii) State and explain the effect on the kinetic energy of the satellite when the satellite moves in this new smaller orbit.

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

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

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

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

[Total: 14]

5 Fig. 5.1 shows a simple transformer.

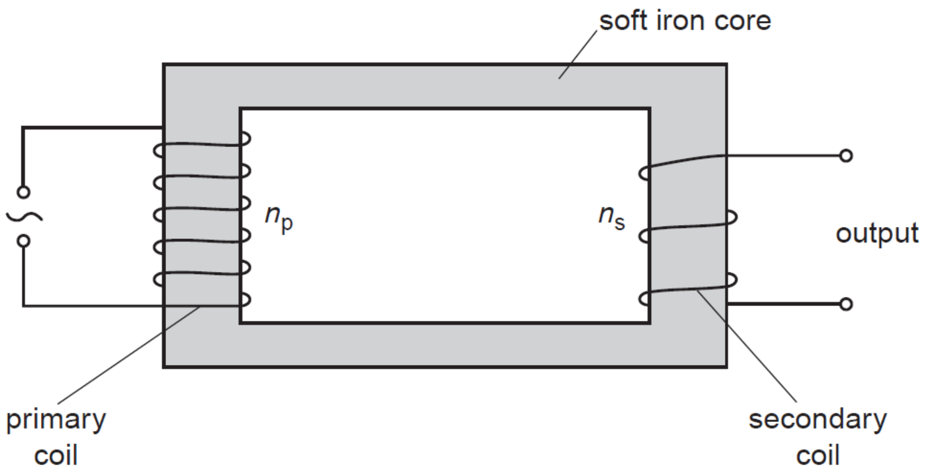

Fig. 5.1

The transformer with 4200 turns in the primary coil is connected to a 230 V mains supply. The e.m.f. across the output is 12 V. Assume the transformer is 100% efficient.

(a) Calculate the number of turns in the secondary coil.

number of turns = ………………….. [2]

(b) The transformer output terminals are connected to a lamp using leads that have a total resistance of 0.35 Ω. The p.d. across the lamp is 11.8 V. Calculate

(i) the r.m.s. current in the leads connected to the lamp,

current = ………………….. A [2]

(ii) the maximum power dissipated in the leads.

power = ………………….. W [2]

[Total: 6]

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6 A beam of light consists of a continuous range of wavelengths from 420 nm to 740 nm.

The light passes through a cloud of cool gas, as shown in Fig. 6.1.

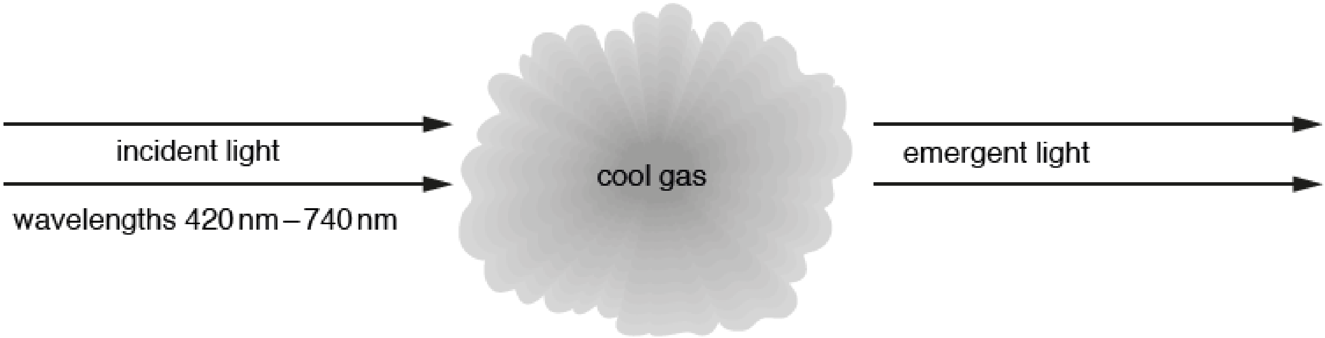

Fig. 6.1

(a) State what is meant by a *photon.*

………

……… [1]

(b) The spectrum of the light emerging from the cloud of cool gas is viewed using a diffraction grating.

Explain why this spectrum contains several dark lines.

………

………

………

………

………

………

………

………

………

……… [4]

(c) Some of the electron energy levels of the atoms in the cloud of gas are represented in Fig. 6.2.

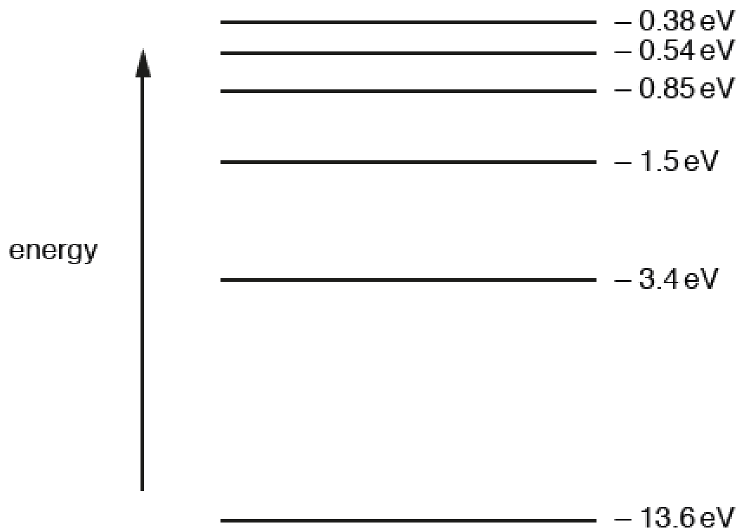

Fig. 6.2 (not to scale)

(i) Show that the photon energy, in eV, of light of wavelength 420 nm and 740 nm are 2.96 eV and 1.68 eV respectively.

[2]

(ii) Use data from **(c)(i)** to show, on Fig. 6.2, the changes in energy levels, giving rise to the dark lines in **(b)**.

[2]

(d) Calculate the speed of an electron having a de Broglie wavelength equal to the shortest wavelength of the beam of light.

speed = ………………….. m s^{-1} [2]

[Total: 11]

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

Measuring the Planck constant

A simple experiment can be carried out in the laboratory to calculate one of the fundamental constants which is central to the tenets of quantum physics – Planck constant h.

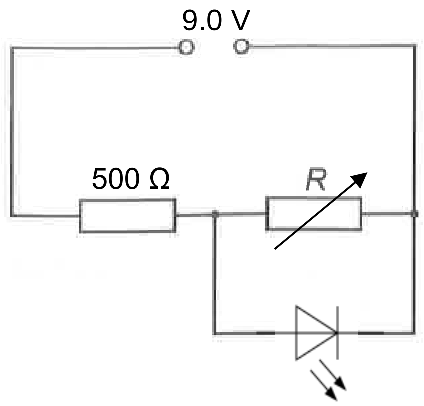

Fig. 7.1 A circuit for determining the Planck constant

A light-emitting diode (LED) is connected in parallel to a variable resistor. These are connected in series to a resistor of 500 Ω and a power supply of electromotive force (e.m.f.) of 9.0 V and of negligible internal resistance, as shown in Fig. 7.1.

The light-emitting diode (LED), which is a type of diode, emits light when a large enough potential difference, which is known as threshold p.d. V is applied across the semi-conducting diode. This effect is called electroluminescence. The electrons in the semiconductor are excited to a higher energy level. The excited electrons recombine with holes (electron deficient sites) within the semiconducting material, emitting out light. During the recombination process, the energy that the electron had previously gained is released in the form of a photon.

The threshold p.d. V is the minimum potential difference needed to start a current flowing through an LED. To measure V, the experiment is carried out in a blacked-out room where light is isolated from the LED. The resistance of the variable resistor is varied until light is detected from the LED. The threshold p.d. allows the determination of the amount of energy required to emit photons of light of wavelength λ, thus the value of Planck constant h.

(a) **(i)** Suggest why a light-emitting diode (LED) does not operate at full power with an alternating current power supply as compared to a direct current power supply.

……………………………………………………………………………………………..

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

(ii) When the experiment is carried out in a blacked-out room, the light emitted may not be strong enough to be detected by human eye at voltages just above the threshold p.d. V. Suggest how the experiment can be improved with the use of another electrical device in the circuit to determine if the threshold p.d. V is achieved.

……………………………………………………………………………………………..

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

(iii) The LEDs have sufficiently large resistance.

Determine the resistance R of the variable resistor needed to achieve the threshold p.d. V of 1.66 V for a green LED.

R = ………………….. Ω [2]

(b) By considering the definition of potential difference, show that the threshold p.d. V is related to the wavelength λ of the emitted light photon by the following equation:

$$V = \frac{hc}{e\lambda}$$

where c is the speed of light and e is the elementary charge

[2]

(c) The experiment is repeated with other LEDs of different wavelengths.

Data relating the wavelength λ of the light photons emitted by the LED and the threshold p.d. V needed across the LED are given for five LEDs in Fig. 7.2.

LED colour	V / V	λ / nm	$\frac{1}{\lambda}$ / 10^6 m^{-1}
Blue	2.50	420	2.38
Green	1.66	563	1.78
Yellow	1.58	585	1.71
Red 1	1.45	620	1.61
Red 2	1.32	650	1.54

Fig. 7.2

With the experimental data, the variation with $\frac{1}{\lambda}$ of V is shown in Fig. 7.3.

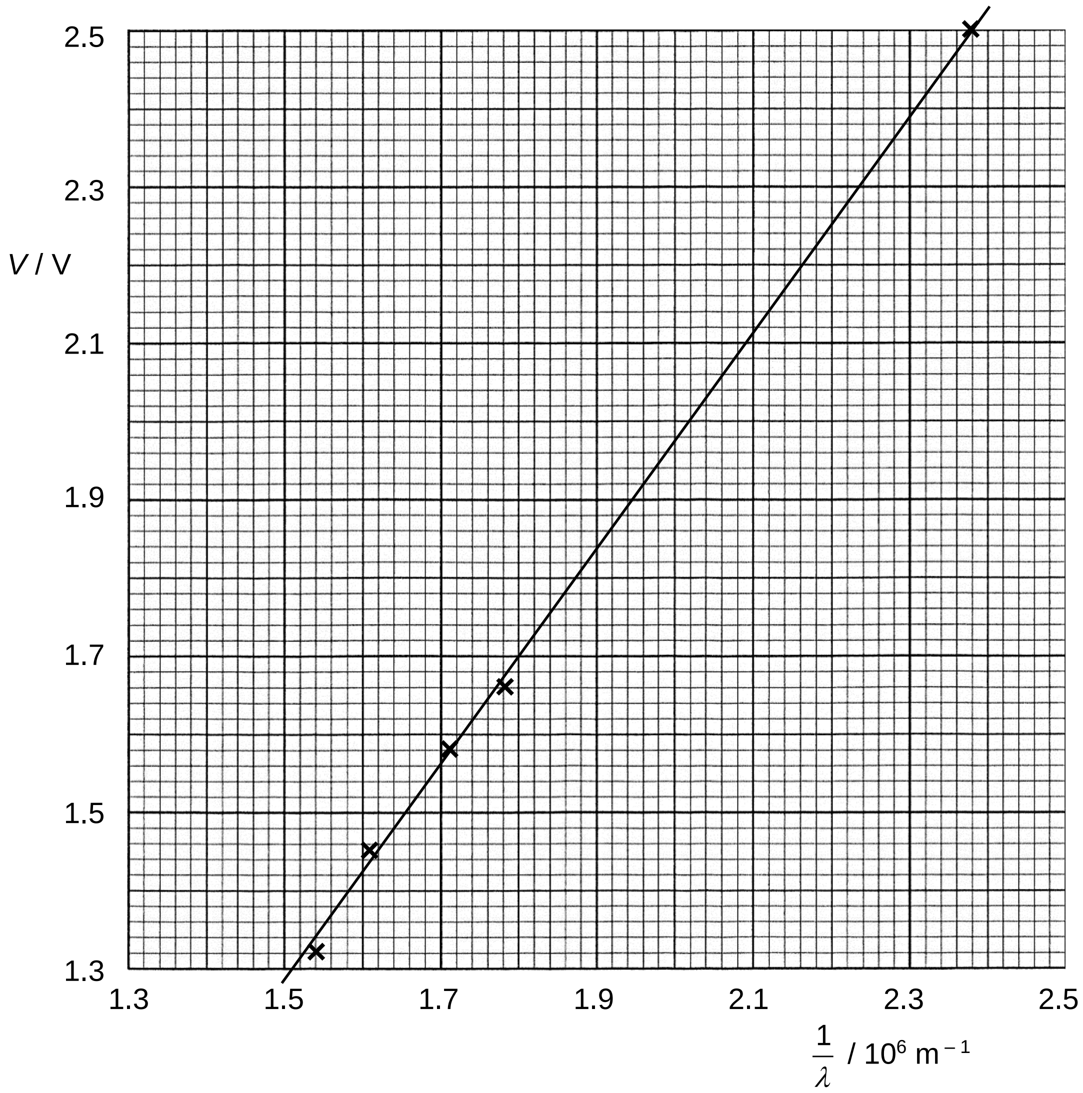

Fig. 7.3

(i) Determine the gradient of the line that is drawn in Fig. 7.3.

gradient = ………………….. [2]

(ii) Determine the value of Planck constant *h*.

h = ………………….. J s [1]

(d) In reality, the best-fit line drawn does not go through the origin as theorised.

Suggest any reason for the discrepancy.

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

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

[Total: 10]

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

Building the pyramids

The Egyptian pyramids and the Great Sphinx of Giza rise out of the desert on the outskirts of Cairo as a legacy to a long-lost civilisation. The largest pyramid, the Great Pyramid of Giza, built for the Pharaoh Khufu in around 2530 BCE, was the tallest building on Earth until Lincoln Cathedral was erected in 1311. The pyramid projects a dazzling white figure against the desert, having 53000 outer casing blocks of quality limestones where its density is about 2600 kg m^{-3}.

The Great Pyramid is 147 m high and its square base has sides of 230 m. It is made up of around 2.7 million limestone blocks. These limestone blocks vary in size with an average mass of each limestone block estimated to be around 2.5 tonnes where 1 tonne is equivalent to 1000 kg.

According to the Greek historian Herodotus, it took 100 thousand men 20 years to build the Great Pyramid while the physicist Mendelssohn estimated that only about 13% of that workforce was involved in lifting the limestones. The work done in building such a structure is equivalent to raising all the material to its centre of mass which, in the case of a pyramid, is a quarter of its height.

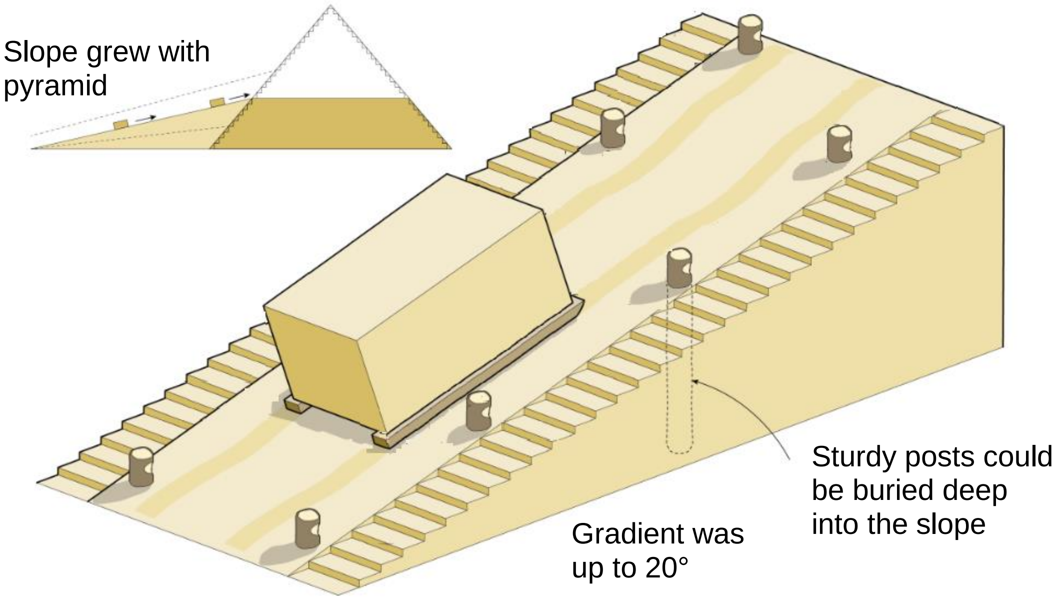

Fig. 8.1 (Source: Khalil, M. Methods of Pyramid Construction)

In 2018, an Anglo-French team discovered an ancient ramp at the site of the quarries at Hatnub, providing the evidence that ramps could be used to drag limestones from the quarry to build the pyramids. The linear ramp has an incline of 20° with steps either side, and holes that could allow sturdy vertical posts half a metre in diameter to be buried in them as shown in Fig. 8.1.

A typical man today obtains around 2500 kcal of energy per day from food where 1 kcal is equivalent to 4.18 kJ. After considering the energy required to stay alive, there is 870 kcal of energy left for doing physical work. Research on factory workers suggests that humans are about 20% efficient when performing manual tasks. These figures can be used to apply to the ancient Egyptians to estimate the workforce needed to build the Great Pyramid.

(a) The volume *V* of a pyramid is related to its height *h* and a square base with side length *b* by the following equation:

$$V = \frac{1}{3}b^2h$$

Hence, if the limestones could be lifted into position, determine the work done in building the Great Pyramid.

work done = ………………….. J [2]

(b) Evidence suggests that various ramp configurations were used to construct different pyramids, including the Great Pyramid.

Assuming a linear ramp with a 5.0° incline was employed, the friction played a significant role in dragging limestone blocks up the ramp. The friction *f* acting on the limestone block is proportional to its normal force *N* which is given by

$f = \mu N$ where μ is the coefficient of sliding friction between two surfaces.

When limestone blocks are dragged up a limestone ramp, the coefficient of friction for limestone against limestone is 0.75.

(i) Explain why dragging limestone blocks up a slope involves doing more work than lifting them.

……………………………………………………………………………………………..

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

(ii) On Fig 8.2, draw a labelled free-body diagram, showing all the forces acting on the limestone block as it is being dragged up a slope.

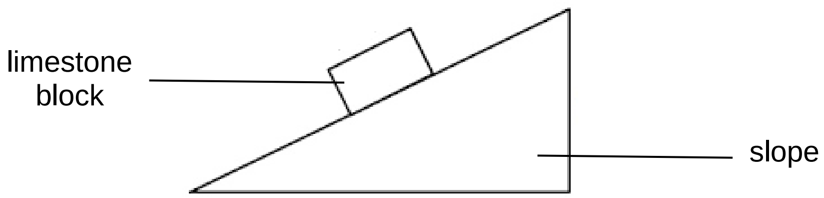

Fig. 8.2 [2]

(iii) Determine the friction acting on the limestone as it is dragged up at constant speed.

friction = ………………….. N [2]

(iv) Hence, show that the force needed to drag a limestone block is 2.0×10^4 N.

(v) With such a large dragging force needed, suggest how having sturdy vertical posts in buried deep into the slope could make it easier to drag the limestone blocks up.

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

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

(c) **(i)** Determine the work done in dragging all the limestone blocks up a ramp of 5.0° through a quarter of the height of the Great Pyramid.

work done = ………………….. J [2]

(ii) Hence, estimate the number of people needed to drag the limestone blocks up and complete the Great Pyramid in 20 years.

number of people = ………………….. [2]

[Total: 13]

End of Paper

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