

Surname						Other Names					
Centre Number						Candidate Number					
Candidate Signature											

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General Certificate of Education
 January 2005
 Advanced Subsidiary Examination



PHYSICS (SPECIFICATION A)
Unit 3 Practical

PHA3/P

Thursday 20th January 2005 Morning Session

In addition to this paper you will require:

- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour 45 minutes

Instructions

- Use a blue or black ball-point pen. Draw diagrams in pencil. Use pencil only for drawing.
- Fill in the boxes at the top of this page.
- Answer **both** questions in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.

Information

- The maximum mark for this paper is 30.
- Mark allocations are shown in brackets.
- The paper carries 15% of the total marks for Physics Advanced Subsidiary and carries 7½% of the total marks for Physics Advanced.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- You are advised to spend no more than 30 minutes on Question 1.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
Total (Column 1)	→		
Total (Column 2)	→		
TOTAL			
Examiner's Initials			

Data Sheet

- A perforated Data Sheet is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

Fundamental constants and values				Mechanics and Applied Physics		Fields, Waves, Quantum Phenomena	
Quantity	Symbol	Value	Units				
speed of light in vacuo	c	3.00×10^8	m s^{-1}	$v = u + at$		$g = \frac{F}{m}$	
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}	$s = \left(\frac{u+v}{2}\right)t$		$g = -\frac{GM}{r^2}$	
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}	$s = ut + \frac{at^2}{2}$		$g = -\frac{\Delta V}{\Delta x}$	
charge of electron	e	1.60×10^{-19}	C	$v^2 = u^2 + 2as$		$V = -\frac{GM}{r}$	
the Planck constant	h	6.63×10^{-34}	J s	$F = \frac{\Delta(mv)}{\Delta t}$		$a = -(2\pi f)^2 x$	
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$	$P = Fv$		$v = \pm 2\pi f \sqrt{A^2 - x^2}$	
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}	$\text{efficiency} = \frac{\text{power output}}{\text{power input}}$		$x = A \cos 2\pi ft$	
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$	$\omega = \frac{v}{r} = 2\pi f$		$T = 2\pi \sqrt{\frac{m}{k}}$	
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}	$a = \frac{v^2}{r} = r\omega^2$		$T = 2\pi \sqrt{\frac{l}{g}}$	
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$		$\lambda = \frac{\omega s}{D}$	
the Wien constant	a	2.90×10^{-3}	m K	$E_k = \frac{1}{2} I\omega^2$		$d \sin \theta = n\lambda$	
electron rest mass	m_e	9.11×10^{-31}	kg	$\omega_2 = \omega_1 + at$		$\theta = \frac{\lambda}{D}$	
(equivalent to $5.5 \times 10^{-4}u$)				$\theta = \omega_1 t + \frac{1}{2} at^2$		$n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$	
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$		$n_2 = \frac{n_2}{n_1}$	
proton rest mass	m_p	1.67×10^{-27}	kg	$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$		$\sin \theta_c = \frac{1}{n}$	
(equivalent to 1.00728u)				$T = I\alpha$		$E = hf$	
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}	<i>angular momentum</i> = $I\omega$		$hf = \phi + E_k$	
neutron rest mass	m_n	1.67×10^{-27}	kg	$W = T\theta$		$hf = E_1 - E_2$	
(equivalent to 1.00867u)				$P = T\omega$		$\lambda = \frac{h}{p} = \frac{h}{mv}$	
gravitational field strength	g	9.81	N kg^{-1}	<i>angular impulse</i> = change of <i>angular momentum</i> = Tt		$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$	
acceleration due to gravity	g	9.81	m s^{-2}	$\Delta Q = \Delta U + \Delta W$		Electricity	
atomic mass unit	u	1.661×10^{-27}	kg	$\Delta W = p\Delta V$		$\epsilon = \frac{E}{Q}$	
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$		$\epsilon = I(R + r)$	
Fundamental particles				<i>work done per cycle</i> = area of loop		$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$	
<i>Class</i>	<i>Name</i>	<i>Symbol</i>	<i>Rest energy</i>	<i>input power</i> = calorific value \times fuel flow rate		$R_T = R_1 + R_2 + R_3 + \dots$	
			/MeV	<i>indicated power</i> as (area of $p-v$ loop) \times (no. of cycles/s) \times (no. of cylinders)		$P = I^2 R$	
photon	photon	γ	0	<i>friction power</i> = indicated power - brake power		$E = \frac{F}{Q} = \frac{V}{d}$	
lepton	neutrino	ν_e	0	<i>efficiency</i> = $\frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$		$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$	
		ν_μ	0	<i>maximum possible efficiency</i> = $\frac{T_H - T_C}{T_H}$		$E = \frac{1}{2} QV$	
	electron	e^\pm	0.510999			$F = BIl$	
mesons	muon	μ^\pm	105.659			$F = BQv$	
	pion	π^\pm	139.576			$Q = Q_0 e^{-t/RC}$	
		π^0	134.972				
	kaon	K^\pm	493.821				
		K^0	497.762				
baryons	proton	p	938.257				
	neutron	n	939.551				
Properties of quarks							
<i>Type</i>	<i>Charge</i>	<i>Baryon number</i>	<i>Strangeness</i>				
u	$+\frac{2}{3}$	$+\frac{1}{3}$	0				
d	$-\frac{1}{3}$	$+\frac{1}{3}$	0				
s	$-\frac{1}{3}$	$+\frac{1}{3}$	-1				
Geometrical equations							
<i>arc length</i> = $r\theta$							
<i>circumference of circle</i> = $2\pi r$							
<i>area of circle</i> = πr^2							
<i>area of cylinder</i> = $2\pi rh$							
<i>volume of cylinder</i> = $\pi r^2 h$							
<i>area of sphere</i> = $4\pi r^2$							
<i>volume of sphere</i> = $\frac{4}{3}\pi r^3$							

$$\text{magnitude of induced e.m.f.} = N \frac{\Delta\Phi}{\Delta t}$$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

Mechanical and Thermal Properties

$$\text{the Young modulus} = \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F}{A} \frac{l}{e}$$

$$\text{energy stored} = \frac{1}{2} Fe$$

$$\Delta Q = mc \Delta\theta$$

$$\Delta Q = ml$$

$$pV = \frac{1}{3} Nmc^2$$

$$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

Nuclear Physics and Turning Points in Physics

$$\text{force} = \frac{eV_p}{d}$$

$$\text{force} = Bev$$

$$\text{radius of curvature} = \frac{mv}{Be}$$

$$\frac{eV}{d} = mg$$

$$\text{work done} = eV$$

$$F = 6\pi\eta rv$$

$$I = k \frac{I_0}{x^2}$$

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

$$\lambda = \frac{h}{\sqrt{2}meV}$$

$$N = N_0 e^{-\lambda t}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

$$R = r_0 A^{\frac{1}{3}}$$

$$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

$$l = l_0 \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$$

$$t = \frac{t_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

Astrophysics and Medical Physics

Body	Mass/kg	Mean radius/m
Sun	2.00×10^{30}	7.00×10^8
Earth	6.00×10^{24}	6.40×10^6

$$1 \text{ astronomical unit} = 1.50 \times 10^{11} \text{ m}$$

$$1 \text{ parsec} = 206265 \text{ AU} = 3.08 \times 10^{16} \text{ m} = 3.26 \text{ ly}$$

$$1 \text{ light year} = 9.45 \times 10^{15} \text{ m}$$

$$\text{Hubble constant } (H) = 65 \text{ kms}^{-1} \text{ Mpc}^{-1}$$

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

$$M = \frac{f_o}{f_e}$$

$$m - M = 5 \log \frac{d}{10}$$

$$\lambda_{\text{max}} T = \text{constant} = 0.0029 \text{ m K}$$

$$v = Hd$$

$$P = \sigma AT^4$$

$$\frac{\Delta f}{f} = \frac{v}{c}$$

$$\frac{\Delta \lambda}{\lambda} = -\frac{v}{c}$$

$$R_s \approx \frac{2GM}{c^2}$$

Medical Physics

$$\text{power} = \frac{1}{f}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \text{ and } m = \frac{v}{u}$$

$$\text{intensity level} = 10 \log \frac{I}{I_0}$$

$$I = I_0 e^{-\mu x}$$

$$\mu_m = \frac{\mu}{\rho}$$

Electronics

Resistors

Preferred values for resistors (E24)

Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms

and multiples that are ten times greater

$$Z = \frac{V_{\text{rms}}}{I_{\text{rms}}}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

$$C_T = C_1 + C_2 + C_3 + \dots$$

$$X_C = \frac{1}{2\pi f C}$$

Alternating Currents

$$f = \frac{1}{T}$$

Operational amplifier

$$G = \frac{V_{\text{out}}}{V_{\text{in}}} \quad \text{voltage gain}$$

$$G = -\frac{R_f}{R_1} \quad \text{inverting}$$

$$G = 1 + \frac{R_f}{R_1} \quad \text{non-inverting}$$

$$V_{\text{out}} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right) \quad \text{summing}$$

TURN OVER FOR THE FIRST QUESTION

Answer **both** questions.

You are advised to spend no more than 30 minutes on Question 1.

- 1 A student wishes to investigate the characteristics of a battery-powered outboard motor to be fitted to a model boat.

The student mounts the motor on a horizontal pivot passing through the centre of gravity of the motor. A spring is attached to the top of the motor, the free end being held in a clamp. A fixed horizontal scale is positioned above the clamp.

With the motor turned off, the position of the clamp holding the spring is adjusted until a pointer, attached to the motor, is vertical, as shown in **Figure 1**.

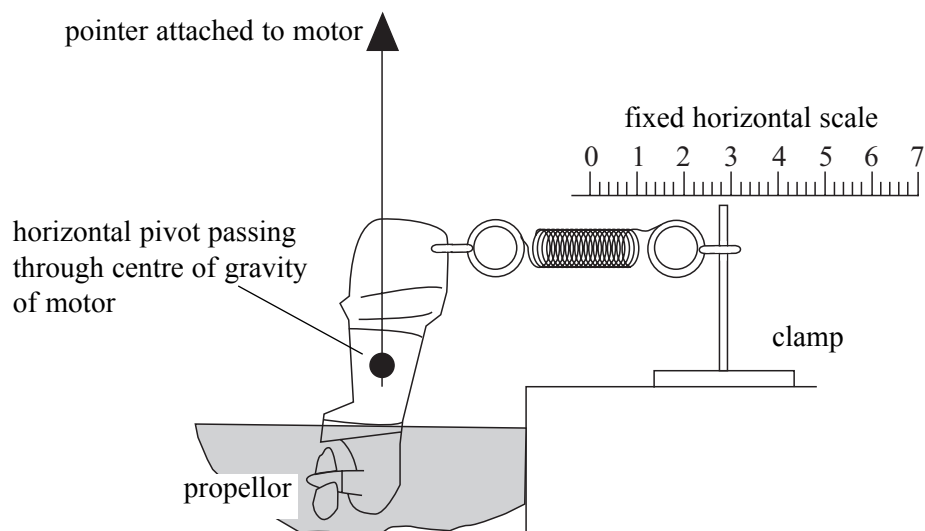


Figure 1

When the motor is turned on, the thrust provided by the propeller produces a turning moment on the motor about the pivot. The rotation produced stretches the spring, as shown in **Figure 2**.

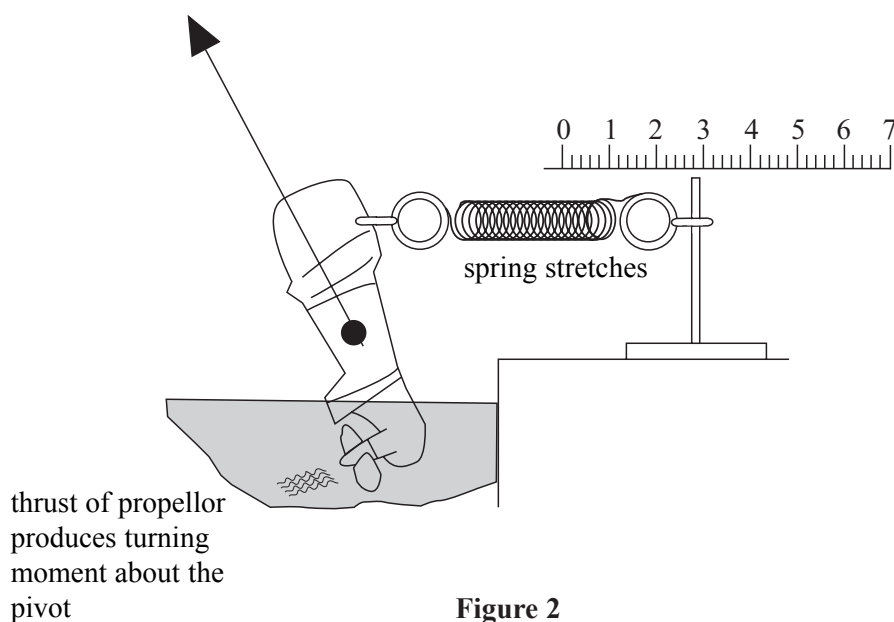


Figure 2

The clamp is then moved until the pointer is vertical again, as shown in **Figure 3**.

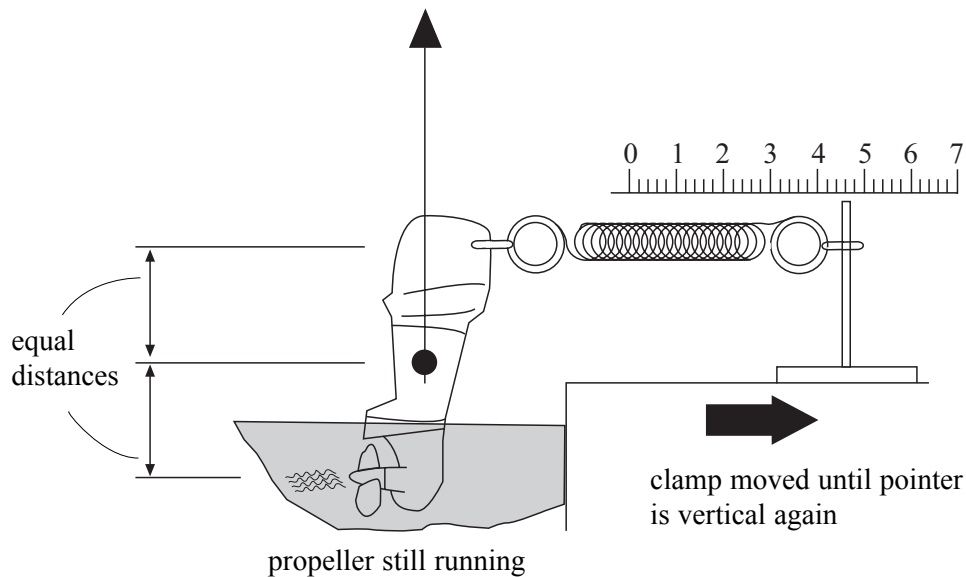


Figure 3

Note that the perpendicular distance from the spring to the pivot is the same as that from the axis of the propeller to the pivot.

Design an experiment that will enable the student to investigate how the thrust produced by the propeller depends on the electrical power supplied to the motor. You should assume that the normal laboratory apparatus used in schools and colleges is available to you. You should draw a suitable circuit diagram to illustrate your answer.

You should also include the following in your answer:

- The quantities you intend to measure and how you will measure them.
- How you propose to use your measurements to obtain reliable results for the thrust produced by the propeller.
- The factors you will need to control and how you will do this.
- How you could overcome any difficulties in obtaining reliable results.

Write your answers to Question 1 on **pages 8 and 9** of this booklet.

(8 marks)

Handwriting practice area with 25 horizontal dotted lines.

- 2 In this experiment you are required to investigate the equilibrium conditions for a pivoted metre ruler. **No description of the experiment is required.**

Record the mass, M , of the metre ruler that has been provided for your use.

$$M = \dots\dots\dots$$

The metre ruler is suspended above the bench from a horizontal pivot passing through a hole near the upper end of the ruler. The pivot is held in a clamp fixed to a retort stand, placed on a stool.

Do not adjust the height of the clamp or the position of the stand during the experiment.

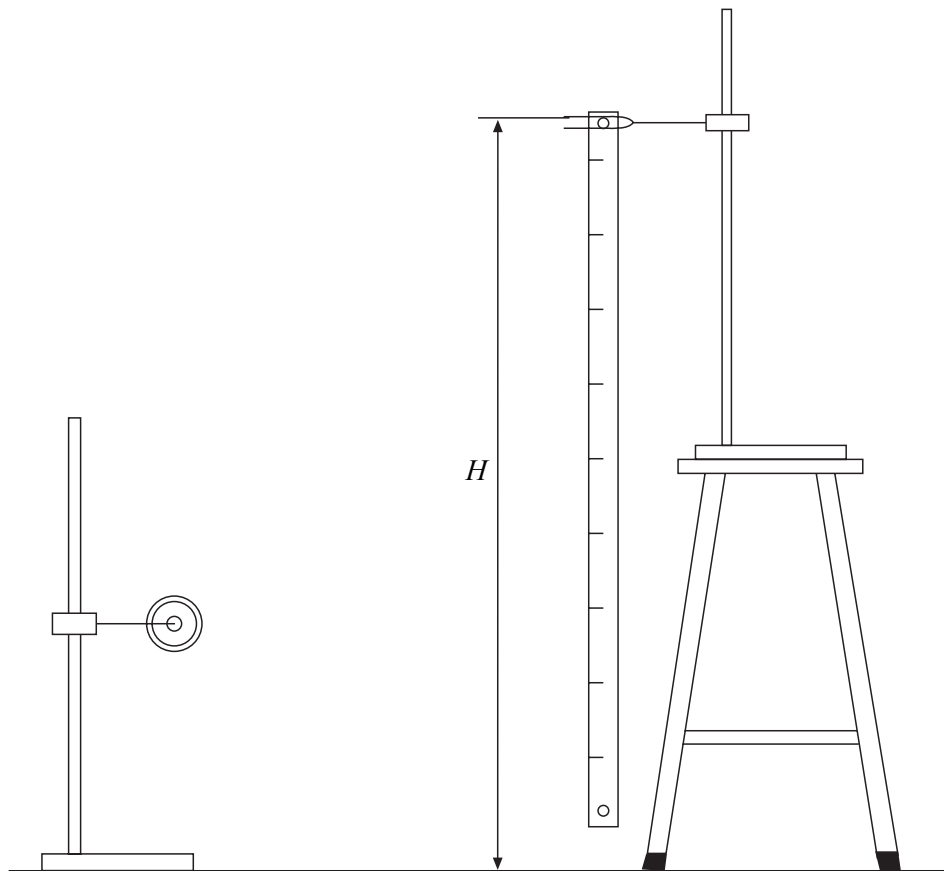


Figure 4

- (a) Using the additional metre ruler, make suitable measurements to determine H , the vertical distance between the top surface of the pivot and the bench, as shown in **Figure 4**.

$$H = \dots\dots\dots$$

(1 mark)

- (b) Attach one end of the string to the suspended ruler through the hole at the lower end. Pass the string over the pulley and fasten the hook to the free end of the string. Hang a mass, m , ($= 100\text{ g}$) from the hook. Adjust the height of the pulley, and, if necessary, the position of its stand until the string between the ruler and the pulley is horizontal, with the ruler, string and pulley in the same vertical plane. Measure and record the vertical height, h , defined in **Figure 5**, between the top of the string and the bench.

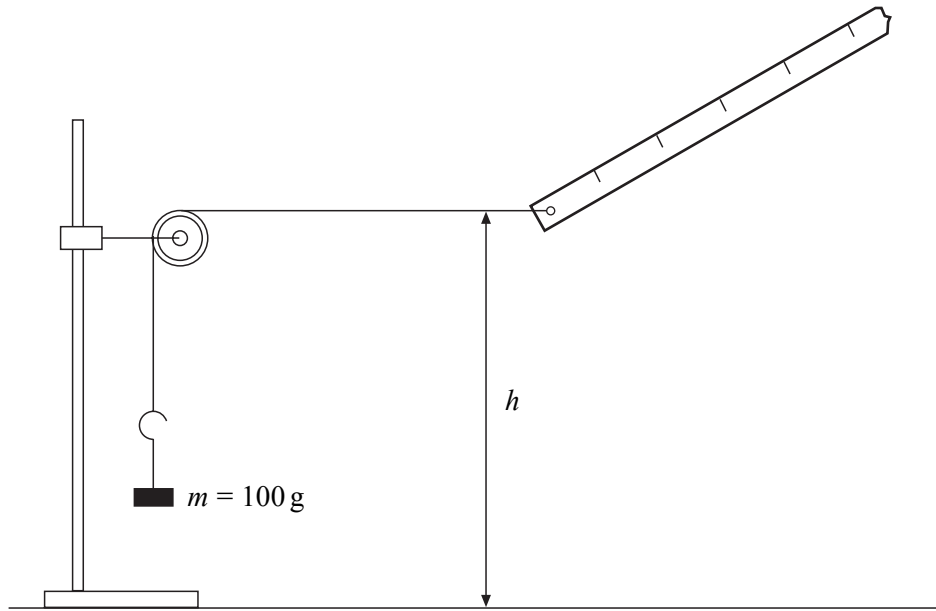


Figure 5

Repeat the procedure for additional **smaller** values of m .
Record below your measurements and observations.

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(4 marks)

- (c) Plot a graph with $\frac{1}{(H-h)^2}$ on the vertical axis and m^2 on the horizontal axis.

Tabulate below the data you will plot on your graph.

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(8 marks)

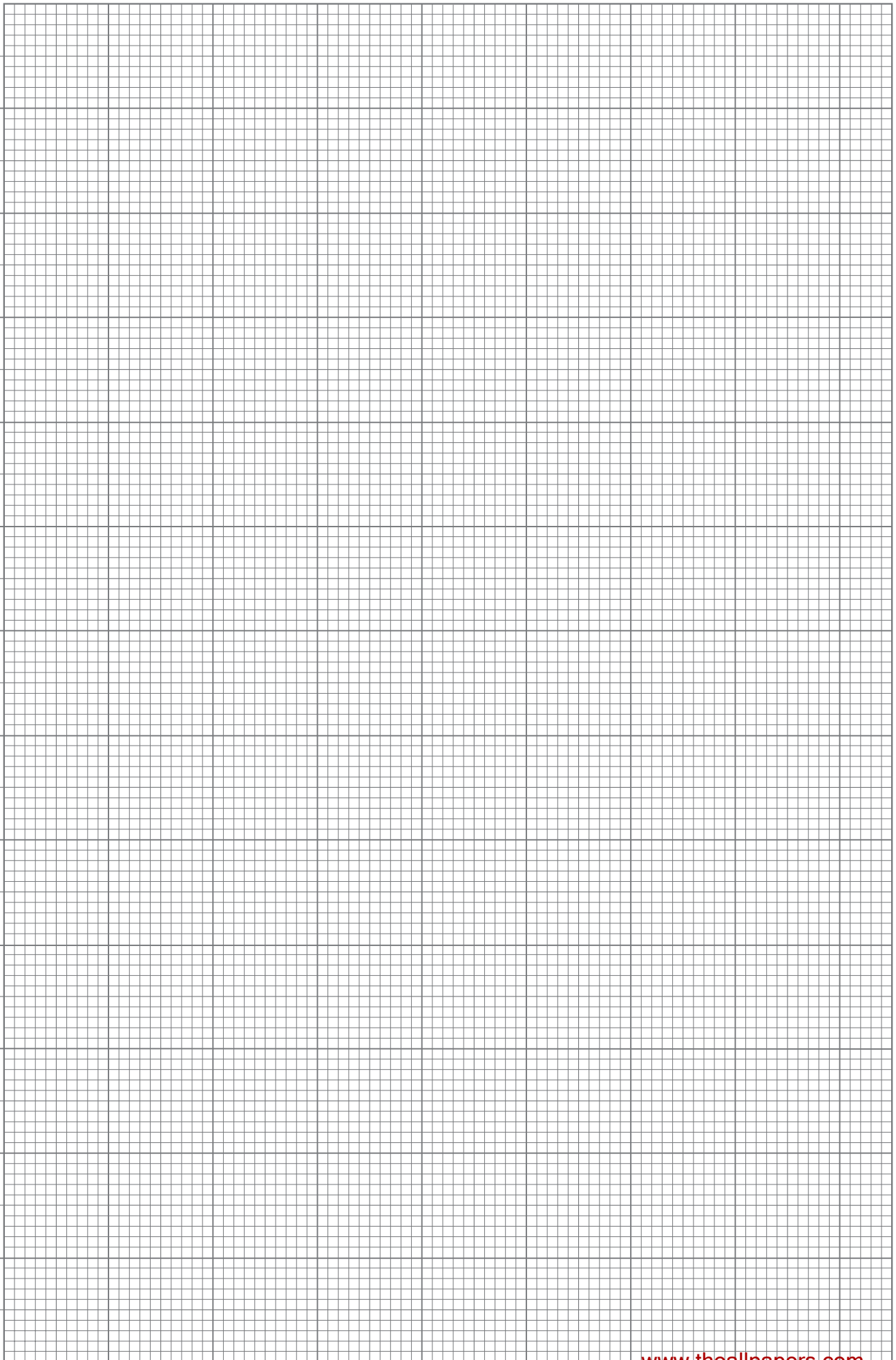
- (d) (i) Measure and record the gradient, G , of your graph.

$G = \dots\dots\dots$

- (ii) Evaluate $M\sqrt{G}$.

$M\sqrt{G} = \dots\dots\dots$

(3 marks)



- (e) (i) Describe the procedure you used to ensure that the string between the ruler and the pulley was horizontal.

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- (ii) Suppose that a mass equal to $\frac{M}{2}$ is connected to the end of the string passing over the pulley. The apparatus is adjusted until the string between the pulley and the ruler is horizontal. Showing your working clearly, use your graph to determine $(H - h')$, where h' is the vertical height between the top of the string and the bench.

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- (iii) Draw a diagram showing the approximate position of the ruler for the situation described in part (e)(ii). Label and show on your diagram the directions of the forces acting on the ruler.

(6 marks)

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END OF QUESTIONS