

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
 January 2004
 Advanced Subsidiary Examination



PHYSICS (SPECIFICATION A)
Unit 3 Practical

PHA3/P

Tuesday 20th January 2004 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	Nnumber	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.

Data Sheet

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	α	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	$\omega_2 = \omega_1 + at$	$\theta \approx \frac{\lambda}{D}$		
(equivalent to $5.5 \times 10^{-4}u$)				$\theta = \omega_1 t + \frac{1}{2} at^2$	${}^1n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$		
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2a\theta$	${}^1n_2 = \frac{n_2}{n_1}$		
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}	$\text{angular momentum} = I\omega$	$hf = \phi + E_k$		
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}	$\text{angular impulse} = \text{change of angular momentum} = Tt$	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$		
acceleration due to gravity	g	9.81	m s^{-2}	$\Delta Q = \Delta U + \Delta W$			
atomic mass unit	u	1.661×10^{-27}	kg	$\Delta W = p\Delta V$			
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$			
Fundamental particles				Electricity			
Class	Name	Symbol	Rest energy /MeV	$\text{work done per cycle} = \text{area of loop}$	$\epsilon = \frac{E}{Q}$		
photon	photon	γ	0	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$	$\epsilon = I(R + r)$		
lepton	neutrino	ν_e	0	$\text{indicated power as (area of } p-v \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$		
		ν_μ	0	$\text{friction power} = \text{indicated power} - \text{brake power}$	$R_T = R_1 + R_2 + R_3 + \dots$		
	electron	e^\pm	0.510999	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$	$P = I^2 R$		
	muon	μ^\pm	105.659	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$	$E = \frac{F}{Q} = \frac{V}{d}$		
mesons	pion	π^\pm	139.576		$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$		
		π^0	134.972		$E = \frac{1}{2} QV$		
	kaon	K^\pm	493.821		$F = BI$		
		K^0	497.762		$F = BQv$		
baryons	proton	p	938.257		$Q = Q_0 e^{-t/RC}$		
	neutron	n	939.551		$\Phi = BA$		
Properties of quarks							
Type	Charge	Baryon number	Strangeness				
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							
arc length = $r\theta$							
circumference of circle = $2\pi r$							
area of circle = πr^2							
area of cylinder = $2\pi rh$							
volume of cylinder = $\pi r^2 h$							
area of sphere = $4\pi r^2$							
volume of sphere = $\frac{4}{3}\pi r^3$							

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

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

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

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

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$X_C = \frac{1}{2\pi fC}$$

Alternating Currents

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

Operational amplifier

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

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

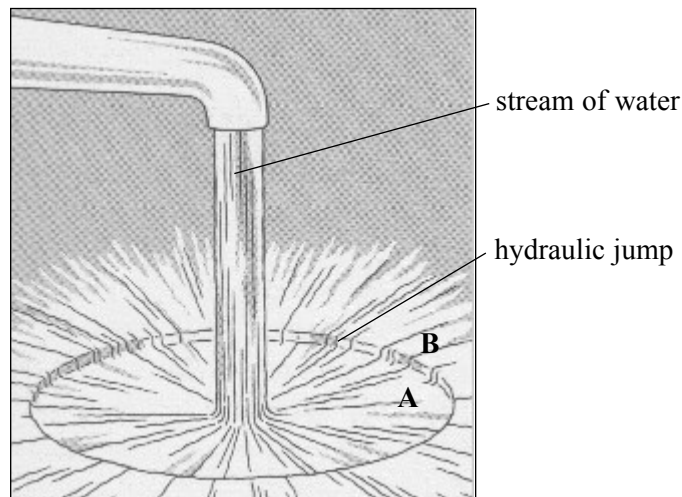
$$G = 1 + \frac{R_f}{R_1} \quad \text{non-inverting}$$

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

Answer **both** questions.

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

- 1 When a stream of water falls from a tap into a sink, the water spreads out in a relatively thin layer until it reaches a particular distance from the stream where the water suddenly increases in depth. The phenomenon where this depth change occurs is called a *hydraulic jump* and separates two distinct regions **A** and **B**, as shown below.



A student observes a stream of water falling vertically on to a smooth plate placed in a sink and notices that the rate at which water falls on to the plate affects the diameter of region **A**.

Design an experiment to determine whether any **quantitative** link exists between the diameter of region **A** and the volume of water falling on the plate each second.

You should assume that the normal laboratory apparatus used in schools and colleges is available to you.

You may wish to use a diagram to illustrate your solution to this problem.

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 determine reliable results for the diameter of the hydraulic jump and for the volume flow rate of the stream of water.
- 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 6 and 7** of this booklet.

(8 marks)

Turn over ►

Handwriting practice area with 25 horizontal dotted lines.

- 2 In this experiment you are required to investigate the equilibrium of a metre ruler, suspended from a horizontally clamped beam, under different loading conditions.

Do not adjust the position of the clamps supporting the beam.

No description of the experiment is required.

You are provided with the arrangement shown in **Figure 1**.

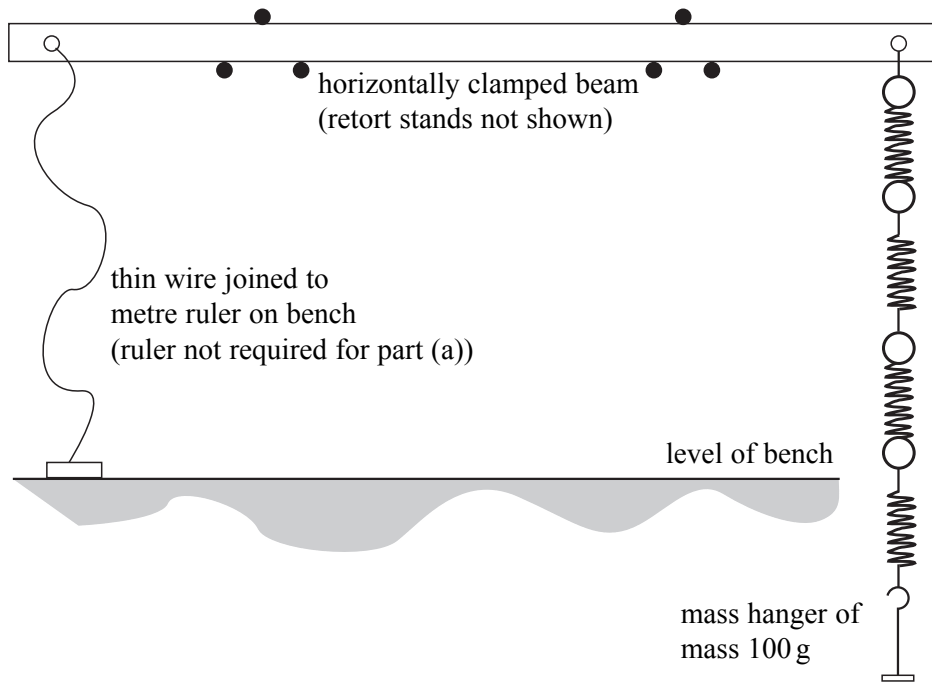


Figure 1

You are also provided with two masses, each of mass 100 g. These can be placed on the mass hanger, also of mass 100 g, that is attached to the lower end of the four connected springs suspended from the right-hand end of the beam.

- (a) Make suitable measurements to determine the **change in extension**, Δy , of the four connected springs, when the mass attached to the lower end changes by 100 g.

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$\Delta y =$

(2 marks)

Turn over ►

- (b) Remove the masses and mass hanger and using the hook at the 95 cm mark, connect the metre ruler to the lower end of the springs. Allow the ruler to hang freely over the edge of the bench suspended by the wire at the left-hand end and by the springs at the right-hand end.

Slacken the terminal T and adjust the length of the wire joining the beam to the ruler until the left-hand end of the ruler is approximately 5 cm below the level of the right-hand end, as shown in **Figure 2**. Tighten terminal T again once this condition is satisfied.

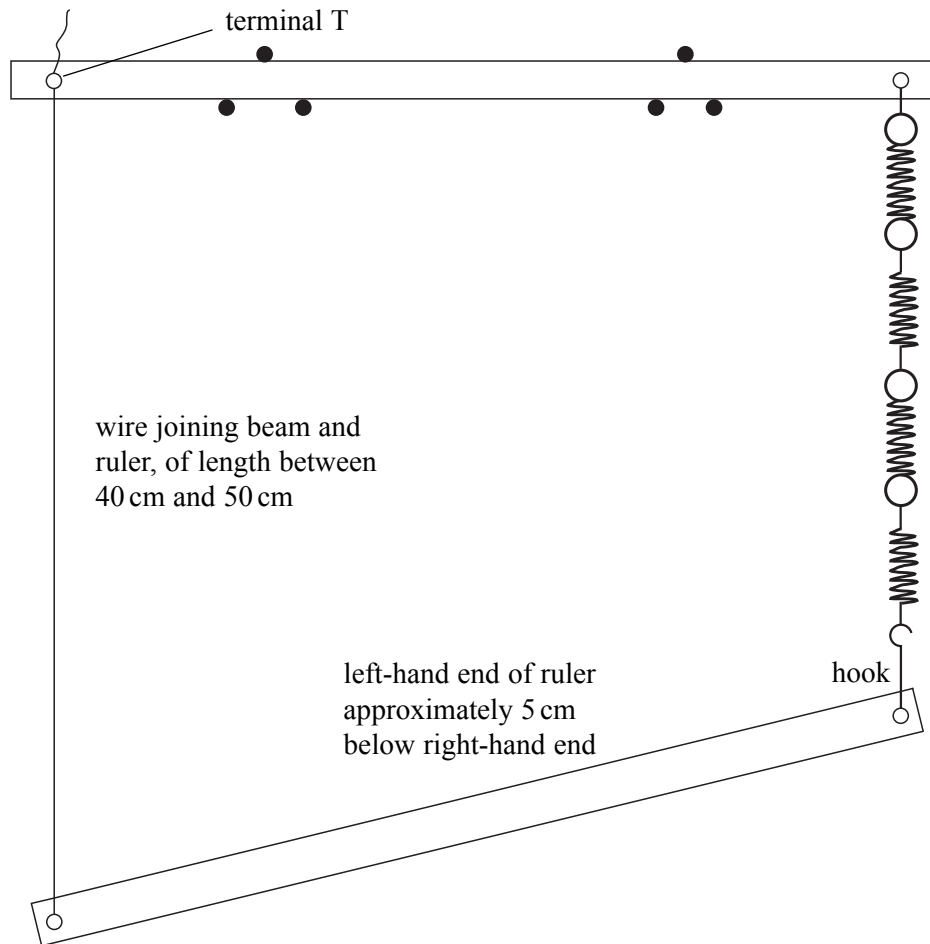


Figure 2

Suspend a 300 g mass from the ruler close to the point of attachment between the wire and the ruler.

Adjust the position of the mass until the ruler is suspended horizontally, as shown in **Figure 3**.

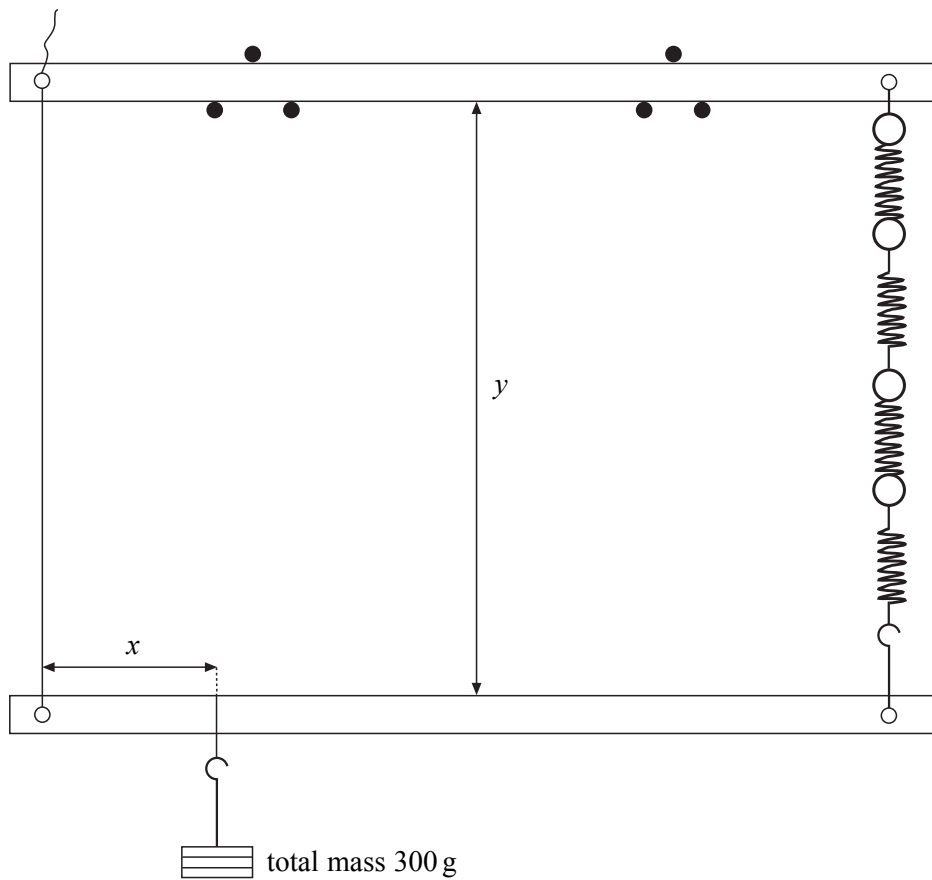


Figure 3

Measure and record x , the horizontal distance between the wire and the point of attachment of the 300 g mass to the ruler, and y , the vertical distance between the lower edge of the beam and the upper edge of the suspended metre ruler.

Increase the length of the wire between the beam and the ruler so that the left-hand end is again lower than the right-hand end.

Adjust the 300 g mass as before to make the ruler horizontal and repeat the procedure to find **four** additional values of x and y .

Record the measurements you make **on page 12** of this booklet.

Turn over ►

Measurements and observations.

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(5 marks)

- (c) Using the grid **on page 13** of this booklet, plot a graph with y on the vertical axis and x on the horizontal axis.

(6 marks)

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

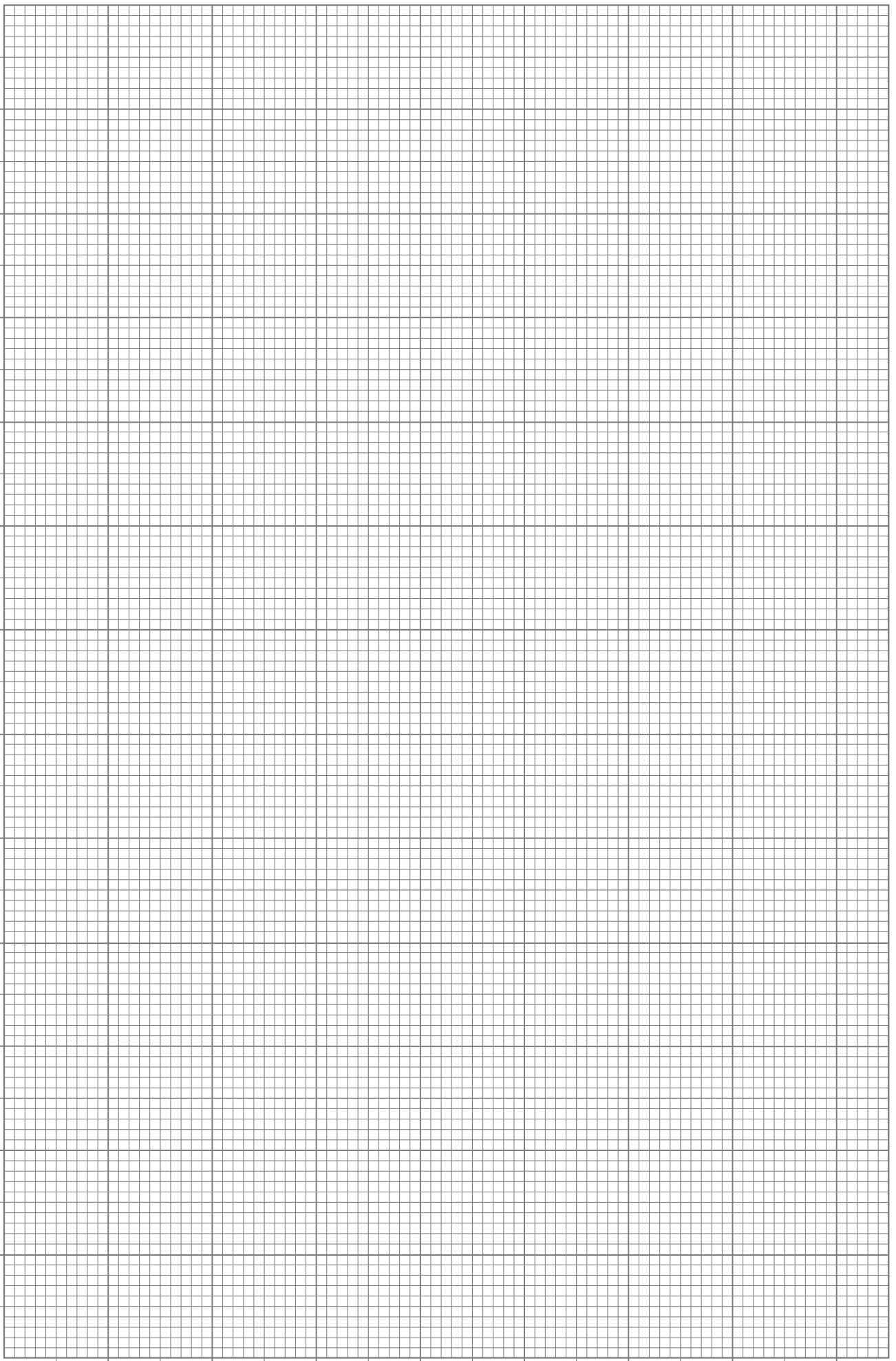
$$G = \dots\dots\dots$$

- (ii) Evaluate $\frac{G}{\Delta y}$.

$$\frac{G}{\Delta y} = \dots\dots\dots$$

(3 marks)

QUESTION 2 CONTINUES ON PAGE 14



Turn over ►

- (e) (i) Explain how you ensured that the suspended metre ruler was horizontal before making measurements of y .

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- (ii) State and explain how you would use your graph to deduce the value of y if the 300 g mass were to be completely removed from the ruler.

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- (iii) State and explain how the gradient, G , would be affected, if at all, if in part (b) of the experiment the mass suspended from the ruler had been 200 g rather than 300 g.

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(6 marks)

END OF QUESTIONS