Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
January 2005
Advanced Level Examination

PHYSICS (SPECIFICATION A) **PHAP**
Units 5-9 Practical

Wednesday 2 February 2005 Morning Session

In addition to this paper you will require:
- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour 45 minutes

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

Instructions
- Use blue or black ink or ball-point pen.
- 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.
- 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.

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

Quantity	Symbol	Value	Units
speed of light in vacuo	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}	$F\ m^{-1}$
charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$N\ m^{2}\ kg^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$J\ K^{-1}\ mol^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	$J\ K^{-1}$
the Stefan constant	σ	5.67×10^{-8}	$W\ m^{-2}\ K^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4}u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	$C\ kg^{-1}$
proton rest mass (equivalent to 1.00728u)	m_p	1.67×10^{-27}	kg
proton charge/mass ratio	e/m_p	9.58×10^{7}	$C\ kg^{-1}$
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	$N\ kg^{-1}$
acceleration due to gravity	g	9.81	$m\ s^{-2}$
atomic mass unit (1u is equivalent to 931.3 MeV)	u	1.661×10^{-27}	kg

Fundamental particles

Class	Name	Symbol	Rest energy /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^{\pm}$	0.510999
	muon	$\mu^{\pm}$	105.659
mesons	pion	$\pi^{\pm}$	139.576
		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

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 = $\frac{4}{3}\pi r^3$

Mechanics and Applied Physics

$v = u + at$

$s = \left(\frac{u + v}{2}\right) t$

$s = ut + \frac{at^2}{2}$

$v^2 = u^2 + 2as$

$F = \frac{\Delta(mv)}{\Delta t}$

$P = Fv$

$efficiency = \frac{power\ output}{power\ input}$

$\omega = \frac{v}{r} = 2\pi f$

$a = \frac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

angular momentum = $I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum = Tt

$\Delta Q = \Delta U + \Delta W$

$\Delta W = p\Delta V$

pV^{γ} = constant

work done per cycle = area of loop

input power = calorific value × fuel flow rate

indicated power as (area of p – V loop) × (no. of cycles/s) × (no. of cylinders)

friction power = indicated power – brake power

$efficiency = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

maximum possible efficiency = $\frac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$g = -\frac{\Delta V}{\Delta x}$

$V = -\frac{GM}{r}$

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f\sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \frac{\lambda}{D}$

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{1}{n}$

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

$\lambda = \frac{h}{p} = \frac{h}{mv}$

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2 R$

$E = \frac{F}{Q} = \frac{V}{d}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

$E = \frac{1}{2} QV$

$F = BIl$

$F = BQv$

$Q = Q_0 e^{-t/RC}$

$\Phi = BA$

Turn over ▶

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

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

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

Mechanical and Thermal Properties

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

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

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

$\Delta Q = ml$

$pV = \frac{1}{3} N m\overline{c^2}$

$\frac{1}{2} m\overline{c^2} = \frac{3}{2} kT = \frac{3RT}{2N_A}$

Nuclear Physics and Turning Points in Physics

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

$force = Bev$

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

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

$work\ done = eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

$E = mc^2 = \frac{m_0c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

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

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

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 astronomical unit = 1.50×10^{11} m

1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly

1 light year = 9.45×10^{15} m

Hubble constant (H) = 65 km s^{-1} Mpc^{-1}

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

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

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

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

$v = Hd$

$P = \sigma AT^4$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

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

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

TURN OVER FOR THE FIRST QUESTION

Answer **both** questions.

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

1 Newton showed that the motion of comets is controlled by the gravitational attraction of the Sun. Many comets move in long elliptical orbits with the Sun at one focus: this makes their regular reappearance predictable. But if a comet arives from outer space very fast it swings around the Sun along a path called a *hyperbola*: in this case the comet will never return. **Figure 1** illustrates these different trajectories.

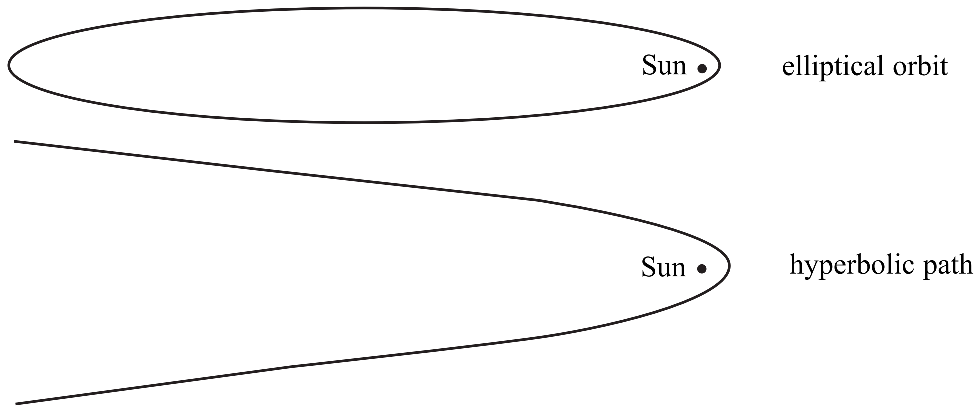

Figure 1

A student attempts to model the hyperbolic trajectory of such a fast-moving comet using steel ball bearings and a bar magnet. His idea is to roll the ball bearing along the bench close to one pole of a bar magnet so that the path of the ball bearing is deviated by the magnetic field around the magnet.

Following preliminary tests with ball bearings of various diameters he discovers that the angle of deviation, ϕ, defined in **Figure 2**, is minimal for the smallest and largest sized ball bearings but increases significantly for ball bearings between these limits.

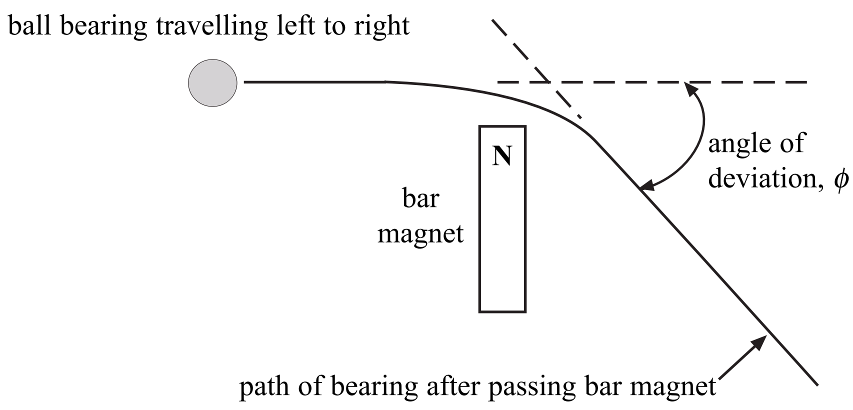

Figure 2

Design an experiment that will enable the student to determine the diameter of the ball bearing that produces the maximum angle of deviation.

You should assume that the normal laboratory apparatus used in schools and colleges is available, as is a supply of ball bearings of different diameters.
You may wish to draw a 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 determine the diameter of ball bearing that produces the maximum angular deviation.
- Any factor(s) 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)

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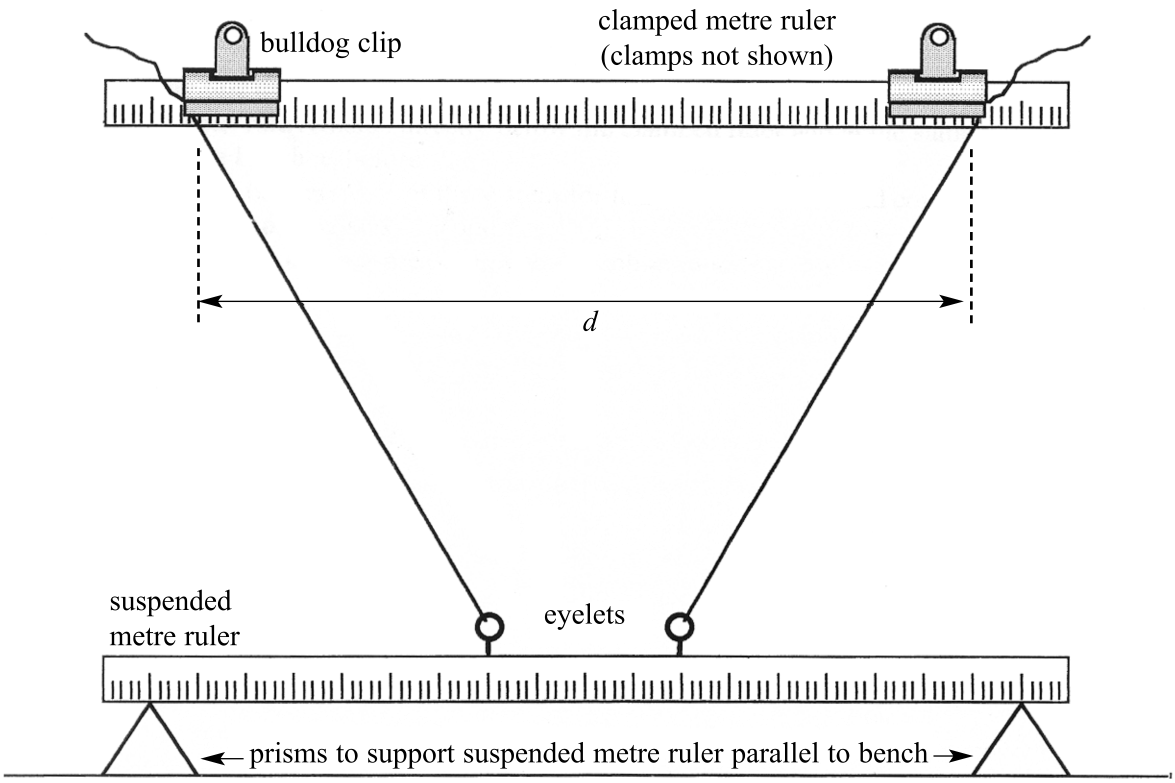
LEAVE MARGIN BLANK

2 In this experiment you will investigate the rotational oscillation of a metre ruler suspended from two threads, as the inclination of the threads is varied.
No description of the experiment is required.

The metre ruler is to be suspended above the bench by threads connected to an additional ruler that has been clamped parallel to the bench with its graduated face in a vertical plane.
Do not adjust the position of the clamped ruler during the experiment.

(a) Two lengths of thread have been tied to eyelets fixed into one edge of the metre ruler. Place the two prisms below the clamped ruler then position the metre ruler on the prisms **directly below** the clamped ruler with the graduated face of the ruler towards you and with the eyelets uppermost, as shown in the diagram.
Secure the free ends of the threads to the clamped ruler by trapping each thread between the graduated face of the suspended ruler and a bulldog clip.
The threads should meet the clamped ruler at the 10.0 cm and 90.0 cm graduations so that the distance, d, between their points of suspension is 80.0 cm.



Ensuring that the lengths of thread connecting the two rulers are tight, remove the prisms so that the lower ruler is suspended parallel to the bench.
Keeping this ruler in a horizontal plane, displace each end of the ruler by equal small amounts **in opposite directions**.
Release the system from rest so that it performs small amplitude rotational oscillations about its central vertical axis.
Make suitable measurements to determine the period, *T*, of these oscillations.

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(1 mark)

(b) Replace the prisms then move the points of attachment between the thread and the clamped ruler **by equal amounts** towards the centre of the clamped ruler so that *d* is reduced.
Ensure that the connecting threads are tight before removing the prisms so that the suspended ruler remains directly below the clamped ruler and at the same height above the bench as before.
Determine the period, *T*, of the system for this new value of *d*, and continue until you have a **total of five sets** of *d* and *T*.
Record below all your measurments and observations.

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(4 marks)

(c) Plot a graph with log d on the vertical axis and log T on the horizontal axis.
Tabulate below the data you will plot on your graph.

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(8 marks)

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

G = ...

(3 marks)

(e) Theory shows the variables to be connected by an expression of the form

$$d = kT^n,$$

where n is an integer and k is a constant.

(i) Deduce from your graph the value of the **integer**, n.

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(ii) Hence deduce the **unit** of the constant, k.

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(2 marks)

Turn over

LEAVE MARGIN BLANK

(f) Describe and explain **two** procedures you used to reduce the uncertainty in your values of T.

procedure 1

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procedure 2

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(4 marks)

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END OF QUESTIONS