Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2009
Advanced Subsidiary Examination

PHYSICS (SPECIFICATION A) **PHA3/P**
Unit 3 Practical

Thursday 15 January 2009 1.30 pm to 3.15 pm

For this paper you must have:
- a pencil and a ruler
- a calculator
- a data sheet insert.

Time allowed: 1 hour 45 minutes

Instructions
- Use black ink or a black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Show all working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The maximum mark for this paper is 30.
- The marks for questions are shown in brackets.
- A *Data Sheet* is provided as a loose insert to this question paper.
- You are expected to use a calculator where appropriate.
- You are advised to spend no more than 30 minutes on question 1.

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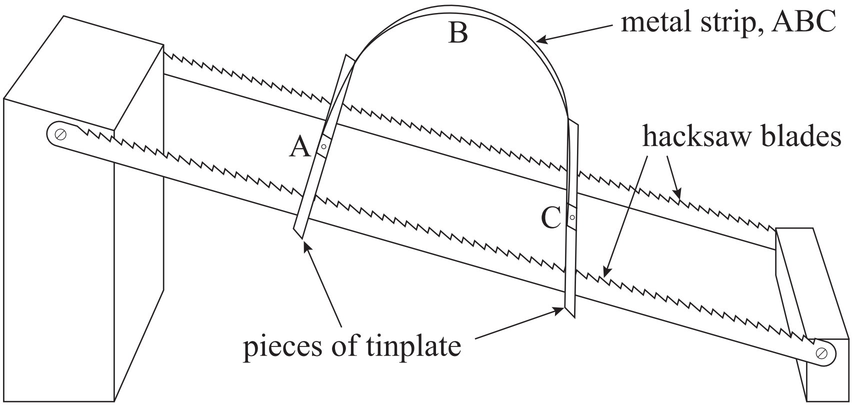
Question	Mark	Question	Mark
1			
2			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Answer **both** questions.

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

1 The device shown in **Figure 1** transforms heat energy from a radiant heat source (not shown) into gravitational potential energy.

Figure 1



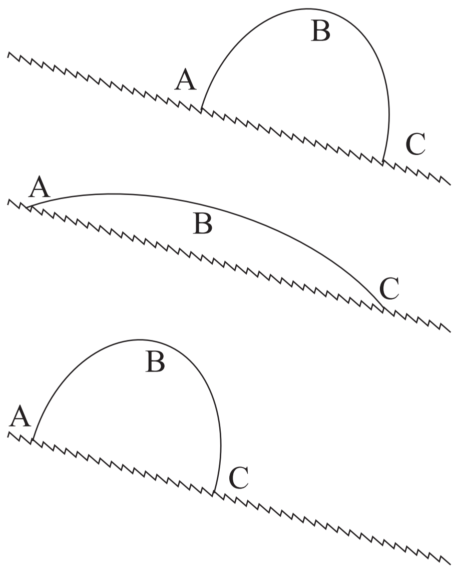
Two hacksaw blades are mounted parallel to each other to form an incline. A metal strip, ABC, is bent into an arc and narrow pieces of tinplate are fixed at ends A and C. The pieces of tinplate rest against the teeth of the hacksaw blades so that ends A and C stay in the same positions on the incline.

If a radiant heat source is directed at point B on the metal strip, the shape of ABC becomes less curved. End A advances up the incline but end C is held at the same position by the teeth of the hacksaw blades.

When the heat source is removed, the metal strip cools and slowly returns to its original shape. This time, end C advances up the incline and end A is held at the same position.

This sequence is explained in **Figure 2**.

Figure 2



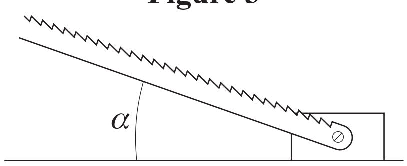
The metal strip is placed on the incline.
Ends A and C are held in position by the teeth of the hacksaw blades.

Heat is applied to the metal strip at point B causing it to become less curved.
End A advances up the incline while end C remains in the same position.

The heat source is removed and the metal strip slowly returns to its original shape.
End A remains in the same position while end C advances up the incline.
Finally the metal strip returns to its original shape coming to rest in a position further up the incline.

A student suggests that there might be a quantitative link between the ability of the device to transform heat energy into gravitational potential energy, and the angle, α, between the incline formed by the hacksaw blades and the horizontal bench, as shown in **Figure 3**.

Figure 3



The teacher points out that there is no reliable way of measuring how much heat energy is transferred to the device but tells the student that the suggestion can still be tested provided a heat source of **constant power output** is used.

Design an experiment that the student could perform to determine if the suggestion is correct. You should assume that a radiant heat source of constant power output is available, as is the normal laboratory apparatus used in schools and colleges.

Your answer should:

- identify the quantities the student should measure and explain how these measurements will be made
- explain how the student should use these measurements to determine whether the ability of the device to transform heat energy into gravitational potential energy depends on α
- list any factors that should be controlled during the student's experiment and explain how this will be done
- identify any difficulties in obtaining reliable results that the student might encounter and explain safe and relevant procedures that will enable these difficulties to be overcome.

Write your answer to Question 1 on **pages 4 and 5** of this booklet. *(8 marks)*

Turn over ▸

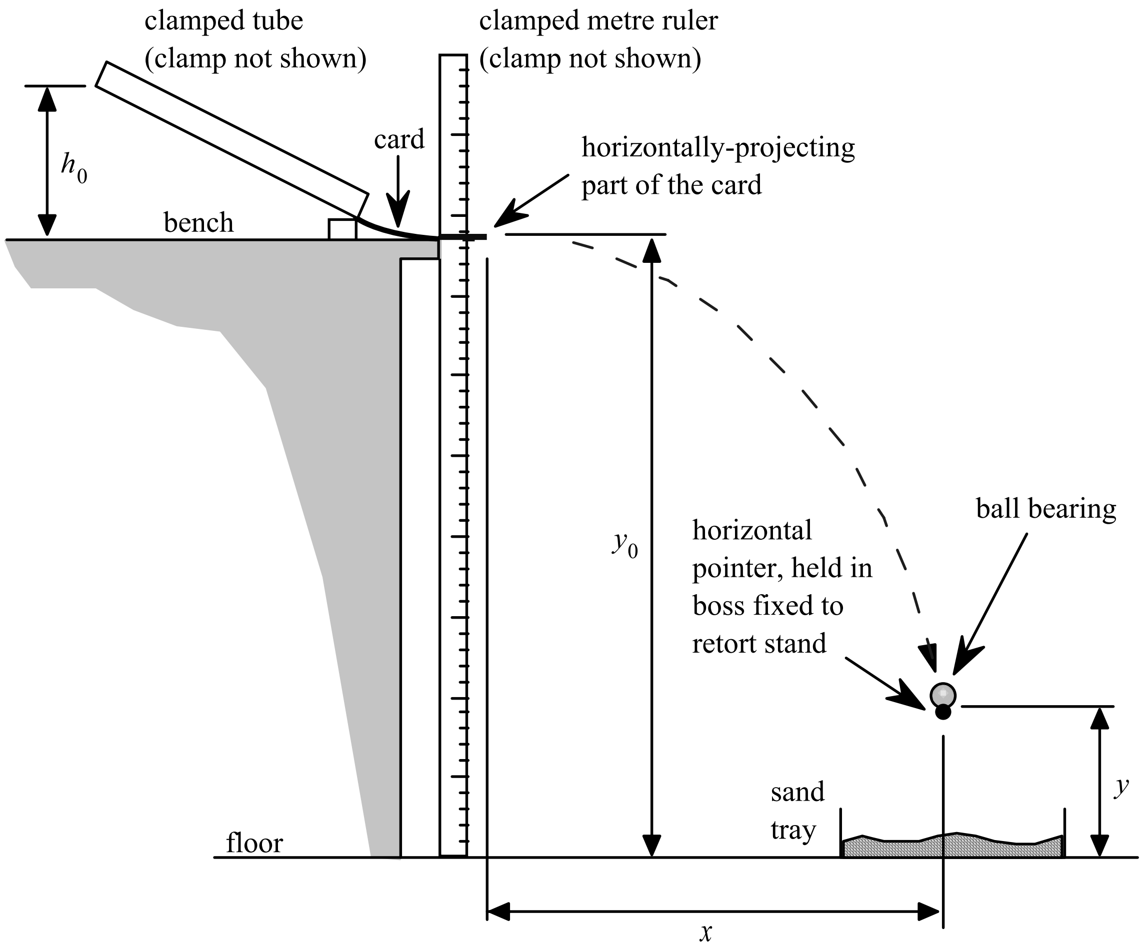
Turn over ▶

2 You are provided with a tube down which a ball bearing may be rolled.
Do not make any adjustment to the position of the tube.

No description of the experiment is required.

Using the retort stand to which a boss and clamp are fitted, clamp a metre ruler vertically, as shown in **Figure 4**, so that the end of the ruler is in contact with the floor and the (horizontally) projecting part of the card at the lower end of the tube passes in front of the graduated face of the ruler.
The metre ruler must not obstruct the exit of the ball bearing.

Figure 4



2 (a) (i) Measure the vertical height y_0 from the top surface of the (horizontally) projecting part of the card to the floor.

y_0 = ...

2 (a) (ii) Measure the vertical height h_0 as shown in **Figure 4**.

h_0 = ...

(1 mark)

2 (b) Release a ball bearing from rest at the top of the tube so that it rolls straight down the tube before landing in the sand tray.

You are also provided with a horizontal pointer held in a boss fixed to a retort stand. Arrange the stand so that the direction of the horizontal pointer is parallel to the edge of the bench then adjust the position of the stand until the ball bearing, when released as before, strikes the pointer, as shown in **Figure 4**.

Use the clamped metre ruler to measure the vertical distance, y, from the top surface of the pointer to the floor. (You may move the sand tray to make this measurement.) Use the additional metre ruler to measure the corresponding horizontal distance, x, from the pointer to the point of projection of the ball bearing, as shown in **Figure 4**.

Repeat this procedure to find additional values of x corresponding to **four** larger values of y. Record your data below.
Note that it may be necessary to place the retort stand on a laboratory stool in order to cover the whole trajectory of the ball bearing.

Measurements and observations

(4 marks)

Question 2 continues on the next page

Turn over ▶

2 (c) Plot a graph with $(y_0 - y)$ on the vertical axis and x^2 on the horizontal axis.
Tabulate the data you will plot on your graph.

(8 marks)

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

....

....

G = ...

2 (d) (ii) Evaluate Gh_0.

....

....

....

Gh_0 = ...

(3 marks)

Areas outside the box will not be scanned for marking

Turn over ▶

2 (e) (i) Describe the procedure you used to measure the distance *x*.
You may wish to use a diagram to illustrate your answer.

....

....

....

....

....

....

2 (e) (ii) State **two** measures in the procedure that **you were required** to carry out that made the ball bearing have the same kinetic energy each time it left the card.

first measure ....

....

second measure..

....

2 (e) (iii) A student performs the experiment but fails to ensure that the end of the clamped ruler is in contact with the floor when measuring y_0.
State and explain what affect, if any, this will have on the graph that the student produces.

....

....

....

....

(6 marks)

22

END OF QUESTIONS

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PHYSICS (SPECIFICATION A) **PHA3P**
Unit 3 Practical

Data Sheet

Fundamental constants and values

Quantity	*Symbol*	*Value*	*Units*
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\,s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\,m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\,m^{-1}}$
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}	$\mathrm{N\,m^2\,kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\,K^{-1}\,mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\,K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\,m^{-2}\,K^{-4}}$
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}	$\mathrm{C\,kg^{-1}}$
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}	$\mathrm{C\,kg^{-1}}$
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	$\mathrm{N\,kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\,s^{-2}}$
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 $= \pi r^2$

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

This insert page should **not** be sent to the examiner

Turn over ▸

magnitude of induced emf $= N \frac{\Delta\Phi}{\Delta t}$

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

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

Mechanical and Thermal Properties

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

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 $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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 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}

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

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

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

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

$v = Hd$

$P = \sigma A T^4$

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

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

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

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

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

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

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

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

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