Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

Leave blank

General Certificate of Education
January 2006
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION B) **PHB4**
Unit 4 Further Physics

Friday 20 January 2006 9.00 am to 10.30 am

For this paper you must have:
- a calculator
- a ruler

Time allowed: 1 hour 30 minutes

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions
- Answer the questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want marked.
- *Formulae Sheets* are provided on pages 3 and 4. Detach this perforated page at the start of the examination.

Information
- The maximum mark for this paper is 75.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- You are reminded of the need for good English and clear presentation in your answers. Questions 2(b) and 5(a), should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

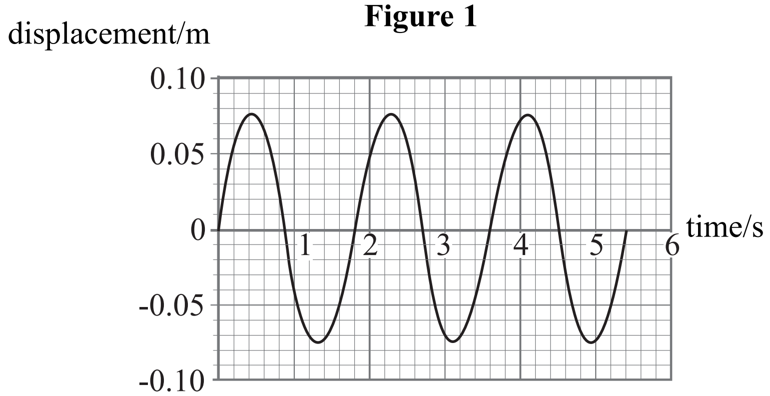
For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

LEAVE MARGIN BLANK

Answer **all** questions.

1 **Figure 1** shows how the displacement of the bob of a simple pendulum varies with time.

Figure 1



(a) (i) Calculate the frequency of the oscillation.

(ii) State the magnitude of the amplitude of the oscillation.

....

(iii) State how the frequency and amplitude of a simple pendulum are affected by increased damping.

....

....

(5 marks)

(b) Draw on **Figure 1** the displacement - time graph for a pendulum that has the same period and amplitude but oscillates 90° (π/2 radian) out of phase with the one shown.

(2 marks)

(c) The pendulum bob has a mass of 8.0×10^{-3} kg. Calculate

(i) the maximum acceleration of the bob during the oscillation,

(ii) the total energy of the oscillations.

(5 marks)

Detach this perforated page at the start of the examination.

Foundation Physics Mechanics Formulae

moment of force $= Fd$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

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

$s = \frac{1}{2}(u + v)t$

for a spring, $F = k\Delta l$

energy stored in a spring $= \frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$

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

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

in series circuit, $R = R_1 + R_2 + R_3 + ...$

in parallel circuit, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$

output voltage across $R_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times$ input voltage

Waves and Nuclear Physics Formulae

fringe spacing $= \frac{\lambda D}{d}$

single slit diffraction minimum $\sin\theta = \frac{\lambda}{b}$

diffraction grating $n\lambda = d\sin\theta$

Doppler shift $\frac{\Delta f}{f} = \frac{v}{c}$ for $v << c$

Hubble law $v = Hd$

radioactive decay $A = \lambda N$

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\frac{2}{3}e$	$+\frac{1}{3}$
down d	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\bar{u}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\bar{d}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

Particle	Lepton number L		
	L_e	L_μ	L_τ
e^-	1		
e^+	–1		
ν_e	1		
$\bar{\nu}_e$	–1		
μ^-		1	
μ^+		–1	
ν_μ		1	
$\bar{\nu}_\mu$		–1	
τ^-			1
τ^+			–1
ν_τ			1
$\bar{\nu}_\tau$			–1

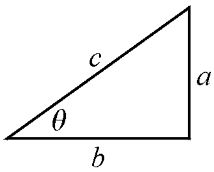
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

area of a circle $= \pi r^2$

surface area of sphere $= 4\pi r^2$

volume of sphere $= \frac{4}{3}\pi r^3$



$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

$c^2 = a^2 + b^2$

Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$$v = r\omega$$

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

$$x = A\cos 2\pi ft$$

$$\text{maximum } a = (2\pi f)^2 A$$

$$\text{maximum } v = 2\pi fA$$

$$\text{for a mass-spring system, } T = 2\pi\sqrt{\frac{m}{k}}$$

$$\text{for a simple pendulum, } T = 2\pi\sqrt{\frac{l}{g}}$$

Fields and their Applications

$$\text{uniform electric field strength, } E = \frac{V}{d} = \frac{F}{Q}$$

$$\text{for a radial field, } E = \frac{kQ}{r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0}$$

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

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

$$\text{for point masses, } \Delta E_p = GM_1M_2\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\text{for point charges, } \Delta E_p = kQ_1Q_2\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\text{for a straight wire, } F = BIl$$

$$\text{for a moving charge, } F = BQv$$

$$\phi = BA$$

$$\text{induced emf} = \frac{\Delta(N\phi)}{t}$$

$$E = mc^2$$

Temperature and Molecular Kinetic Theory

$$T/\text{K} = \frac{(pV)_T}{(pV)_{tr}} \times 273.16$$

$$pV = \tfrac{1}{3}Nm\langle c^2\rangle$$

$$\text{energy of a molecule} = \tfrac{3}{2}kT$$

Heating and Working

$$\Delta U = Q + W$$

$$Q = mc\Delta\theta$$

$$Q = ml$$

$$P = Fv$$

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

$$\text{work done on gas} = p\Delta V$$

$$\text{work done on a solid} = \tfrac{1}{2}F\Delta l$$

$$\text{stress} = \frac{F}{A}$$

$$\text{strain} = \frac{\Delta l}{l}$$

$$\text{Young modulus} = \frac{\text{stress}}{\text{strain}}$$

Capacitance and Exponential Change

$$\text{in series, } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\text{in parallel, } C = C_1 + C_2$$

$$\text{energy stored by capacitor} = \tfrac{1}{2}QV$$

$$\text{parallel plate capacitance, } C = \frac{\varepsilon_0\varepsilon_r A}{d}$$

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

$$\text{time constant} = RC$$

$$\text{time to halve} = 0.69\,RC$$

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

$$A = A_0 e^{-\lambda t}$$

$$\text{half-life, } t_{\frac{1}{2}} = \frac{0.69}{\lambda}$$

Momentum and Quantum Phenomena

$$Ft = \Delta(mv)$$

$$E = hf$$

$$hf = \Phi + E_{k(\max)}$$

$$hf = E_2 - E_1$$

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

Turn over for the next question

LEAVE MARGIN BLANK

2 (a) **Figure 2** shows how the force F on a steel ball varies with time t when the ball is dropped onto a thick steel plate and rebounds. The kinetic energy of the ball after the collision is the same as it was before the collision.

Figure 2

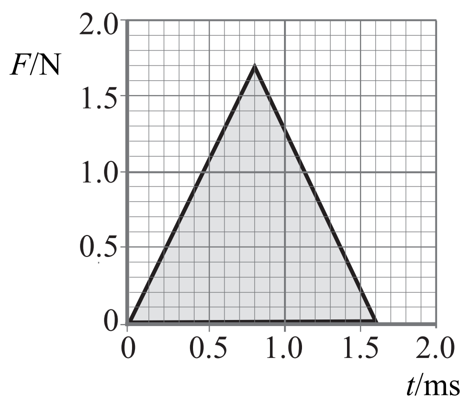
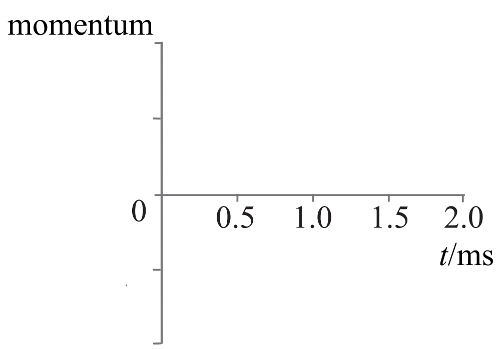


Figure 3



(i) State the name of the quantity that is obtained by determining the shaded area.

....

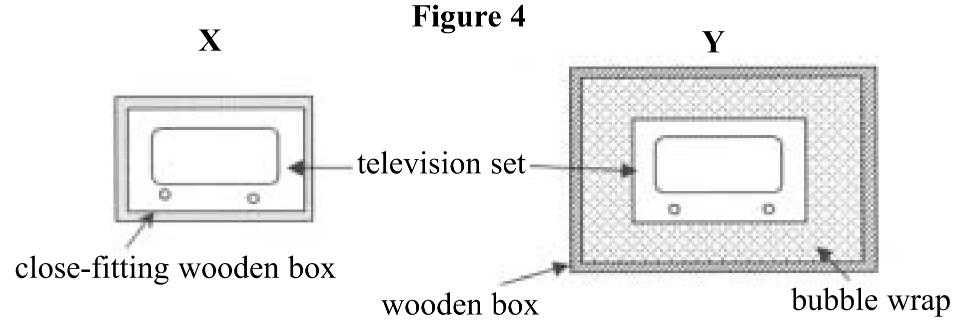
(ii) Use the graph to determine the initial momentum of the ball.

(iii) Sketch, on **Figure 3** above, a graph to show how the momentum of the ball varies during the time of impact. *(6 marks)*

LEAVE MARGIN BLANK

(b) **Figure 4** shows two packages **X** and **Y** which have been prepared for transporting a television set.

Figure 4



In transit each of the packages is dropped from the same height onto a concrete path. Explain, in terms of the impulse received, which television set is more likely to survive without damage.

Two of the 6 marks for this question are available for the quality of your written communication.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

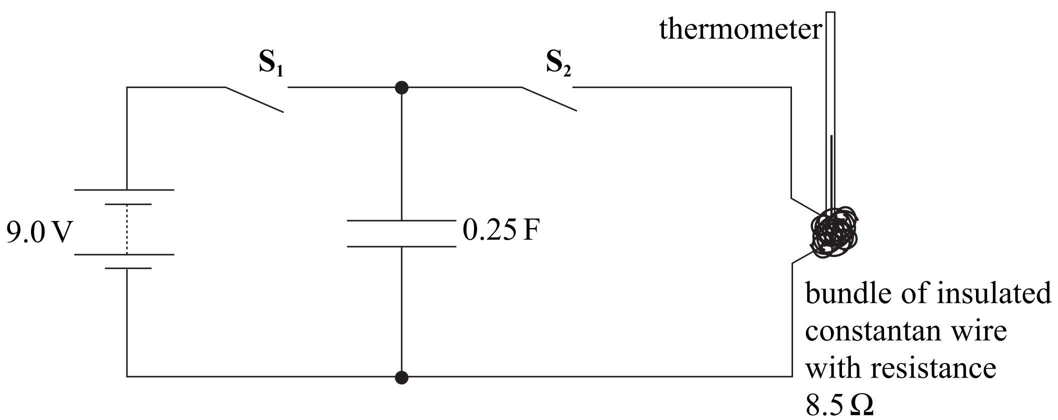
....*(6 marks)*

3 (a) A 500 μF capacitor and a 1000 μF capacitor are connected in series. Calculate the total capacitance of the combination.

(2 marks)

(b) **Figure 5** shows a diagram of an arrangement used to investigate the energy stored by a capacitor.

Figure 5



The bundle of constantan wire has a resistance of 8.5 Ω. The capacitor is initially charged to a potential difference of 9.0 V by closing $\mathbf{S_1}$.

(i) Calculate the charge stored by the 0.25 F capacitor.

(ii) Calculate the energy stored by the capacitor.

(iii) Switch $\mathbf{S_1}$ is now opened and $\mathbf{S_2}$ is closed so that the capacitor discharges through the constantan wire. Calculate the time taken for the potential difference across the capacitor to fall to 0.10 V.

(7 marks)

(c) The volume of constantan wire in the bundle in **Figure 5** is $2.2 \times 10^{-7}\ \text{m}^3$.

density of constantan = $8900\ \text{kg m}^{-3}$
specific heat capacity of constantan = $420\ \text{J kg}^{-1}\ \text{K}^{-1}$

(i) Assume that all the energy stored by the capacitor is used to raise the temperature of the wire. Use your answer to part (b)(ii) to calculate the expected temperature rise when the capacitor is discharged through the constantan wire.

(ii) Give **two** reasons why, in practice, the final temperature will be lower than that calculated in part (c)(i).

....

....

....

(5 marks)

14

4 (a) **Figure 6** represents a wire fixed at **A**. When a tensile stress is applied to the wire a tensile strain is produced in it.

Explain what is meant by *tensile stress* and *tensile strain*. Make additions to **Figure 6** to show clearly any quantities that you refer to in your explanations.

Figure 6

tensile stress

....

....

tensile strain

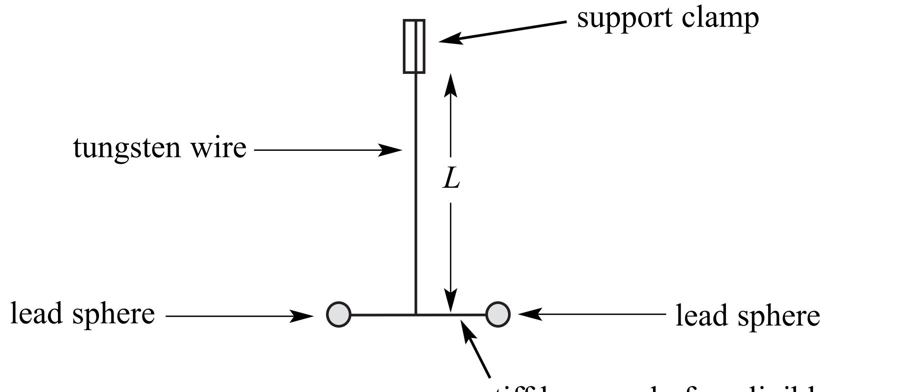
....

....

(4 marks)

(b) **Figure 7** shows part of an apparatus that is to be used in an experiment to measure the value of G, the universal gravitational constant. The two lead spheres, each of mass 1.5×10^{-2} kg, have to be suspended from a tungsten wire that is as thin as possible.

Figure 7



Young modulus of tungsten $= 4.1 \times 10^{11}$ Pa
breaking stress of tungsten $= 1.2 \times 10^{8}$ Pa
gravitational field strength of the Earth $= 9.8\,\text{N kg}^{-1}$

(i) Calculate the minimum cross-sectional area of the wire needed.

(ii) In practice a wire of diameter 2.0×10^{-4} m is used. The unstretched length L of the wire is 0.14 m. Calculate the extension of the wire when the two lead spheres are suspended from it.

(6 marks)

10

Turn over for the next question

5 (a) Use the kinetic theory of gases to explain why the pressure of an ideal gas decreases

(i) when it is expanded at constant temperature,
(ii) when its temperature is lowered at constant volume.

Two of the 7 marks for this question are available for the quality of your written communication.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

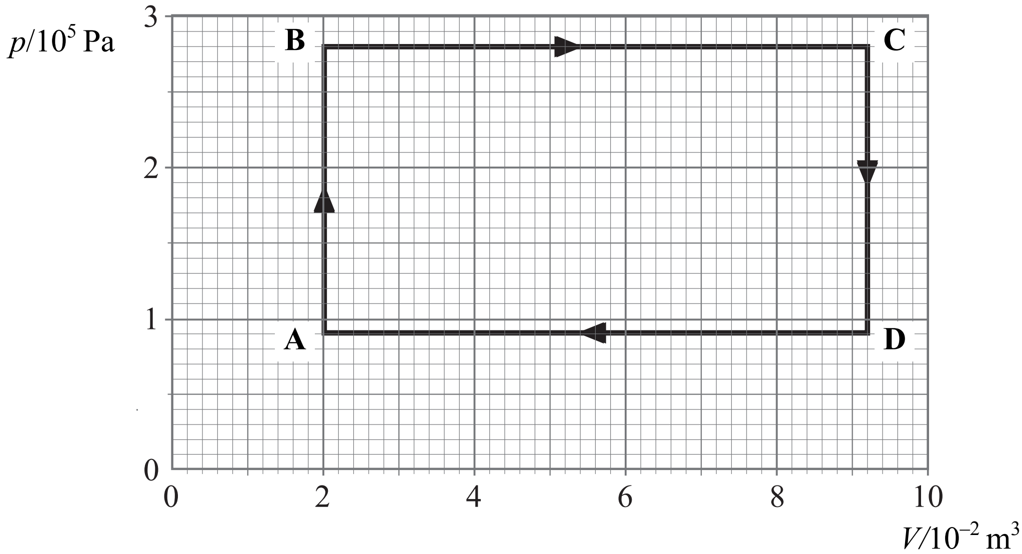
....

....

(7 marks)

(b) **Figure 8** shows how pressure varies with volume for a fixed mass of gas when it undergoes a cycle of changes **ABCDA**.

Figure 8



(i) State the process that must occur for the pressure change **CD** to take place.

....

(ii) Work is done by the gas in the change **BC**. State the other process that must be taking place for this change to occur and explain why it is necessary.

....

....

....

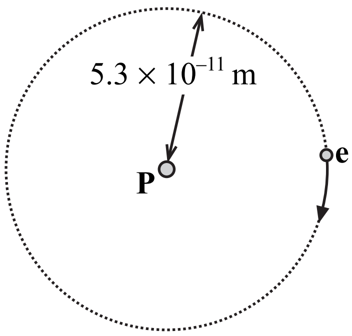
(iii) Calculate the net work done during the cycle.

(iv) The net work done is the useful work. The efficiency of the system in which the cycle takes place is 35%. Calculate the energy input that takes place during one cycle.

(7 marks)

6 The Bohr model of a hydrogen atom assumes that an electron **e** is in a circular orbit around a proton **P**. The model is shown schematically in **Figure 9**.

Figure 9



In the ground state the orbit has a radius of 5.3×10^{-11} m. At this separation the electron is attracted to the proton by a force of 8.1×10^{-8} N.

(a) State what is meant by *the ground state.*

....

....

(1 mark)

(b) (i) Show that the speed of the electron in this orbit is about $2.2 \times 10^{6}\,\text{m s}^{-1}$.

mass of an electron = 9.1×10^{-31} kg

(ii) Calculate the de Broglie wavelength of an electron travelling at this speed.

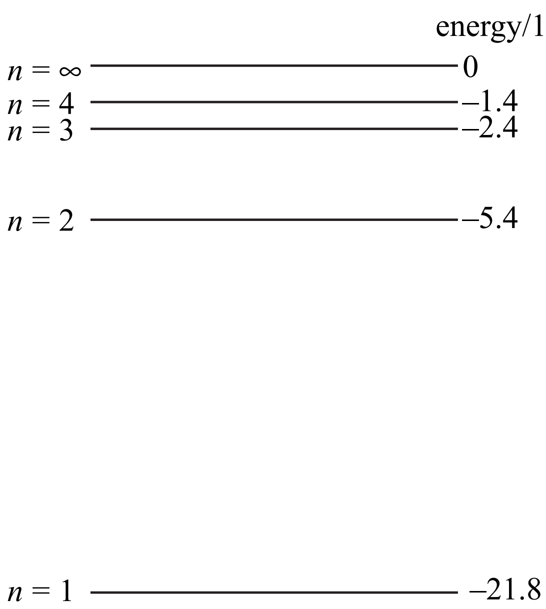
Planck constant = 6.6×10^{-34} J s

(iii) How many waves of this wavelength fit the circumference of the electron orbit? Show your reasoning.

(7 marks)

(c) The quantum theory suggests that the electron in a hydrogen atom can only exist in certain well-defined energy states. Some of these are shown in **Figure 10**.

Figure 10



An electron **E** of energy 2.5×10^{-18} J collides with a hydrogen atom that is in its ground state and excites the electron in the hydrogen atom to the $n = 3$ level.

Calculate

(i) the energy that is needed to excite an electron in the hydrogen atom from the ground state to the $n = 3$ level,

(ii) the kinetic energy of the incident electron **E** after the collision,

(iii) the wavelength of the lowest energy photon that could be emitted as the excited electron returns to the ground state.
speed of electromagnetic radiation= 3.0×10^{8} m s^{-1}

(5 marks)

13

END OF QUESTIONS

There are no questions are printed on this page