Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION B) — PHB4
Unit 4 Further Physics

Thursday 14 June 2007 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.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- *Formula 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.
- Four of these marks will be awarded for using good English, organising information clearly and using specialist vocabulary where appropriate.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- Questions 3(d) and 5(c) should be answered in continuous prose. In these questions you may be marked on your ability to use good English, to organise information clearly and to use specialist vocabulary where appropriate.

For Examiner's Use			
Question	Mark	Question	Mark
1			
2			
3			
4			
5			
6			
7			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Answer **all** questions.

1 A mass of 30 g is attached to a thread and whirled in a circle of radius 45 cm. The circle is in a horizontal plane. The tension in the thread is 0.35 N.

(a) Calculate

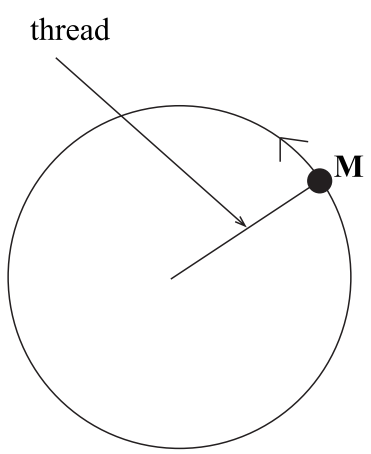
(i) the speed of the mass,

(ii) the period of rotation of the mass.

(4 marks)

(b) The mass **M** is now whirled in a circle in a vertical plane as shown in **Figure 1**.

Figure 1



(i) On **Figure 1**, label the forces acting on the mass, and use arrows to show their direction.

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

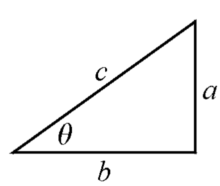
Geometrical and Trigonometrical Relationships

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

$$v = r\omega$$

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

$$x = A\cos 2\pi f t$$

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

$$\text{maximum } v = 2\pi f A$$

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

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

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

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

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

(ii) Without performing calculations, state and explain the difference between the tension in the thread when **M** is at the top of the circle and when it is at the bottom.

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(5 marks)

9

Turn over for the next question

2 (a) (i) Explain the terms *heat transfer* and *internal energy* in relation to an ideal gas.

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(ii) Write down, in equation form, the first law of thermodynamics. State what each of the symbols represents when that quantity is **negative**.

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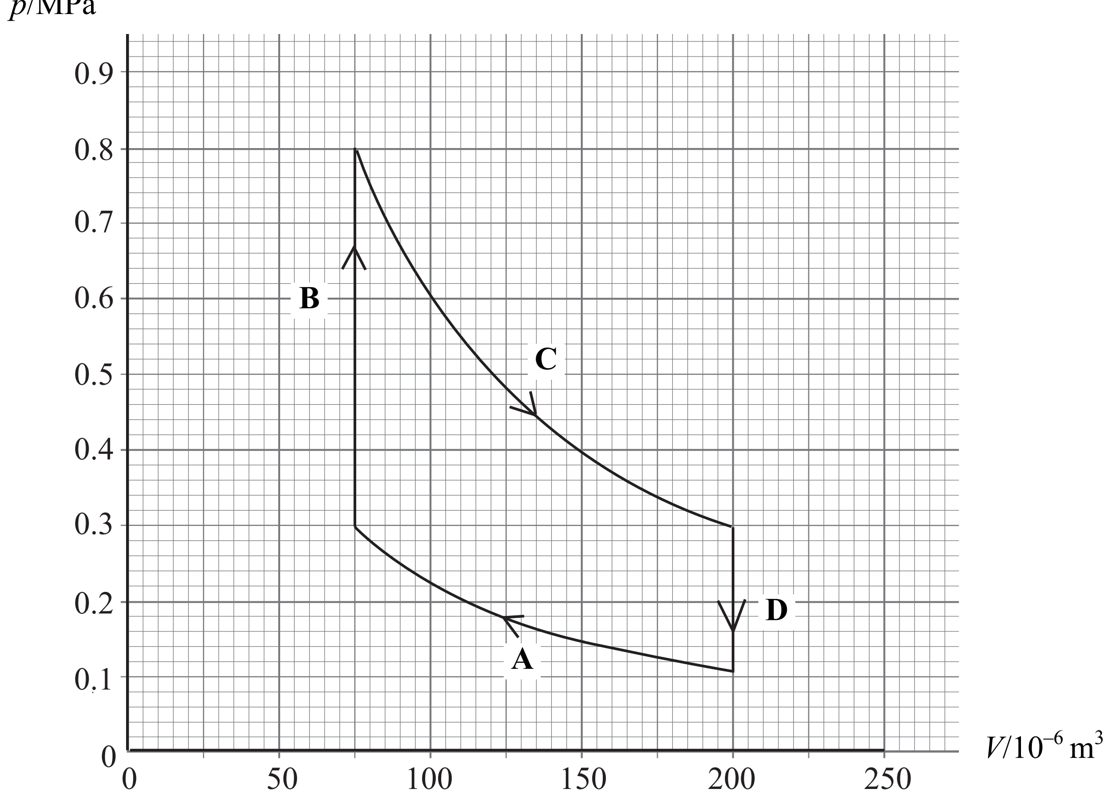
(6 marks)

(b) **Figure 2** shows the variation of pressure p with volume V for a sample of an ideal gas.

Figure 2



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(i) State and explain which change in the cycle corresponds to work having been done **by** the ideal gas.

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(ii) Using the data on the graph show that change **C** is isothermal.

(iii) The temperature at which the isothermal change **A** occurs is 450 K. Calculate the temperature at which the second isothermal change **C** occurs.

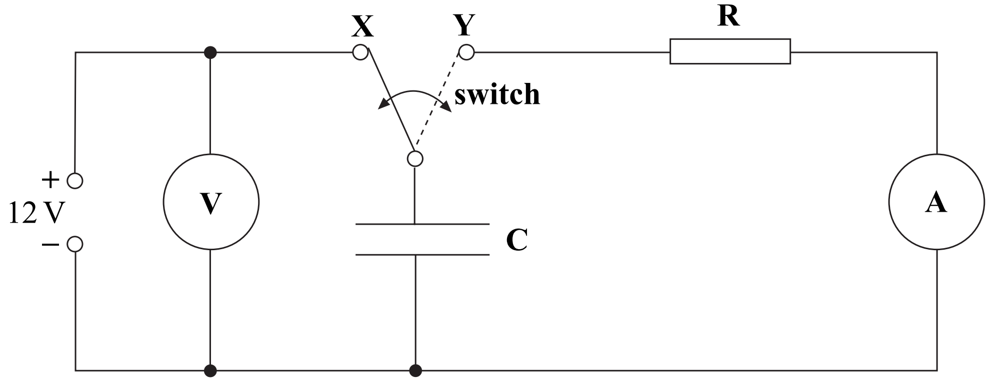
(7 marks)

13

Turn over for the next question

3 **Figure 3** shows a circuit that may be used to investigate the properties of a capacitor. The switch moves rapidly between **X** and **Y**, making contact with each terminal 400 times per second. When it makes contact with **X** the capacitor **C** charges, when it makes contact with **Y** the capacitor discharges through the resistor **R**.

Figure 3



(a) **R** has a value of 220 Ω. The time constant for the circuit is 2.2×10^{-4} s. Calculate the value of capacitor **C**.

(1 mark)

(b) Calculate the periodic time T for the oscillation of the switch.

(2 marks)

(c) The switch makes contact with **Y** for time $T/2$. The capacitor discharges from 12 V during this time.

(i) Calculate the voltage across the charged capacitor after a time $T/2$.

(ii) Explain whether or not it is reasonable to assume that the capacitor has completely discharged in the time $T/2$.

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(4 marks)

(d) For the circuit in **Figure 3**, the current measured on the ammeter is proportional to the capacitance of the capacitor. Explain how the circuit of **Figure 3** might be used to show that the capacitance of a pair of adjustable parallel metal plates is proportional to the area of overlap of the plates.

Two of the 8 marks are available for the quality of your written communication.

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(8 marks)

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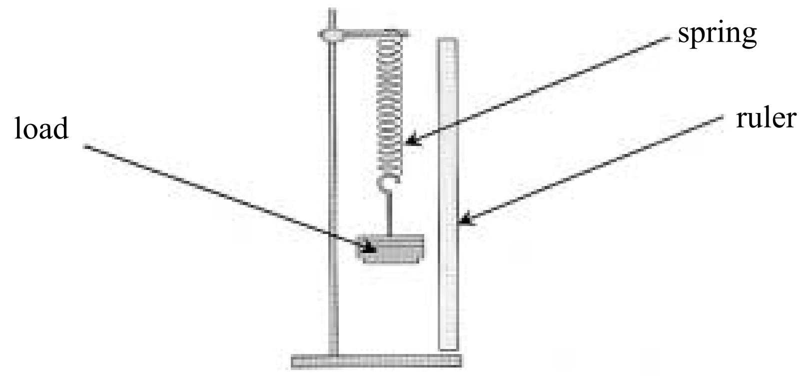
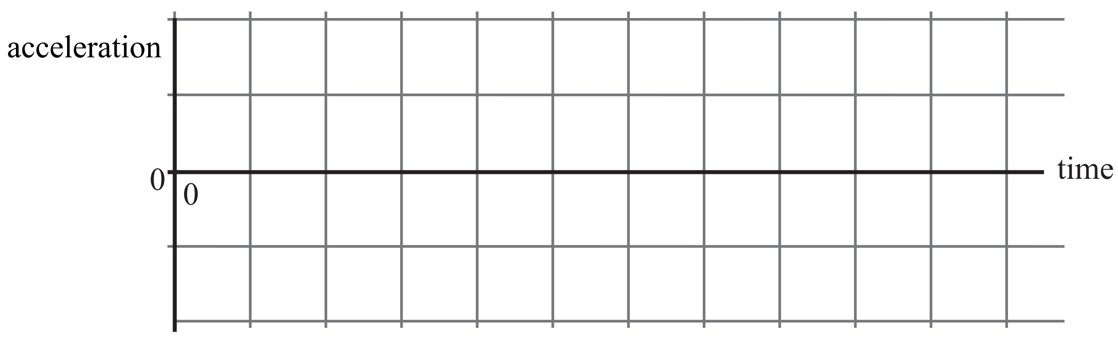
4 **Figure 4** shows a loaded helical spring. The load is displaced vertically upwards from its rest position and released at time = 0.

Figure 4



(a) Taking upward displacement as being positive, on the grid in **Figure 5** sketch a graph showing **two** cycles of the acceleration of the load, starting at time = 0.

Figure 5



(3 marks)

(b) The spring constant for the spring is 250 N m^{-1} and the mass of the load is 0.40 kg. The amplitude of the oscillation is 0.085 m.

(i) Show that the frequency of oscillation of the loaded spring is approximately 4 Hz.

(ii) Calculate the maximum velocity of the oscillating mass.

(iii) Calculate the total energy of the system, assuming it is undamped.

(6 marks)

9

Turn over for the next question

5 (a) Explain the meaning of the term *threshold wavelength* in relation to the photoelectric effect.

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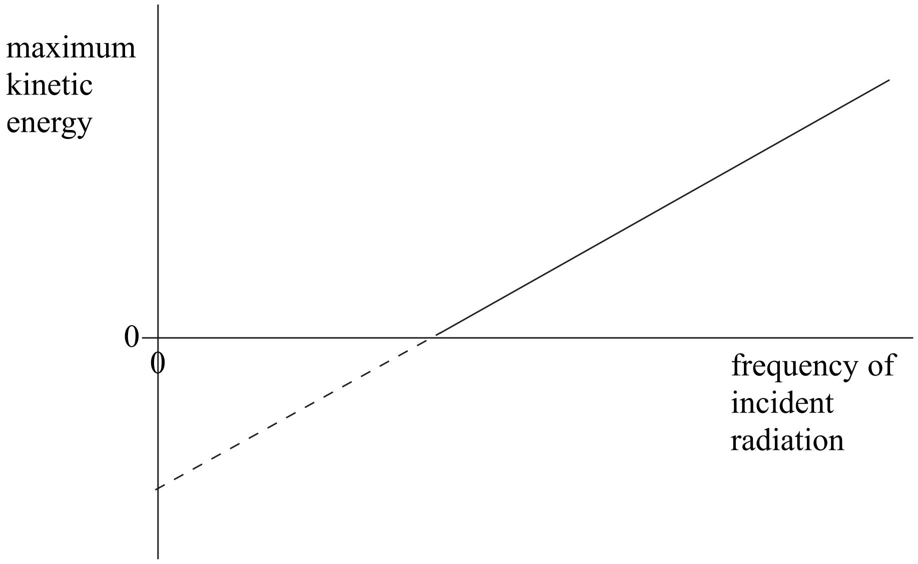
(2 marks)

(b) **Figure 6** shows the relationship between the maximum kinetic energy of photoelectrons and the frequency of the incident radiation.

Figure 6



With reference to the photoelectric equation, explain clearly how you would use the graph to find

(i) a value for the Planck constant,

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(ii) the work function of the metal surface,

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(iii) the threshold wavelength of the metal surface.

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(5 marks)

(c) State and explain the effect of varying the intensity of the incident radiation on the rate of emission and maximum kinetic energy of the photoelectrons.
Assume the wavelength of the incident radiation is constant.

Two of the 5 marks are available for the quality of your written communication.

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(5 marks)

12

Turn over for the next question

6 Energy levels in atoms are *quantised.*

(a) State the meaning of the word quantised.

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(1 mark)

(b) (i) Explain why it is essential for the atoms undergoing laser action to have a metastable energy level.

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(ii) A photon stimulates the emission of radiation in the laser. Explain why the energy of the photon is critical to this process.

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(4 marks)

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(c) In a He-Ne laser 0.050 eV of kinetic energy must be transferred from a helium atom to a neon atom. Calculate the speed of an excited helium atom with this energy.

mass of helium atom $= 6.6 \times 10^{-27}$ kg

$1.0\,\text{eV} = 1.6 \times 10^{-19}$ J

(4 marks)

9

Turn over for the next question

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7 A cycling helmet consists of a hard outer shell which is lined with a plastic foam material which squashes *relatively slowly* when the helmet strikes a hard surface such as the road or a car.

(a) Explain why the process of squashing 'relatively slowly' is helpful in protecting a cyclist wearing the helmet.

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(2 marks)

(b) In one safety test for a cyclist's helmet, the helmet is loaded with a dummy head and dropped so that it reaches a speed of $6.4\,m\,s^{-1}$ before hitting a flat metal block. The helmet 'passes' if the instrumentation connected to the dummy head registers a deceleration of less than $300\,g$, where g is the gravitational acceleration.

gravitational acceleration = $9.8\,m\,s^{-2}$

(i) The total mass of the dummy head and helmet in one test is 5.0 kg and it rebounds at a speed of $3.1\,m\,s^{-1}$. The time of contact between the helmet and the metal block is approximately 4 ms. Explain whether or not this helmet passes the test.

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(ii) The efficiency of the absorbing material is defined as the percentage of the kinetic energy that is absorbed during the test. Calculate the efficiency of the absorbing material.

(6 marks)

8

END OF QUESTIONS