Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2006
Advanced Level Examination

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

Thursday 15 June 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.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want 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.
- The marks for questions are shown in brackets. 4 of these marks will be awarded for the Quality of Written Communication.
- 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 1(d) and 7(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			
7			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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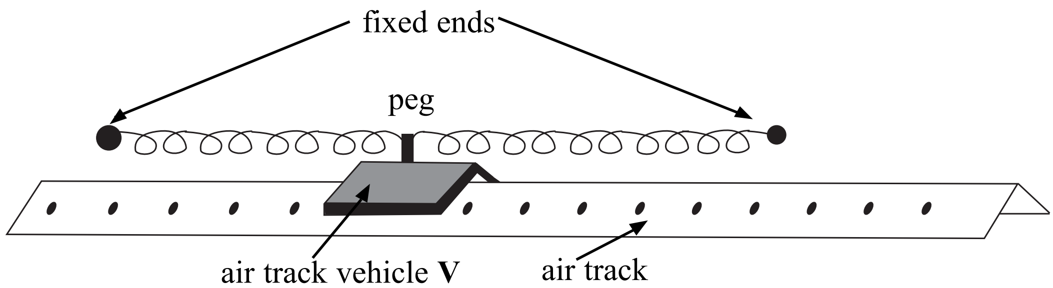
Answer **all** questions.

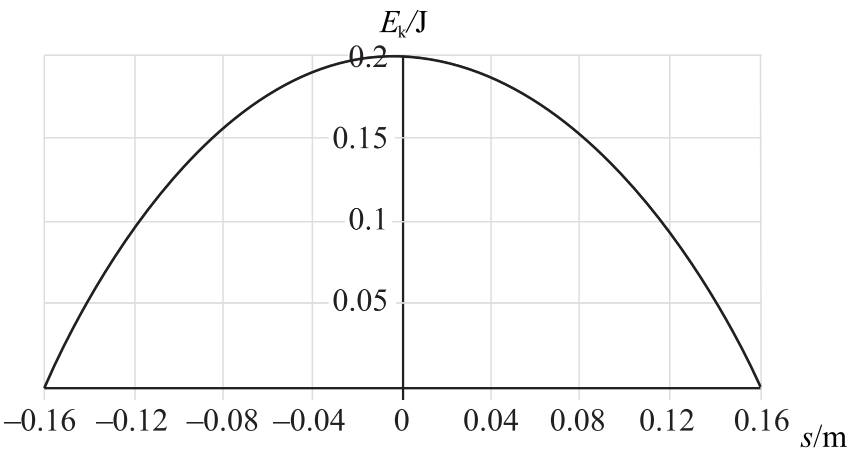
1 **Figure 1** shows a mass-spring system consisting of an air track vehicle **V** of mass 0.60 kg. A peg attached to **V** is connected to two springs that are both fixed at the other end. When **V** is displaced along the air track and released it oscillates about its rest position. The vehicle **V** floats on a cushion of air so that there is negligible friction between **V** and the air track.

Figure 1



(a) **Figure 2** shows how the kinetic energy E_k of **V** varies with its displacement s from the rest position when the initial displacement is 0.16 m.

Figure 2



(i) Draw on **Figure 2** a graph showing how the potential energy of the mass-spring system varies with s.
Label this graph E_p.

(ii) Draw on **Figure 2** a graph to show how the kinetic energy of **V** would vary with s when the initial displacement is 0.080 m.

(4 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 $= \frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$

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

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

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

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

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

Waves and Nuclear Physics Formulae

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

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

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

Doppler shift $\dfrac{\Delta f}{f} = \dfrac{v}{c}$ for $v \ll c$

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	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\overline{\mathrm{u}}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\overline{\mathrm{d}}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

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

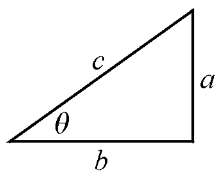
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

Turn over ▶

Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$$v = r\omega$$

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

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

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

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

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

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

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

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

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

(b) State the general conditions necessary for oscillations of a mass to be simple harmonic.

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(2 marks)

(c) A horizontal force of 0.90 N displaces **V** a distance 0.058 m along the track. When **V** is released it oscillates with simple harmonic motion along the track.

(i) Calculate the frequency of the oscillations.

(ii) Write down the equation that represents how the displacement *s* of **V** varies with time *t* when the amplitude of the oscillations is 0.16 m.

(4 marks)

Question 1 continues on the next page

Turn over ▶

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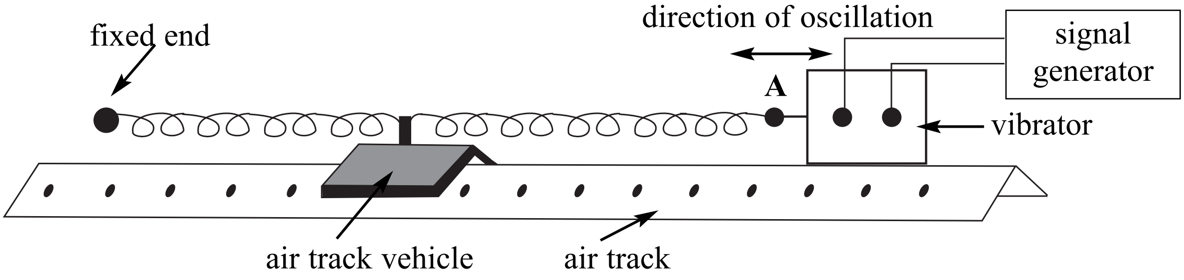
(d) **Figure 3** shows a modification to the system that enables an investigation of *forced oscillations* and *resonance*.

Figure 3



The signal generator causes the vibrator to produce small amplitude oscillations at **A** in the direction shown by the double headed arrow.

Explain what is meant by the terms forced oscillations and resonance and describe what would be observed as the frequency of the signal generator is increased from zero to a frequency that is much higher than that calculated in part (c)(i).

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

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(7 marks)

17

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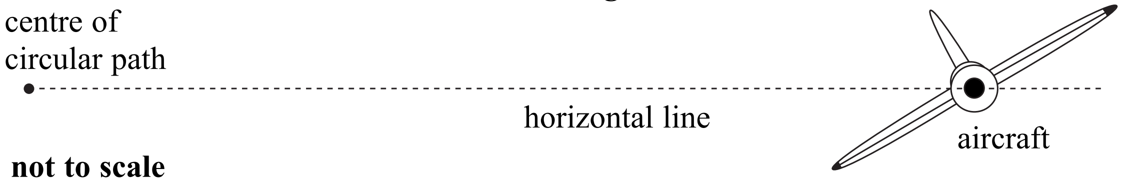
2 (a) **Figure 4** shows an aircraft which is flying in a horizontal circular path at constant speed.

Figure 4



(i) Explain why the aircraft has a *constant speed* but not a *constant velocity*.

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(ii) To turn, the aircraft is banked as shown in **Figure 4**. State how this produces the centripetal force necessary for the circular motion.

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(iii) Write down the equation for the magnitude of the centripetal force, identifying any symbols that you use.

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(5 marks)

(b) The aircraft flies at a speed of $450\,\text{km}\,\text{h}^{-1}$ in a circular path of radius of $3.5\,\text{km}$.

(i) Calculate the horizontal acceleration experienced by the pilot as the aircraft turns.

(ii) State how the force necessary to accelerate the pilot is produced.

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(3 marks)

8

Turn over ▸

3 (a) State the **three** factors upon which the capacitance of a parallel plate capacitor depends.

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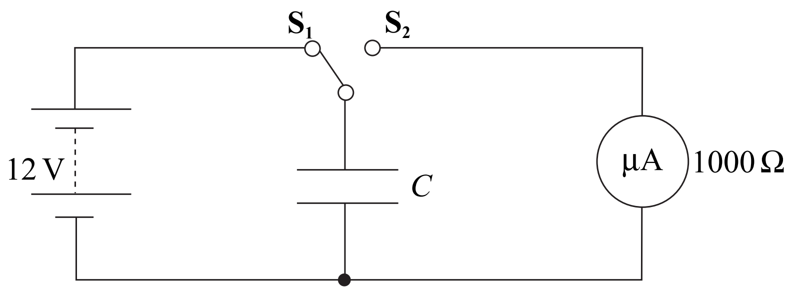
(2 marks)

(b) **Figure 5** shows a circuit for measuring the capacitance of a capacitor.

Figure 5



The switch is driven by a signal generator and oscillates between $\mathbf{S_1}$ and $\mathbf{S_2}$ with frequency f.

When the switch is in position $\mathbf{S_1}$ the capacitor charges until the potential difference across it is equal to the supply emf. When the switch moves to position $\mathbf{S_2}$ the capacitor discharges through the microammeter which has a resistance of 1000 Ω.

In one experiment a 0.047 μF capacitor is used with a 12 V supply.

(i) Calculate the charge stored by the capacitor when the switch is in position $\mathbf{S_1}$.

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(ii) Calculate the time for which the switch must remain in contact with $\mathbf{S_2}$ in order for the charge on the capacitor to fall to 1% of its initial charge.

(iii) Assuming that the capacitor discharges all the stored charge through the microammeter, calculate the reading on the meter when the switch oscillates at 400 Hz.

(6 marks)

8

Turn over for the next question

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4 (a) In a helium-neon laser a neon atom requires 3.302×10^{-18} J of energy to be excited from the ground state into its metastable state. This energy is provided in a collision with an excited helium atom. The excited helium atom provides 8.0×10^{-21} J from its kinetic energy. The rest comes from the excited electron in the helium atom returning to the ground state.

(i) How does a metastable state differ from other excited states?

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(ii) Calculate the temperature of helium that has a mean atomic kinetic energy of 8.0×10^{-21} J.

Boltzmann constant = 1.4×10^{-23} J K^{-1}

(iii) The neon emits light when the electron in the metastable state falls into the level that is 2.996×10^{-18} J above the ground state. Calculate the wavelength of the light.

Planck constant = 6.6×10^{-34} J s

speed of electromagnetic radiation = 3.0×10^{8} m s^{-1}

(6 marks)

(b) In one high-powered laser the beam has an intensity of 8.5×10^{26} W m^{-2}. The photon energy is 4.0×10^{-19} J and the beam diameter is 8.0×10^{-6} m.

(i) Calculate the number of photons per second emitted by the laser.

(ii) Suggest **one** use for a high-powered laser such as this.

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(4 marks)

10

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5 (a) (i) Explain what is meant by the *specific latent heat of vaporisation* of a liquid.

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(ii) Suggest why the specific latent heat of vaporisation of water is much greater than the specific latent heat of fusion of water.

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(3 marks)

(b) A cup contains 0.25 kg of water at a temperature of 15 °C. The water is heated by passing steam at 100 °C into it.

specific heat capacity of water	$= 4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$
specific latent heat of vaporisation of water	$= 2.3 \times 10^{6}\,\mathrm{J\,kg^{-1}}$
boiling point of water	= 100 °C

(i) Use the above data to calculate the minimum mass of water that is in the cup when the temperature of the water reaches its boiling point.

(ii) Explain why there is likely to be a greater mass of water in the cup than you have calculated in part (b)(i).

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(4 marks)

7

Turn over ▶

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6 (a) State **two** assumptions of the kinetic theory of gases that concern the collisions of gas molecules with each other and with the container.

Assumption 1 ....

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Assumption 2 ....

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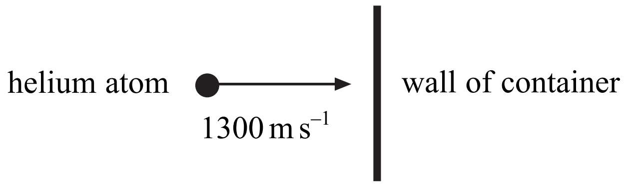
(2 marks)

(b) **Figure 6** shows a helium atom of mass 6.8×10^{-27} kg about to strike the wall of a container. It rebounds with the same speed.

Figure 6



(i) Calculate the momentum change of the helium atom.

(ii) Calculate the number of collisions per second on each cm^2 of the container wall that will produce a pressure of 1.5×10^5 Pa.

(5 marks)

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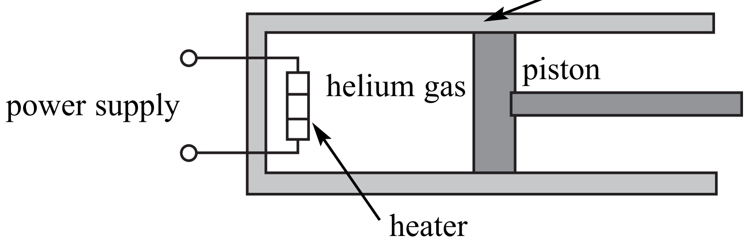
(c) **Figure 7** shows an insulated cylinder fitted with a perfectly fitting piston and a heater. There is negligible friction between the cylinder and the piston. The cylinder contains a fixed mass of helium gas.

Figure 7



The following two experiments are performed.

Experiment 1 The heater provides 150 J of energy with the piston fixed in position. The temperature rise of the gas is found to be 29 K.

Experiment 2 The heater supplies 150 J of energy with the piston free to move so that the gas expands at constant pressure. The temperature rise of the gas is now 18 K.

(i) Explain why the temperature rise is different in the two experiments.

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(ii) The change in internal energy of a gas is proportional to its change in temperature. Complete the table below to show the values of each of the quantities ΔU, W and Q when the first law of thermodynamics is applied **to the gas** in each experiment. Show clearly whether each quantity is positive or negative.

	ΔU/J	**W/J**	**Q/J**
Experiment 1			
Experiment 2			

(7 marks)

14

Turn over ▶

7 (a) State what is meant by the *photoelectric effect* and explain how **two** observations made in photoelectric experiments suggest that electromagnetic radiation behaves like a stream of particles rather than a wave.

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

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(7 marks)

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(b) Photons with energy 1.1×10^{-18} J are incident on a metal surface. The maximum energy of electrons emitted from the surface is 4.8×10^{-19} J.

Planck constant $= 6.6 \times 10^{-34}$ J s
mass of an electron $= 9.1 \times 10^{-31}$ kg

(i) Calculate the work function of the metal.

(ii) Calculate the wavelength of the de Broglie wave associated with the emitted electrons.

(4 marks)

11

END OF QUESTIONS

There are no questions printed on this page