Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

Leave blank

General Certificate of Education
June 2004
Advanced Level Examination

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

Thursday 17 June 2004 Morning Session

In addition to this paper you will require:
- 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 in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want marked.
- All working must be shown, otherwise you may lose marks.
- *Formulae Sheets* are provided on page 3 and 4. Detach this perforated page at the start of the examination.

Information
- The maximum mark for this paper is 75.
- Mark allocations are shown in brackets.
- Marks are awarded for units in addition to correct numerical answers, and for the use of appropriate numbers of significant figures.
- You are expected to use a calculator where appropriate.
- You will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate.
- The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
7			
8			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Answer **all** questions in the spaces provided.

Total for this question: ***10 marks***

1 **Figure 1** shows a number of smoke particles suspended in air. The arrows indicate the directions in which the particles are moving at a particular time.

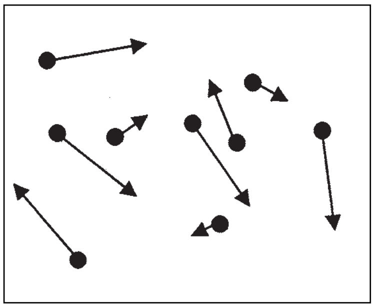


Figure 1

(a) (i) Explain why the smoke particles are observed to move.

....

....

(1 mark)

(ii) Smoke particles are observed to move in a random way.
State **two** conclusions about air molecules and their motion resulting from this observation.

....

....

....

....

(2 marks)

(b) A sample of air has a density of $1.24\,\text{kg}\,\text{m}^{-3}$ at a pressure of $1.01 \times 10^{5}\,\text{Pa}$ and a temperature of $300\,\text{K}$.
the Boltzmann constant = $1.38 \times 10^{-23}\,\text{J}\,\text{K}^{-1}$

(i) Calculate the mean kinetic energy of an air molecule under these conditions.

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

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

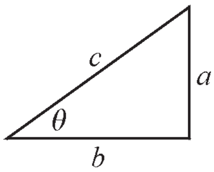
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

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

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

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

LEAVE MARGIN BLANK

(ii) Calculate the mean square speed for the air molecules.

(3 marks)

(iii) Explain why, when the temperature of the air is increased to 320 K, some of the molecules will have speeds much less than that suggested by the value you calculated in part (b) (ii).

....

....

....

....

(2 marks)

10

TURN OVER FOR THE NEXT QUESTION

Total for this question: ***13 marks***

2 **Figure 2** shows a toy engine moving with a constant speed on a circular track of constant radius.

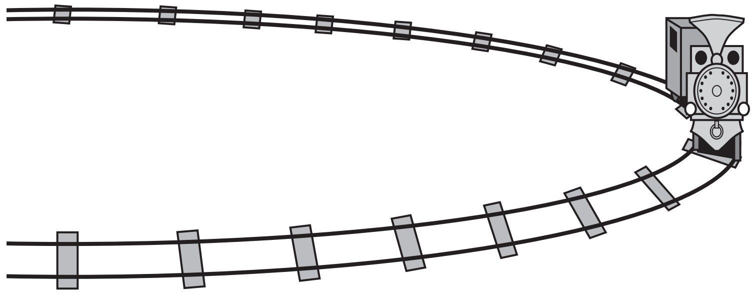


Figure 2

(a) (i) Explain why the engine is accelerating even though its speed remains constant.

....

....

....

....

(2 marks)

(ii) Mark on **Figure 2** the direction of the centripetal force acting on the engine. *(1 mark)*

(b) The total mass of the toy engine is 0.14 kg and it travels with a speed of 0.17 m s^{-1}. The radius of the track is 0.80 m.
Calculate the centripetal force acting on the engine.

(2 marks)

Figure 3 shows a close up of a pair of wheels as the engine moves towards you in the forward direction shown in **Figure 2**.

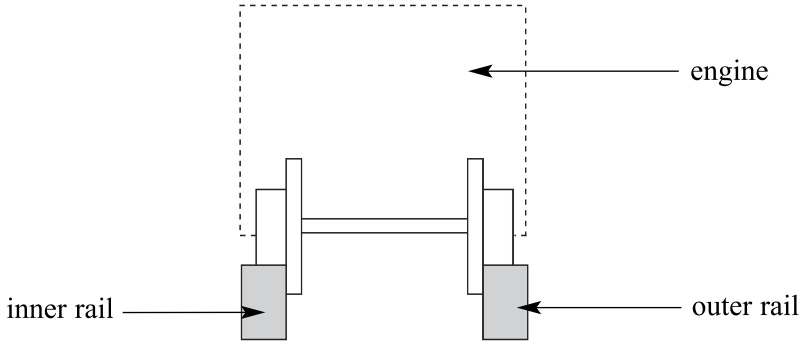


Figure 3

(c) (i) State and explain on which wheel the centripetal force acts at the instant shown. You may use **Figure 3** to help your explanation.

....

....

....

....

(2 marks)

(ii) For the toy engine going round a curved track, state and explain the two factors which determine the stress on each wheel.
Two of the 6 marks are available for the quality of your written communication.

....

....

....

....

....

....

....

....

....

....

....

....

(6 marks)

Total for this question: ***10 marks***

3 (a) Simple harmonic motion may be represented by the equation

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

(i) Explain the significance of the minus sign in this equation.

....

....

(1 mark)

(ii) In **Figure 4** sketch the corresponding *v*-*t* graph to show how the **phase** of velocity *v* relates to that of the acceleration *a*. *(1 mark)*

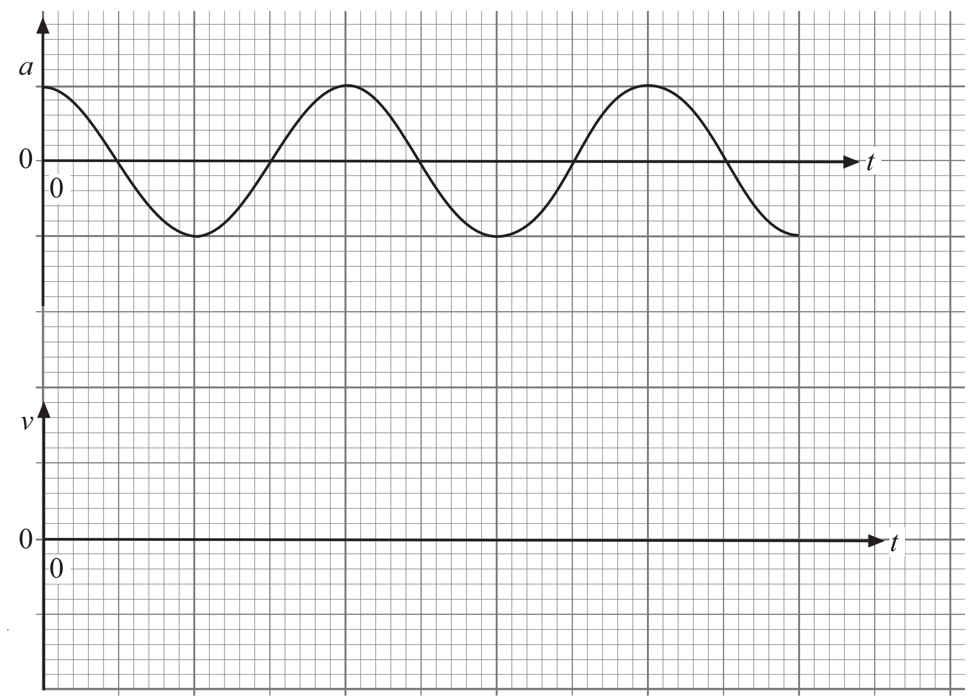


Figure 4

(b) (i) A mass of 24 kg is attached to the end of a spring of spring constant 60 N m^{-1}. The mass is displaced 0.035 m vertically from its equilibrium position and released. Show that the maximum kinetic energy of the mass is about 40 mJ.

(5 marks)

LEAVE MARGIN BLANK

(ii) When the mass on the spring is quite heavily damped its amplitude halves by the end of each complete cycle. On the grid of **Figure 5** sketch a graph to show how the kinetic energy, E_k, of the mass on the spring varies with time over a single period.
Start at time, $t = 0$, with your maximum kinetic energy.
You should include suitable values on each of your scales. *(3 marks)*

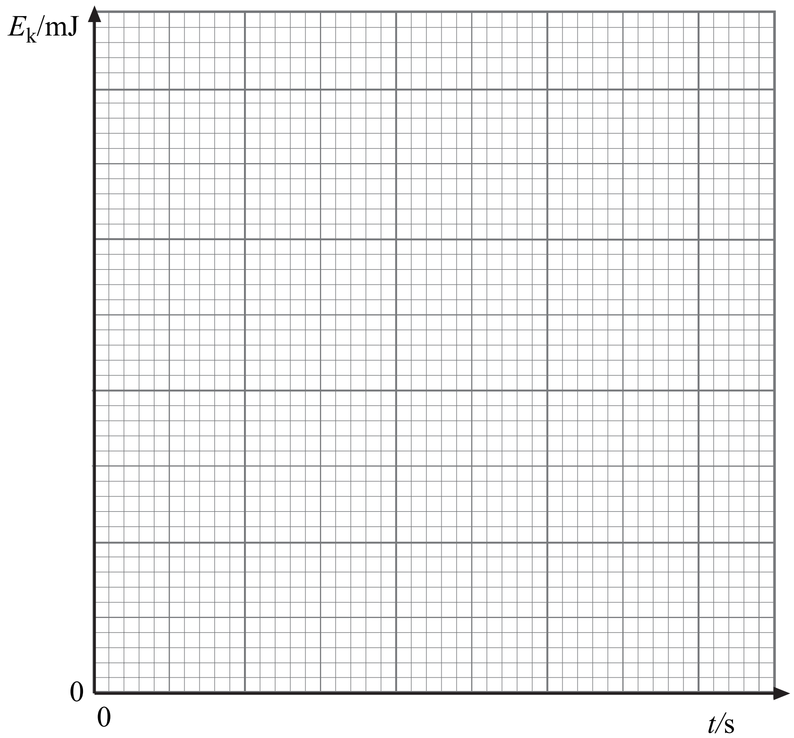


Figure 5

10

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

Total for this question: ***7 marks***

4 (a) Starting with the relationship between impulse and the change in momentum, show clearly that the unit, N, is equivalent to $kg\,m\,s^{-2}$.

(2 marks)

(b) A rocket uses a liquid propellant in order to move.
Explain how the ejection of the waste gases in one direction makes the rocket move in the opposite direction.

....

....

....

....

....

....

....

(3 marks)

(c) A rocket ejects 1.5×10^4 kg of waste gas per second. The gas is ejected with a speed of $2.4\,km\,s^{-1}$ relative to the rocket. Show that the average thrust on the rocket is about 40 MN.

(2 marks)

7

Total for this question: *10 marks*

5 (a) A particular photocell is designed to emit electrons when visible light is incident on its cathode. When yellow light of wavelength 570 nm is incident on the cathode the electrons are emitted with almost zero kinetic energy.

speed of electromagnetic radiation in a vacuum = $3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$
the Planck constant = $6.6 \times 10^{-34}\ \mathrm{J\,s}$
charge on electron = $-1.6 \times 10^{-19}\ \mathrm{C}$

(i) Show that the threshold frequency of the cathode material is about 5×10^{14} Hz.

(2 marks)

(ii) Calculate the work function of the cathode material.

(2 marks)

(b) Ultra-violet radiation of photon energy 4.7×10^{-19} J and of the same intensity as the visible light in part (a) is now incident on the cathode.

(i) Calculate the maximum velocity of the emitted electrons.
mass of electron = 9.1×10^{-31} kg.

(4 marks)

(ii) State and explain the effect on the number of electrons emitted per second resulting from this change in the photon energy of the incident radiation.

....

....

....

....

(2 marks)

Total for this question: ***9 marks***

6 The Earth's surface and the base of a charged cloud can be considered to be two plates of a parallel-plate capacitor.

(a) Calculate the capacitance of an Earth-cloud system when the base of the cloud has an area of $1.4 \times 10^6\,\text{m}^2$ and is 800 m above the Earth's surface.

$\varepsilon_0 = 8.9 \times 10^{-12}\,\text{Fm}^{-1}$
ε_r for air = 1.0

(2 marks)

(b) A potential difference of $3.0 \times 10^6\,\text{V}$ across each metre of air will cause the air to break down and allow the cloud to discharge to the Earth.

(i) Show that the average breakdown p.d. for the 800 m layer of air between the Earth and the base of the cloud is about $2.5 \times 10^9\,\text{V}$.

(1 mark)

(ii) Calculate the maximum energy that the charged Earth – cloud system can store.

(2 marks)

(iii) Calculate the maximum charge stored by the system before breakdown commences.

(1 mark)

(c) By considering the cloud discharge to be modelled by a resistor connected across a capacitor, calculate the resistance that would allow a cloud to discharge 99% of its charge to Earth in a time of 0.25 s.

(3 marks)

Total for this question: ***7 marks***

7 **Figure 6** illustrates the operation of a “three level” ruby laser.

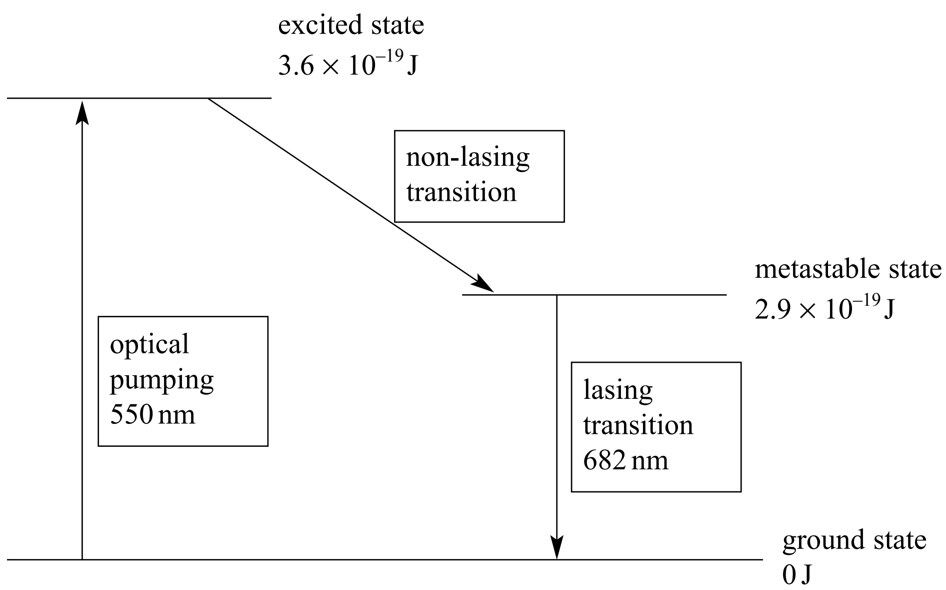


Figure 6

Using the information shown on the diagram, explain the main features of the operation of such a laser.
Two of the 7 marks for this question are available for the quality of your written communication.

....

....

....

....

....

....

....

....

....

....

....

....

(7 marks)

7

Total for this question: *9 marks*

8 The thermodynamic scale of temperature is based on the triple point of water and absolute zero.

(a) Explain what is meant by:

(i) the triple point of water;

....

....

(1 mark)

(ii) absolute zero.

....

....

(1 mark)

(b) **Figure 7** shows a constant volume gas thermometer, which consists of a bulb containing a fixed volume of gas. The pressure is measured using a pressure gauge when the bulb is brought into thermal contact with the system for which the temperature is to be measured.

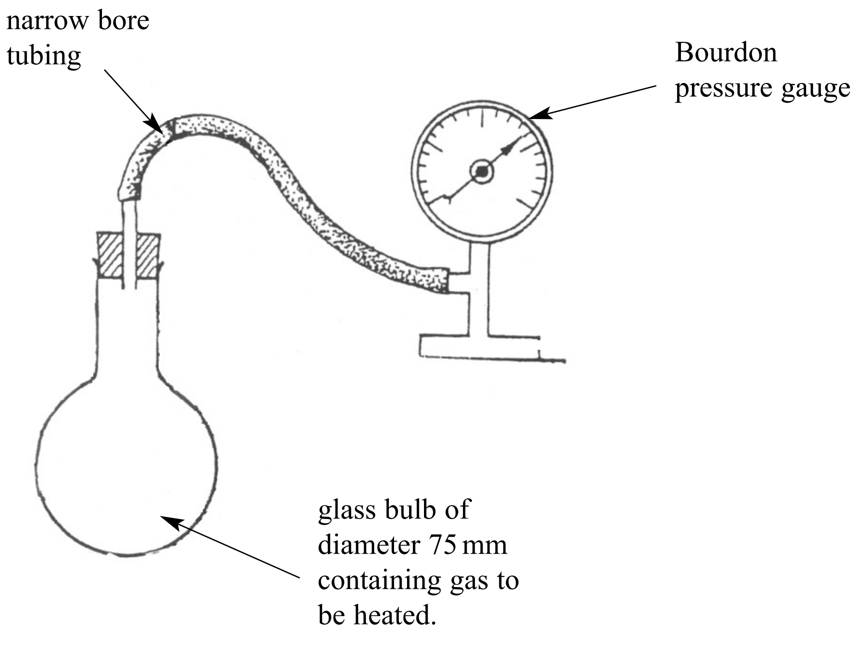


Figure 7

(i) At the triple point of water (273K) the pressure is measured to be 1.05×10^5 Pa. When the bulb is placed in a liquid at an unknown temperature the pressure is measured to be 4.07×10^5 Pa.
Calculate the unknown temperature in K.

(3 marks)

LEAVE MARGIN BLANK

(ii) In practice a constant volume gas thermometer is not a very practical instrument for measuring temperature. Suggest and explain **two** drawbacks when using this instrument as a thermometer.

....

....

....

....

....

....

....

....

(4 marks)

9

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE