Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2007
Advanced Level Examination

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

Monday 22 January 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.
- *Formulae Sheets* are provided on pages 3 and 4. Detach this perforated page at the start of the examination.

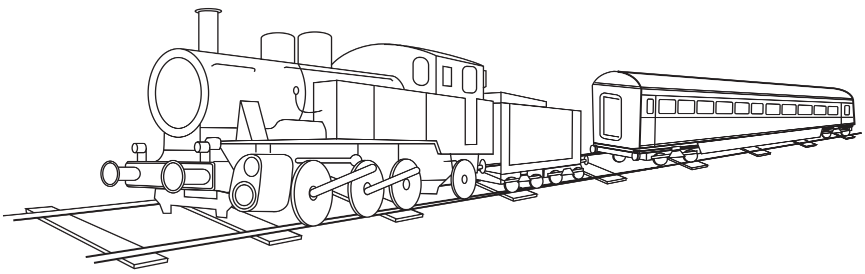
Information
- The maximum mark for this paper is 75.
- Four of these marks will be awarded for using good English, organising information clearly and using specialist vocabulary where appropriate.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- Questions 4(a) and 8(a) 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			
8			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Answer **all** questions.

1 **Figure 1** shows a railway engine which is about to couple with a stationary carriage of mass 4.0×10^4 kg. When they have joined up, the engine and the carriage move at a constant speed.

Figure 1



The engine has a mass of 6.2×10^4 kg and is moving at $0.35\,\mathrm{m\,s^{-1}}$ just before coupling.

(a) (i) Calculate the momentum of the engine.

(ii) Calculate the speed of the engine and carriage after coupling.

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

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

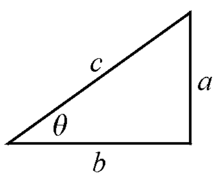
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

Turn over ▸

Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$v = r\omega$

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

$x = A\cos 2\pi ft$

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

maximum $v = 2\pi fA$

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

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

Fields and their Applications

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

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

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

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

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

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

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

for a straight wire, $F = BIl$

for a moving charge, $F = BQv$

$\phi = BA$

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

$E = mc^2$

Temperature and Molecular Kinetic Theory

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

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

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

Heating and Working

$\Delta U = Q + W$

$Q = mc\Delta\theta$

$Q = ml$

$P = Fv$

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

work done on gas $= p\Delta V$

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

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

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

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

Capacitance and Exponential Change

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

in parallel, $C = C_1 + \mathrm{C}_2$

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

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

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

time constant $= RC$

time to halve $= 0.69\,RC$

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

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

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

Momentum and Quantum Phenomena

$Ft = \Delta(mv)$

$E = hf$

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

$hf = E_2 - E_1$

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

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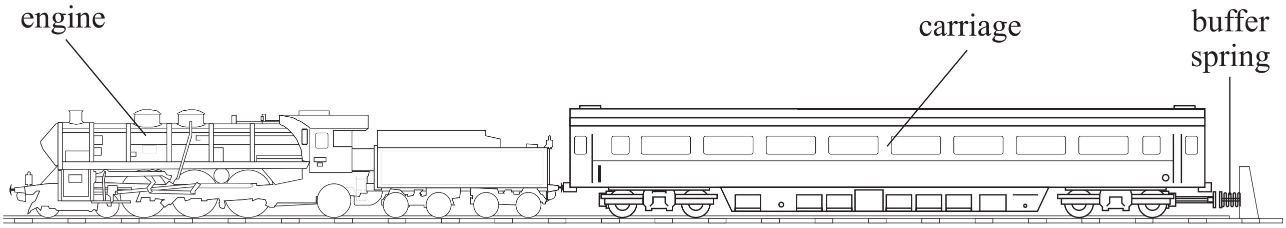
(b) **Figure 2** shows the engine and carriage as they strike a buffer with an initial speed of $0.15\,\mathrm{m\,s^{-1}}$. Assuming that the buffer behaves like a spring of stiffness $320\,\mathrm{kN\,m^{-1}}$, calculate the maximum compression of the 'spring'.

Figure 2



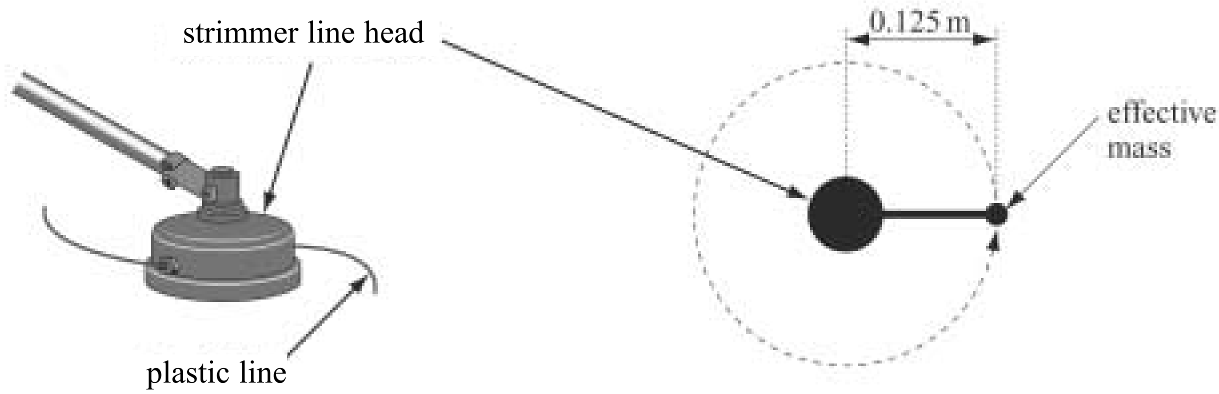
(4 marks)

9

Turn over for the next question

2 A strimmer is a tool for cutting long grass. A strimmer head such as that shown in **Figure 3(a)** is driven by a motor. This makes the plastic line rotate causing it to cut the grass. To simplify analysis, the strimmer line is modelled as the arrangement shown in **Figure 3(b)**. In this model the effective mass of the line is considered to rotate at the end of the line.

Figure 3(a) **Figure 3(b)**



In one strimmer the effective mass of 0.80 g rotates in a circle of radius 0.125 m at 9000 revolutions per minute.

(a) Show that the angular velocity of the line is approximately 9.4×10^2 rad s^{-1}.

(2 marks)

(b) (i) Explain how the centripetal force is applied to the effective mass.

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(ii) Calculate the centripetal force acting on the effective mass.

(4 marks)

(c) The line strikes a pebble of mass 1.2 g, making contact for a time of 0.68 ms. This causes the pebble to fly off at a speed of $15\,\mathrm{m\,s^{-1}}$.

Calculate the average force applied to the pebble.

(3 marks)

9

Turn over for the next question

3 Three ice cubes each of mass 25 g are dropped into a glass containing 330 g of water at a temperature of 22 °C. The ice is at 0 °C and melts so that the temperature of the water decreases.

(a) Considering the water to be the system, explain how the first law of thermodynamics applies to the water when the ice is dropped into it. Make sure you explain whether the change in each of the quantities involved is positive or negative.

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(5 marks)

(b) Calculate the final temperature of the water when all of the ice has melted. Assume that no heat is lost to the glass or the surroundings.

specific latent heat of fusion of ice $= 3.3 \times 10^5\ \mathrm{J\,kg^{-1}}$

specific heat capacity of water $= 4.2 \times 10^3\ \mathrm{J\,kg^{-1}\,K^{-1}}$

(4 marks)

9

Turn over for the next question

4 (a) Describe an experiment which offers evidence for the kinetic theory of gases. Explain how the experiment supports this theory.

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

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(6 marks)

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(b) The molar mass of gaseous nitrogen is $0.028\,\text{kg}\,\text{mol}^{-1}$. The average kinetic energy for nitrogen molecules in a sample is 8.6×10^{-21} J.

Boltzmann constant = $1.4 \times 10^{-23}\,\text{J}\,\text{K}^{-1}$
Avogadro constant = $6.0 \times 10^{23}\,\text{mol}^{-1}$

(i) Calculate the temperature of the sample.

(ii) Calculate the mean square speed of the nitrogen molecules.

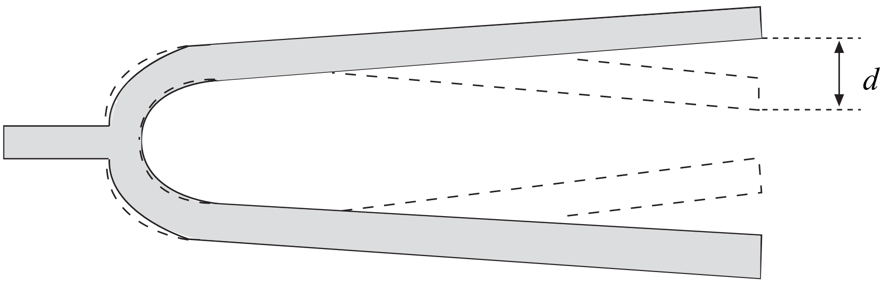
(5 marks)

11

Turn over for the next question

5 The tuning fork shown in **Figure 4** is labelled 512 Hz and has the tip of each of its two prongs vibrating with simple harmonic motion of amplitude 0.85 mm.

Figure 4



(a) (i) **Figure 4** shows the extreme positions of the prongs. How is the distance marked *d* related to the amplitude of the prongs?

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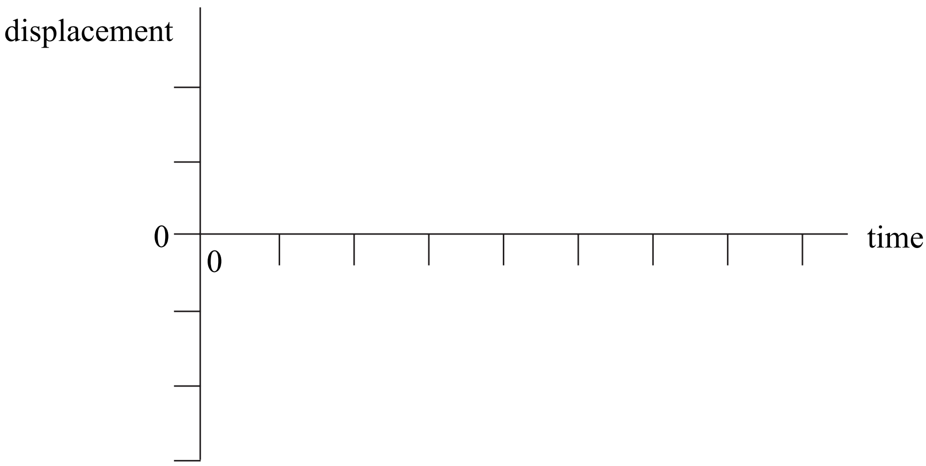
(ii) Sketch a graph on the axes below to show how the displacement of one tip of the tuning fork changes with time. Mark each axis with an appropriate scale.



(4 marks)

(b) (i) Calculate the maximum speed of the tip of a prong.

(ii) Calculate the maximum acceleration of the tip of a prong.

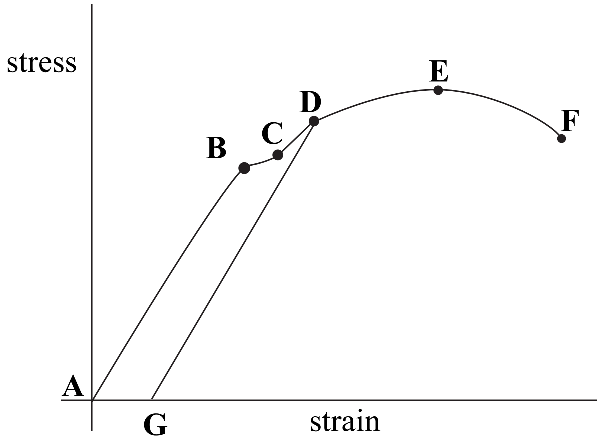
(4 marks)

8

Turn over for the next question

6 **Figure 5** is a stress-strain graph for a ductile metal.

Figure 5



(a) Identify a section of the line for which the material definitely behaves plastically.

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(1 mark)

(b) Identify a section of the line in which the Young modulus may be measured.

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(1 mark)

(c) Explain what the section of the line **D-G** represents.

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(2 marks)

(d) Explain how you would use the graph to calculate the Young modulus of the metal.

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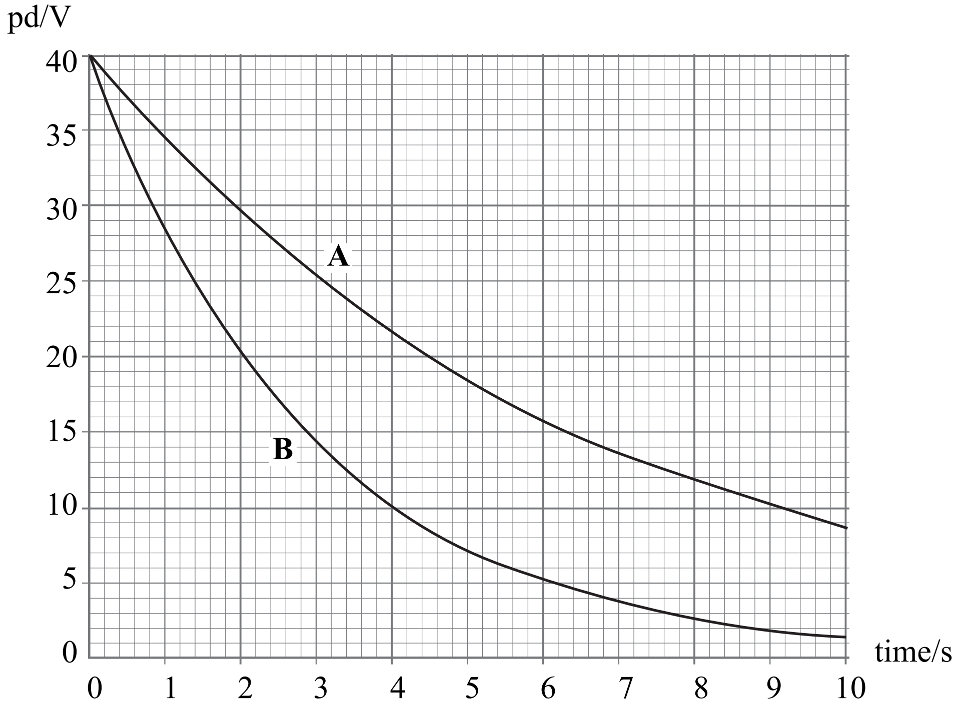
(2 marks)

6

Turn over for the next question

7 Two capacitors **A** and **B** are separately charged to a pd of 40.0 V before being discharged through the same resistor of value 10.0 kΩ. The discharge curves are shown in **Figure 6**.

Figure 6



(a) (i) Show that the time for the pd across capacitor **A** to halve is always approximately 4.5 s.

(ii) Calculate the capacitance of **A**.

(iii) Calculate the total capacitance of **A** and **B** when they are connected in series.

(8 marks)

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(b) Capacitors **A**, **B** and the power supply are connected in series. Explain whether **A** or **B** stores the greater energy.

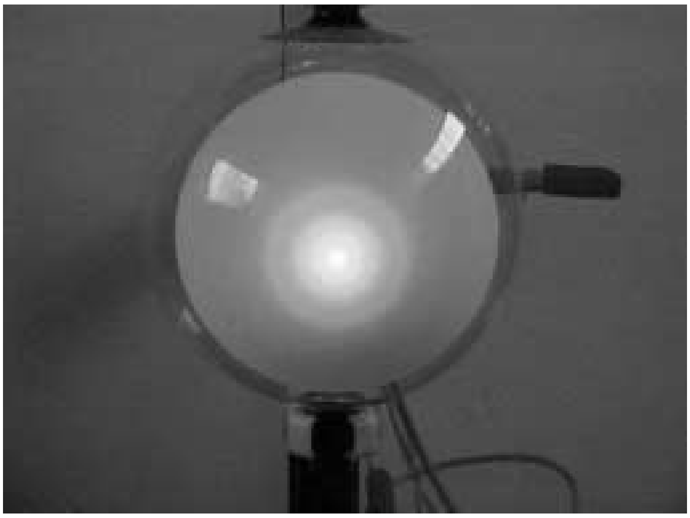
(3 marks)

11

Turn over for the next question

8 **Figure 7** shows the pattern on the screen at the end of an electron diffraction tube.

Figure 7



(a) Explain how the pattern demonstrates that electrons have wave properties.

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

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(5 marks)

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(b) An electron microscope uses the wave behaviour of electrons to investigate the structure of crystals.

(i) In such a microscope an electron is accelerated to $0.12\,c$, where c is the speed of electromagnetic waves in a vacuum. Calculate the de Broglie wavelength of the electron.

speed of electromagnetic waves in a vacuum	$= 3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Planck constant	$= 6.6 \times 10^{-34}\ \mathrm{J\,s}$
electron mass at $0.12\,c$	$= 9.2 \times 10^{-31}\ \mathrm{kg}$

(ii) Calculate the maximum kinetic energy of an electron in this electron microscope.

(iii) Suggest why such a microscope would be more appropriate for investigating crystal structure than an optical microscope.

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(5 marks)

(c) State and explain the information about an electron that can be deduced from the amplitude of its wave.

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(2 marks)

12

END OF QUESTIONS

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