Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2005
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Thursday 16 June 2005 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			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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

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

1 A girl sits at rest on a garden swing. The swing consists of a wooden seat of mass 1.2 kg supported by two ropes. The mass of the girl is 16.8 kg. The mass of the ropes should be ignored throughout this question.

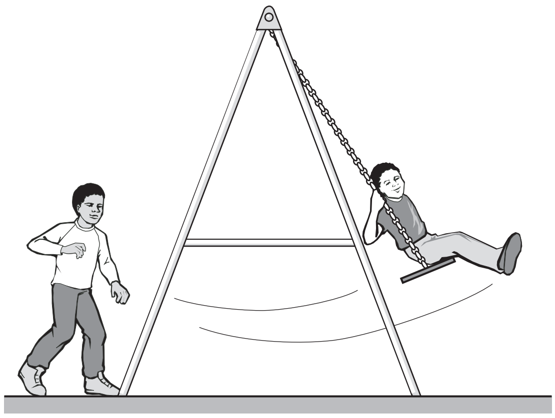


Figure 1

(a) A boy grips the seat and gives a firm push with both hands so that the girl swings upwards as shown in **Figure 1**. The swing just reaches a vertical height of 0.50 m above its rest position.

(i) Show that the maximum gain in gravitational potential energy of the girl and the swing is about 88 J.

acceleration due to gravity = $9.8\,\mathrm{m\,s^{-2}}$

(3 marks)

(ii) The work done against resistive forces as the swing moves upwards is 20 J.
Calculate the work done on the swing by the boy during the push.

(1 mark)

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, $R = R_1 + R_2 + R_3 + \ldots..$

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

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

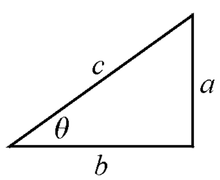
Geometrical and Trigonometrical Relationships

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

$$v = r\omega$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Momentum and Quantum Phenomena

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

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

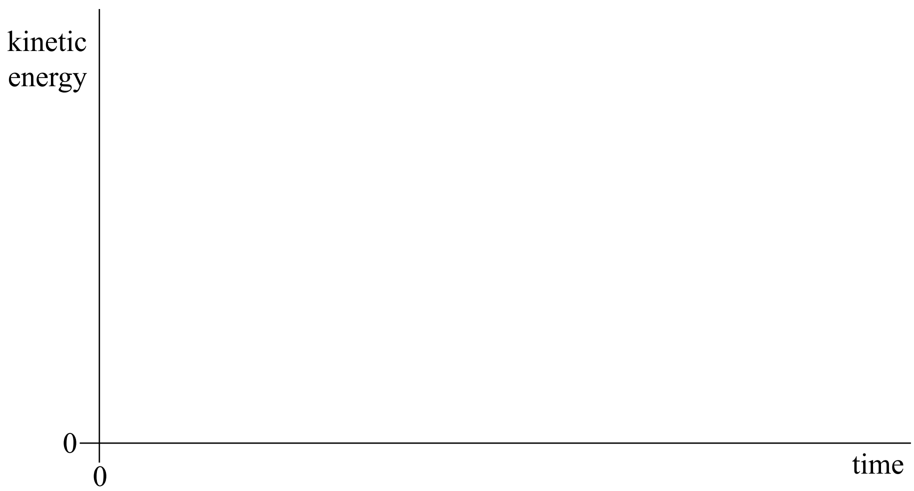
(iii) As he pushed, the boy's hands were in contact with the seat of the swing for a distance of 0.40 m. Calculate the average force applied to the swing.

(2 marks)

(b) Calculate the speed of the girl as she passes back through the lowest point of her ride for the first time. Assume that the work done against resistive forces is the same in both directions.

(4 marks)

(c) The girl is not pushed again. On the axes in **Figure 2**, sketch a graph to show how the kinetic energy of the girl varies with time over two complete cycles of the motion. Start your graph from the time when she is 0.50 m above the rest position. You are not required to mark a scale on either axis.



(3 marks)

Figure 2

13

Total for this question: *16 marks*

2 The International Space Station (ISS) moves in a circular orbit around the Earth at a speed of $7.68\,\text{km}\,\text{s}^{-1}$ and at a height of 380 km above the Earth's surface.

(a) Calculate the centripetal acceleration of the ISS, given that the radius of the Earth is 6380 km.

(3 marks)

(b) Explain why a scientist working on board the ISS experiences "apparent weightlessness".

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(2 marks)

This state of apparent weightlessness makes the space station an ideal laboratory for experiments in "zero gravity" conditions. Examples are the study of lattice vibrations in solids and Brownian Motion in fluids.

(c) **Figure 3** shows a mass-spring system which, in zero gravity, provides a good model of forces acting on an atom in a solid lattice.

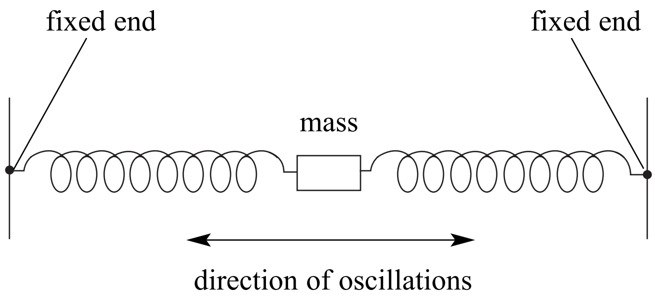

Figure 3

When the mass is displaced and released it oscillates as shown. The motion is very similar to the motion in one dimension of an atom in a crystalline solid. The springs behave like the bonds between adjacent atoms.

(i) The mass in the model system is 2.0 kg and it oscillates with a period of 1.2 s. Show that the stiffness of the spring system is about $55\,\text{N}\,\text{m}^{-1}$.

(2 marks)

(ii) The bonds between the atoms in a particular solid have the same stiffness as the model system and the mass of the oscillating atom is 4.7×10^{-26} kg. Calculate the frequency of oscillation of the atom.

(2 marks)

(d) What is *Brownian Motion* and what evidence does it provide in support of the *molecular model* and the *kinetic theory?*

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

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(7 marks)

16

Turn over

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

3 The graph in **Figure 4** shows the best fit line for the results of an experiment in which the volume of a fixed mass of gas was measured over a temperature range from 20 °C to 100 °C. The pressure of the gas remained constant throughout the experiment.

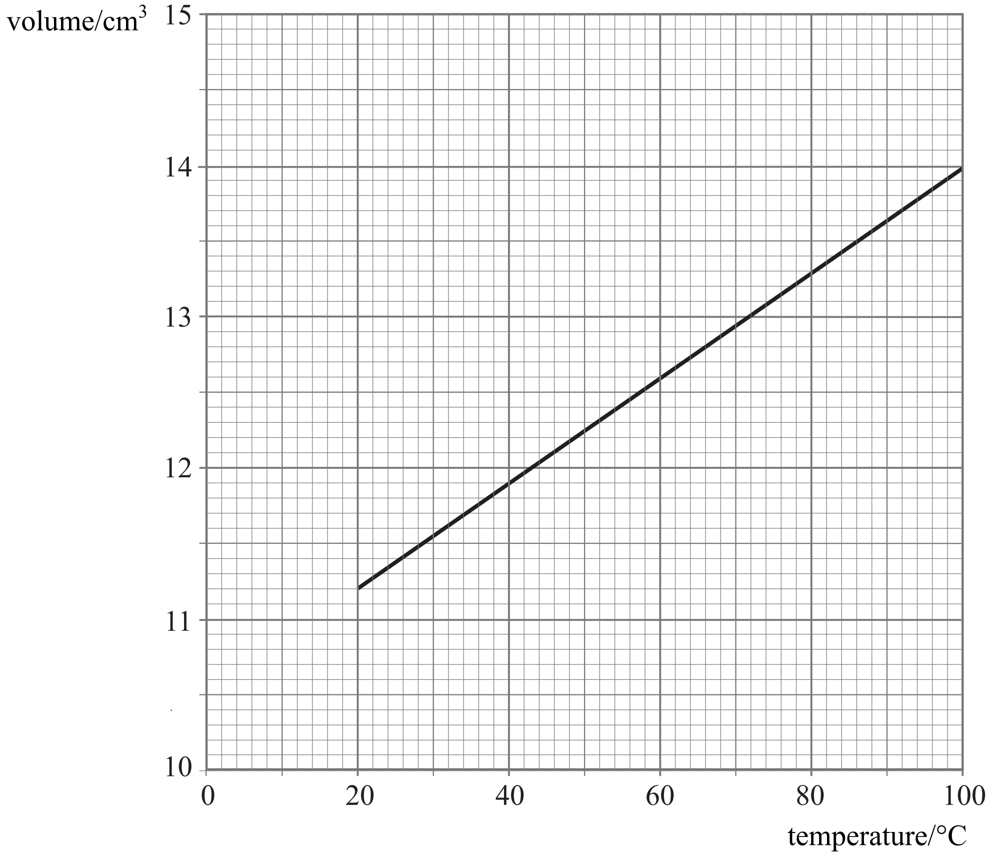

Figure 4

(a) Use the graph in **Figure 4** to calculate a value for the absolute zero of temperature in °C. Show clearly your method of working.

(4 marks)

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(b) Use data from the graph in **Figure 4** to calculate the mass of gas used in the experiment. You may assume that the gas behaved like an ideal gas throughout the experiment.

gas pressure throughout the experiment	=	1.0×10^5 Pa
molar gas constant	=	8.3 J mol^{-1} K^{-1}
molar mass of the gas used	=	0.044 kg mol^{-1}

(5 marks)

9

TURN OVER FOR THE NEXT QUESTION

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

4 **Figure 5** is a graph of tension against extension for a copper wire stretched by a steadily increasing force.

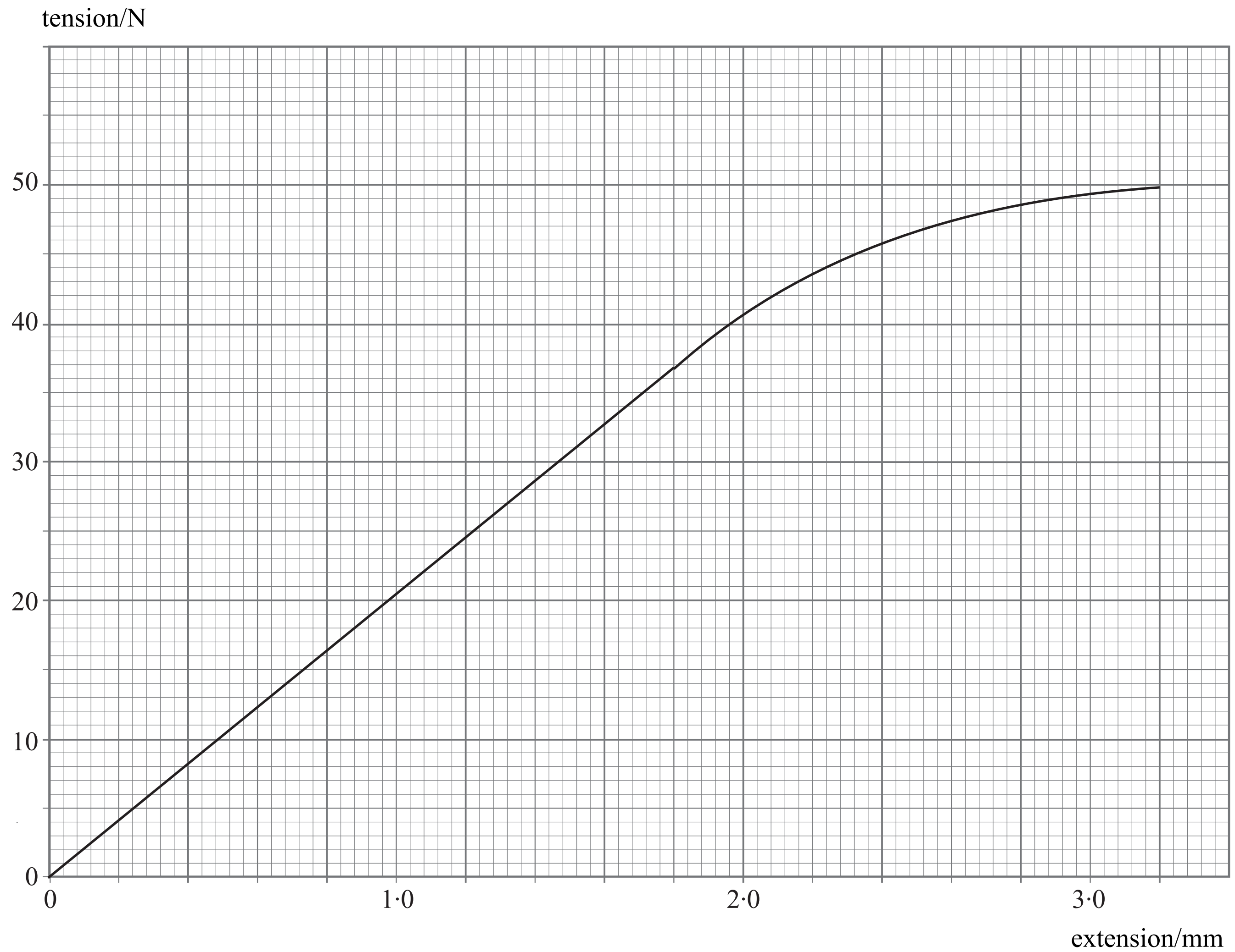

Figure 5

(a) Use the graph in **Figure 5** to estimate the total work done by the force on the wire when the extension reached 3.0 mm. Explain your working.

(4 marks)

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(b) The copper used to make the wire has a Young Modulus of 1.2×10^{11} Pa. Calculate the cross-sectional area of the wire when the extension was 1.2 mm. The original length of the wire was 3.0 m.

(3 marks)

(c) (i) On **Figure 5**, sketch a graph for a wire made of the same copper which is longer than the original one but has the same thickness. Label this L. *(1 mark)*

(ii) On **Figure 5**, sketch a graph for a wire made of the same copper which is thicker than the original one but has the same length. Label this T. *(1 mark)*

9

TURN OVER FOR THE NEXT QUESTION

Total for this question: ***12 marks***

5 In the circuit shown in **Figure 6** both capacitors are initially uncharged and both switches are open. The values of R, C_2 and the emf of the battery are given in **Figure 6**.

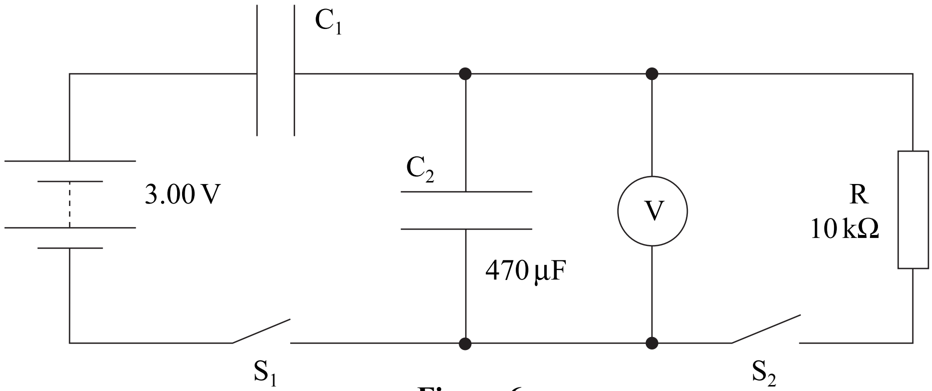

Figure 6

(a) When S_1 is closed, while S_2 remains open, a charge flows until the voltmeter reading is 2.47 V.

(i) Calculate the charge stored by C_2.

(2 marks)

(ii) What is the charge stored by C_1?

(1 mark)

(iii) Calculate the potential difference across C_1.

(1 mark)

(iv) Calculate the capacitance of C_1.

(1 mark)

(b) S_1 is now opened again and S_2 is then closed so that C_2 discharges through R.

(i) Calculate the time constant for this discharge.

(1 mark)

(ii) On the axes given in **Figure 7**, sketch a graph of the potential difference, V, across C_2 against time, t, for this discharge. Mark scales on both axes.

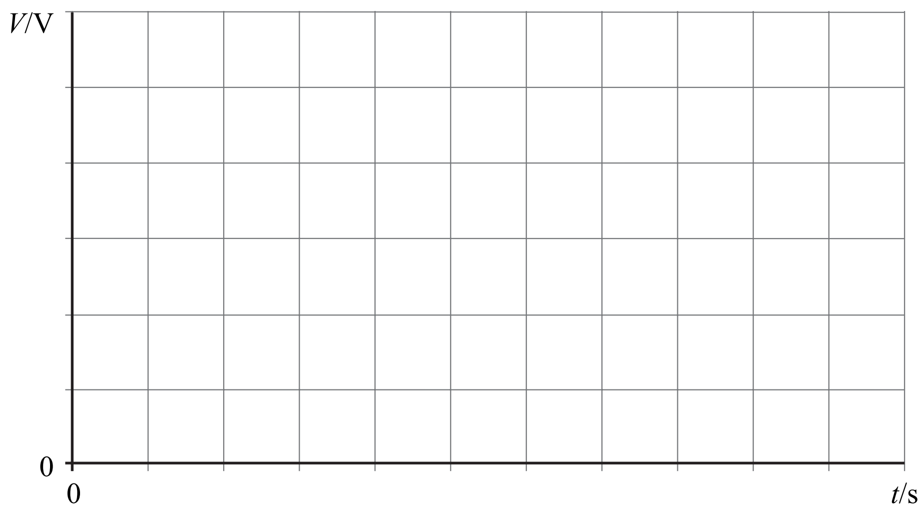

Figure 7

(3 marks)

(c) Calculate the total energy stored by C_1 and C_2 when connected as shown in **Figure 8**.

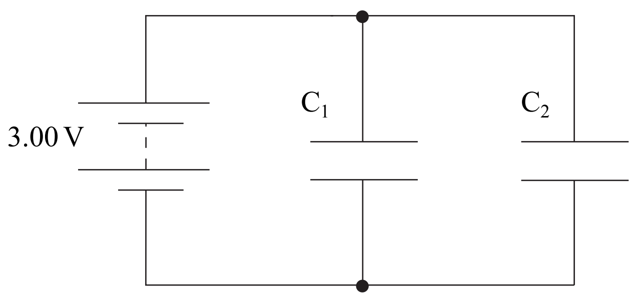

Figure 8

(3 marks)

12

Turn over

Total for this question: ***8 marks***

6 **Figure 9** represents three of the visible lines in the emission spectrum of hydrogen, together with the wavelengths of these lines.

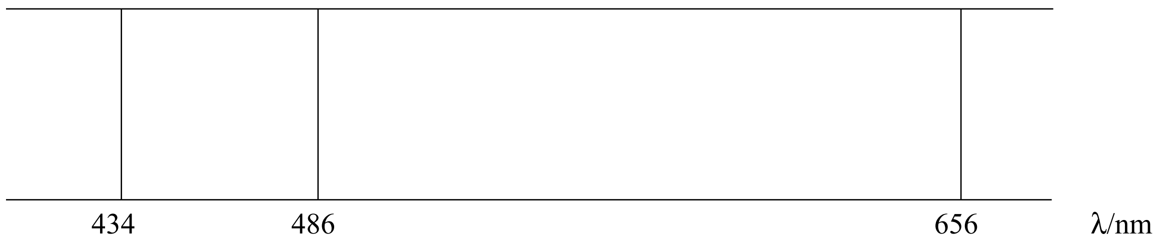

Figure 9

(a) Show that the photon energy for the 486 nm line is about 4×10^{-19} J.

Planck constant = 6.63×10^{-34} J s
speed of light in a vacuum = 3.00×10^{8} m s^{-1}

(3 marks)

Figure 10 represents some of the allowed energy levels within the hydrogen atom. The energy for each is given in the diagram.

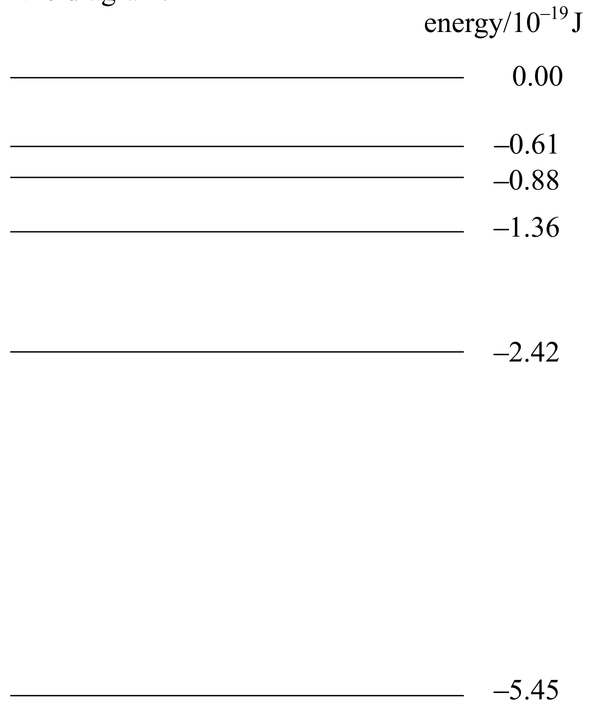

Figure 10

(b) Without calculation, describe how the energy levels shown in **Figure 10** can be used to explain the emission spectrum of hydrogen.

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(3 marks)

(c) Draw an arrow on **Figure 10** to show which transition within the hydrogen atom leads to the 486 nm spectral line shown in **Figure 9**.

(2 marks)

8

TURN OVER FOR THE NEXT QUESTION

Total for this question: *8 marks*

7 The first Law of Thermodynamics is about the relationship between *heat, work* and *internal energy.* Explain how the First Law of Thermodynamics applies to a hot lump of metal when it is dropped into a bucket of cold water.

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

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(8 marks)

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END OF QUESTIONS