Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
January 2004
Advanced Level Examination

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

Monday 26 January 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 pages 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.
- 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			
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6			
7			
8			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

PHB4

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Answer **all** questions.

Total for this question: ***6 marks***

1 (a) State the conditions necessary for a mass to undergo simple harmonic motion.

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(2 marks)

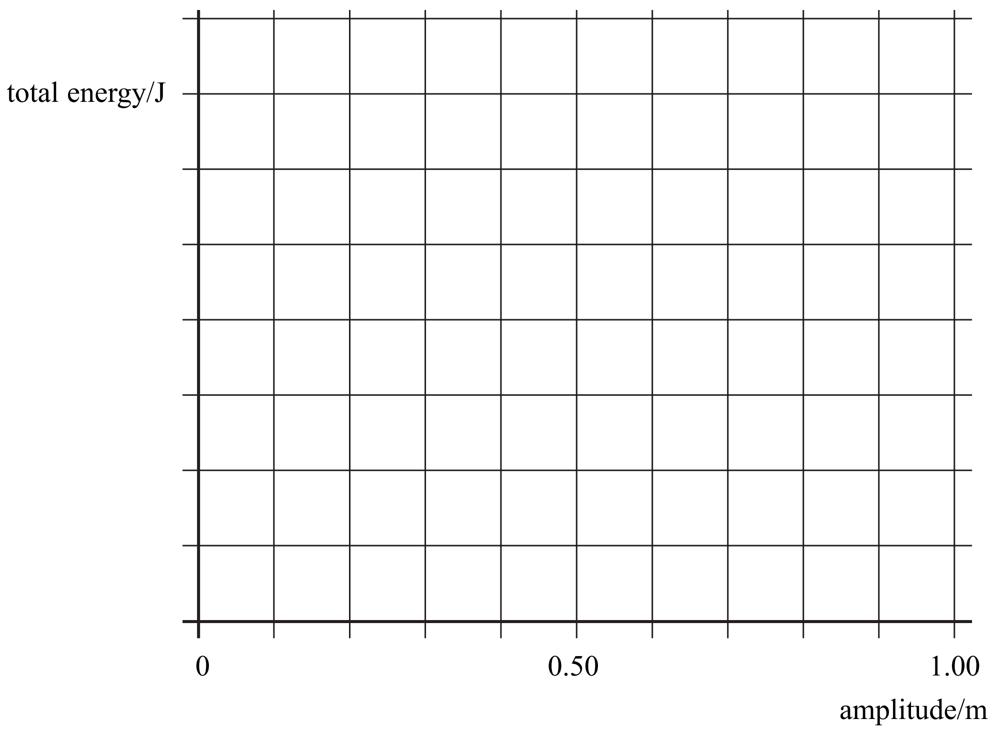
(b) A child on a swing oscillates with simple harmonic motion of period 3.2 s.

acceleration of free fall = $9.8\,\text{m}\,\text{s}^{-2}$

(i) Calculate the distance between the point of support and the centre of mass of the system.

(2 marks)

(ii) The total energy of the oscillations is 40 J when the amplitude of the oscillations is 0.50 m. Sketch a graph showing how the total energy of the child varies with the amplitude of the oscillations for amplitudes between 0 and 1.00 m. Include a suitable scale on the total energy axis.



(2 marks)

6

Detach this perforated page at the start of the examination.

Foundation Physics Mechanics Formulae

moment of force $= Fd$

$v = u + at$

$s = ut + \tfrac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \tfrac{1}{2}(u + v)t$

for a spring, $F = k\Delta l$

energy stored in a spring $= \tfrac{1}{2}F\Delta l = \tfrac{1}{2}k(\Delta l)^2$

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

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

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

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

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 $v << c$

Hubble law $v = Hd$

radioactive decay $A = \lambda N$

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\tfrac{2}{3}e$	$+\tfrac{1}{3}$
down d	$-\tfrac{1}{3}e$	$+\tfrac{1}{3}$
$\overline{u}$	$-\tfrac{2}{3}e$	$-\tfrac{1}{3}$
$\overline{d}$	$+\tfrac{1}{3}e$	$-\tfrac{1}{3}$

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

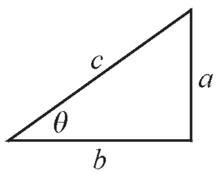
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

Turn over

Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$$v = r\omega$$

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

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

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

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

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

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

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

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

$$\text{in parallel, } C = C_1 + C_2$$

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

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

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

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

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

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

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

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

Momentum and Quantum Phenomena

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

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

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Total for this question: *7 marks*

2 (a) Explain why an engineer needs to consider *the yield stress* of a metal such as steel when deciding on its suitability for use in the construction of a building or a bridge.

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(2 marks)

(b) In order to prevent the collapse of walls of old buildings a metal rod is often used to tie opposite walls together, as shown in **Figure 1**.

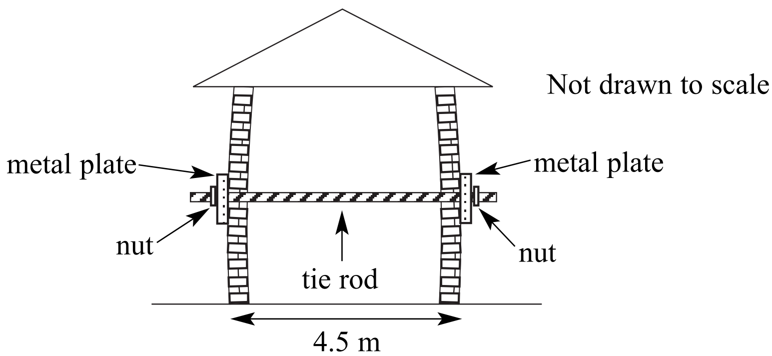

Figure 1

In one case a steel tie rod of diameter 19 mm is used as shown in **Figure 1**. When the nuts are tightened, the rod extends by 1.5 mm. The Young modulus of steel is 2.1×10^{11} Pa.

Calculate:

(i) the force exerted on the walls by the rod;

(3 marks)

(ii) the elastic strain energy in the rod when it is extended by 1.5 mm.

(2 marks)

7

Turn over

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

3 (a) State the principle of conservation of momentum.

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(2 marks)

(b) Two carts **A** and **B**, with a compressed spring between them, are pushed together and held at rest, as shown in **Figure 2**. The spring is not attached to either cart. The carts are then released. **Figure 3** shows how the force, *F*, exerted by the spring on the carts varies with time, *t*, after release.

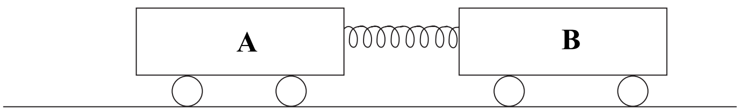

Figure 2

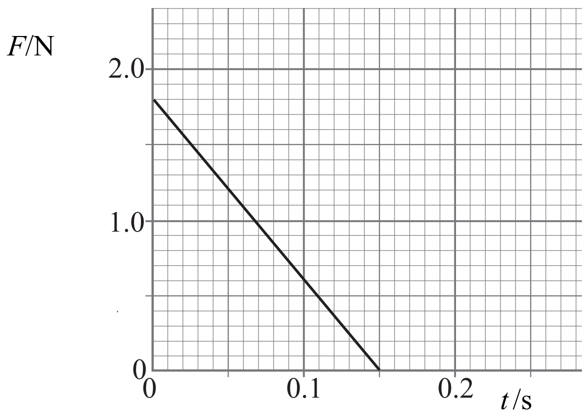

Figure 3

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When the spring returns to its unstretched length and drops away, cart **A** is moving at 0.60 m s^{-1}.

(i) Calculate the impulse given to each cart by the spring as it expands.

(2 marks)

(ii) Calculate the mass of cart **A**.

(2 marks)

(iii) State the final total momentum of the system at the instant the spring drops away.

(1 mark)

7

TURN OVER FOR THE NEXT QUESTION

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

4 **Figure 4** shows a motor lifting a small mass. The energy required comes from a charged capacitor.

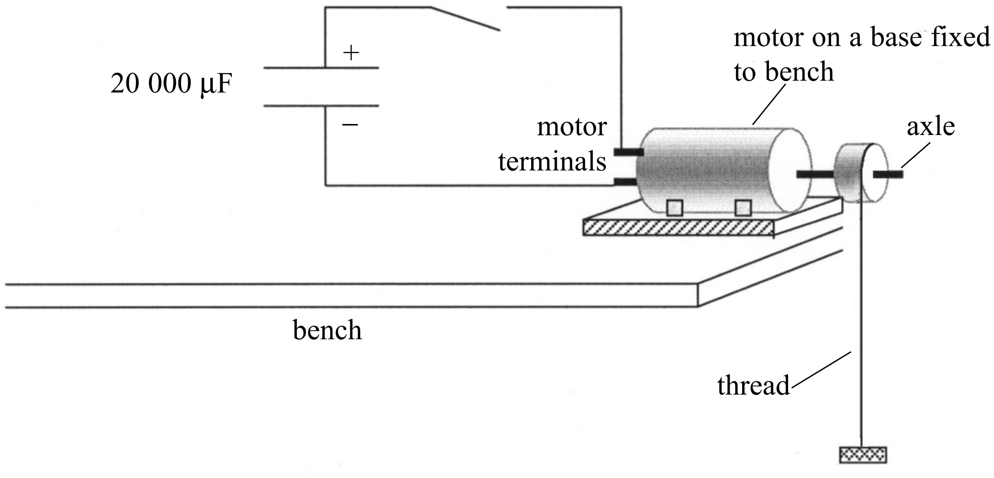

Figure 4

The capacitor was charged to a potential difference of 4.5 V and then discharged through the motor.

(a) (i) The motor only operates when the voltage at its terminals is at least 2.5 V.

Calculate the energy delivered to the motor when the potential difference across the capacitor falls from 4.5 V to 2.5 V.

(3 marks)

(ii) The motor lifted the mass through a distance of 0.35 m. Calculate the efficiency of the transfer of energy from the capacitor to gravitational potential energy of the mass. Give your answer as a percentage.

gravitational field strength = $9.8\ \mathrm{N\,kg^{-1}}$

(2 marks)

(iii) Give **two** reasons why the transfer is inefficient.

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(2 marks)

(b) The motor operated for 1.3 s as the capacitor discharged from 4.5 V to 2.5 V.

Calculate:

(i) the average useful power developed in lifting the mass;

(2 marks)

(ii) the effective resistance of the motor, assuming that it remained constant.

(3 marks)

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12

TURN OVER FOR THE NEXT QUESTION

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Total for this question*: 12 marks*

5 (a) **Figure 5** shows two isothermal *p*-*V* graphs for a fixed mass of an ideal gas trapped in a cylinder by a piston.

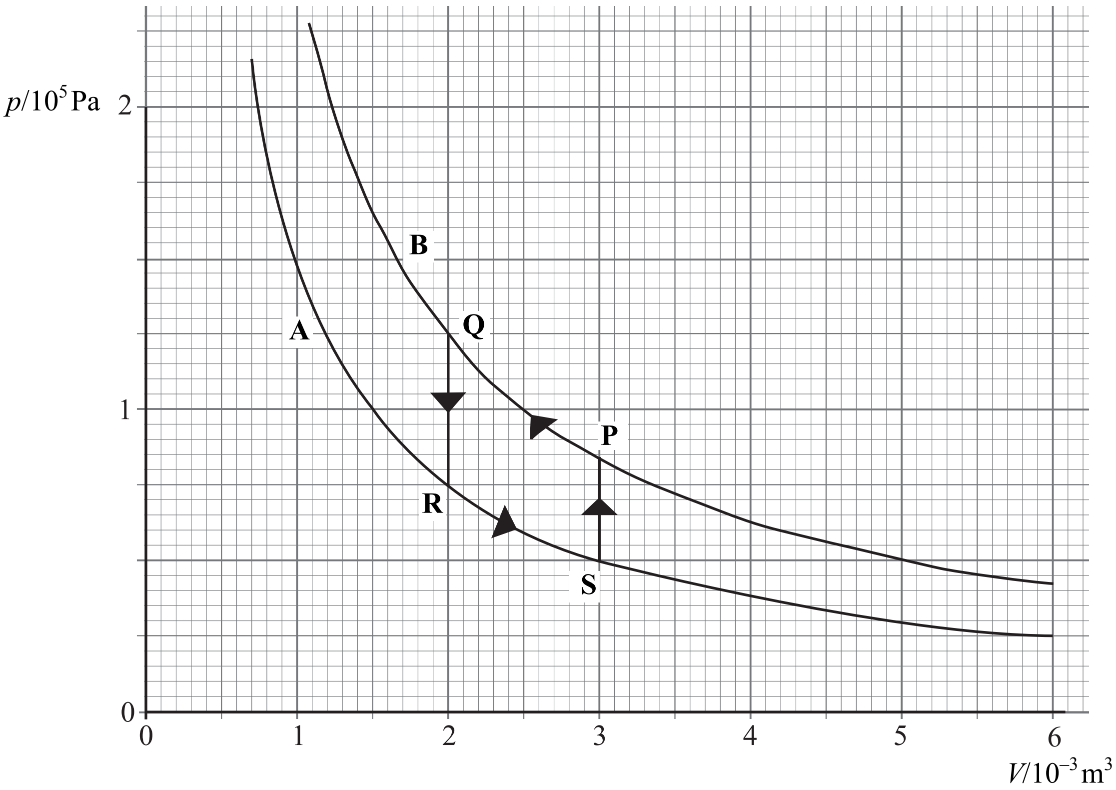

Figure 5

(i) Isothermal **A** is for a temperature of 340 K. Calculate the temperature for isothermal **B**. Show your reasoning clearly.

(2 marks)

(ii) Use data from the graph to determine the number of moles of gas in the container.

universal gas constant, $R = 8.3\ \mathrm{J\,mol^{-1}\,K^{-1}}$.

(3 marks)

(b) The gas is taken around the cycle of changes **PQRSP** shown by the arrows on **Figure 5**.

(i) Calculate the work done during the cycle.

(3 marks)

(ii) State and explain whether this work is done on or by the gas.

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(2 marks)

(iii) The molar heat capacity of the gas at constant volume is $20\,J\,mol^{-1}\,K^{-1}$. Calculate ΔU, the decrease in internal energy of the gas for the change **QR**.

(2 marks)

12

TURN OVER FOR THE NEXT QUESTION

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Total for this question*: 13 marks*

6 When the wheels of a car rotate at 6.5 revolutions per second the external rear view mirror vibrates violently. This is because the centre of mass of one of the wheels is not at the centre of the wheel. To correct this, a mass of 0.015 kg is attached to the rim of the wheel 0.25 m from the centre of the wheel as shown in **Figure 6**.

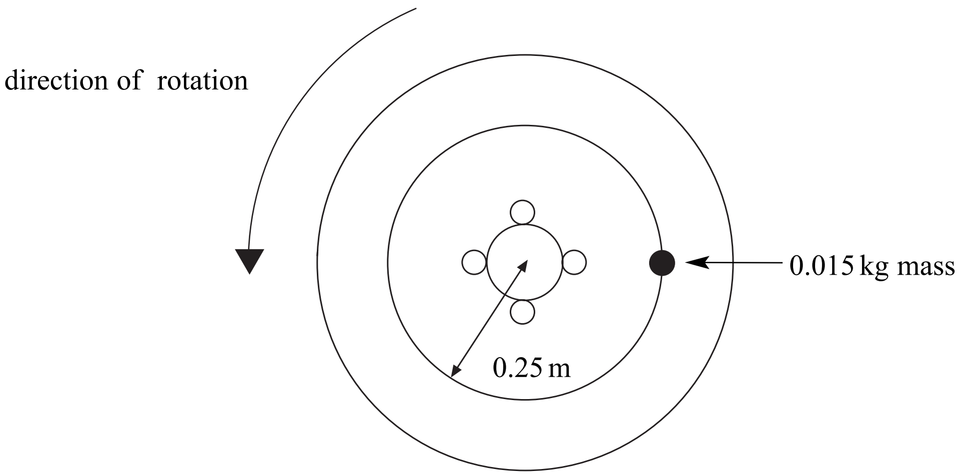


Figure 6

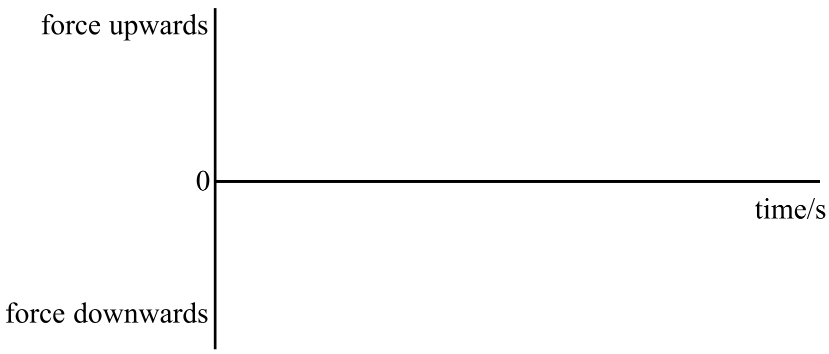
(a) (i) Calculate the force exerted by the wheel on the 0.015 kg mass due to the rotation of the wheel.

(3 marks)

(ii) Draw on **Figure 6** an arrow to show the direction the 0.015 kg mass would move if it became detached when in the position shown in **Figure 6** while the wheel is rotating.

(1 mark)

(b) Sketch, on the axes below, a graph to show how the vertical component of the force acting on the 0.015 kg mass due to the rotation of the wheel varies with time, t, during one complete rotation of the wheel. At $t = 0$ the 0.015 kg mass is in the position shown in **Figure 6**. Include a suitable time scale.



(2 marks)

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(c) Without the mass in place, the rotation of the wheel makes the external rear-view mirror of the car undergo forced oscillations.

Explain what is meant by *forced oscillations* and state and explain how these oscillations will vary as the car increases in speed from rest.

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

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(7 marks)

13

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Total for this question*: 8 marks*

7 **Figure 7** shows some of the allowed energy levels of a helium atom.

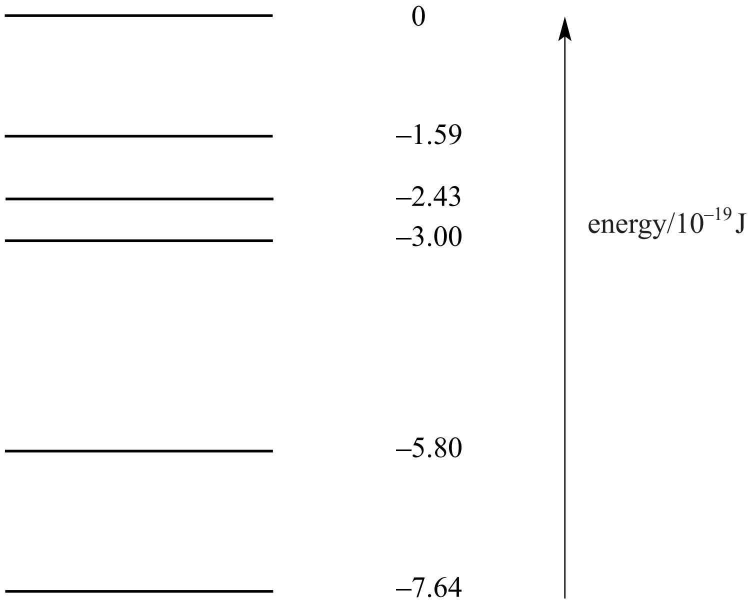

Figure 7

(a) (i) Explain what happens in an atom of helium when it emits the lowest frequency of electromagnetic radiation for these levels.

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(2 marks)

(ii) Calculate the wavelength of this radiation.

Planck constant $= 6.6 \times 10^{-34}$ J s
speed of electromagnetic radiation in free space $= 3.0 \times 10^{8}$ m s^{-1}

(3 marks)

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(b) In a helium-neon laser it is essential that one of the excited states is a *metastable state* so that *population inversion* can take place.

Explain:

(i) how a metastable state is different from the other excited states of an atom;

....

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(1 mark)

(ii) what is meant by population inversion.

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(2 marks)

8

TURN OVER FOR THE NEXT QUESTION

Turn over

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Total for this question: *10 marks*

8 (a) Describe the process known as *the photoelectric effect*.

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(2 marks)

(b) Describe an experiment you could perform which demonstrates that electromagnetic radiation exhibits particle properties.

Your answer should include a diagram of the apparatus, a description of the procedure you would use and an explanation of how the observations made in the experiment suggest a particle nature.

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

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(8 marks)

10

END OF QUESTIONS