Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
January 2003
Advanced Level Examination

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

Thursday 27 January 2003 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			
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7			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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Answer **all** questions

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

1 (a) Explain what is meant by a capacitance of 1 farad (F).

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(1 mark)

(b) A parallel plate capacitor was made from two circular metal plates with air between them. The distance between the plates was 1.8 mm. The capacitance of this capacitor was found to be 2.3×10^{-11} F.

The permittivity of free space $\varepsilon_0 = 8.9 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
The relative permittivity of air = 1.0

Calculate:

(i) the radius of the plates used in the capacitor;

(3 marks)

(ii) the energy stored when the potential difference between the capacitor plates is 6.0 V.

(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

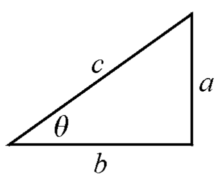
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

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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(c) A student charged the capacitor and then tried to measure the potential difference between the plates using an oscilloscope. The student observed the trace shown in **Figure 1** and concluded that the capacitor was discharging through the oscilloscope.

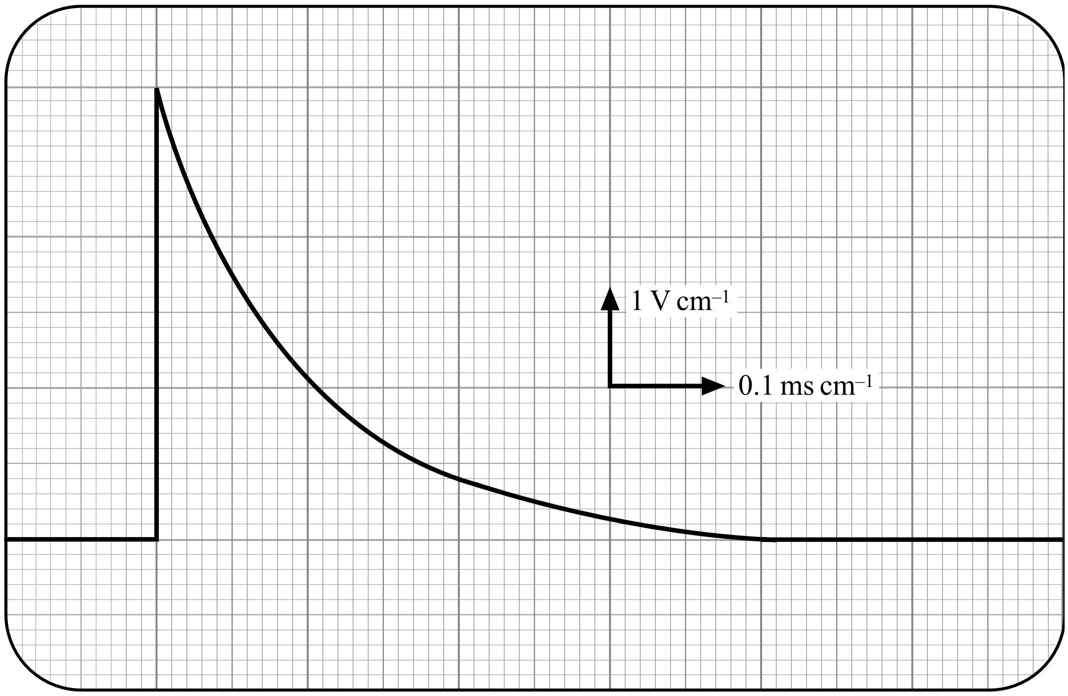

Figure 1

Calculate the resistance of the oscilloscope.

(3 marks)

9

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Total for this question: *8 marks*

2 To allow for expansion, railway lines laid in the winter are pre-stressed so that when they heat up in the summer they do not buckle.

A strain of 1.5×10^{-5} is required for each kelvin rise in temperature that is expected.

In one instance a line is laid when the temperature is 5.0 ºC. The engineer decides to apply a tensile force of 1.9×10^{5} N to a steel rail of cross-sectional area 5.3×10^{-3} m^2.

Young modulus of the steel = 2.0×10^{11} Pa

Calculate:

(a) the strain produced when the rail is laid;

(3 marks)

(b) the temperature at which the rail becomes unstressed;

(2 marks)

(c) the elastic strain energy stored in a 50 m rail at a temperature of 5.0 ºC.

(3 marks)

8

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

3 **Figure 2** shows a simple accelerometer designed to measure the centripetal acceleration of a car going round a bend following a circular path.

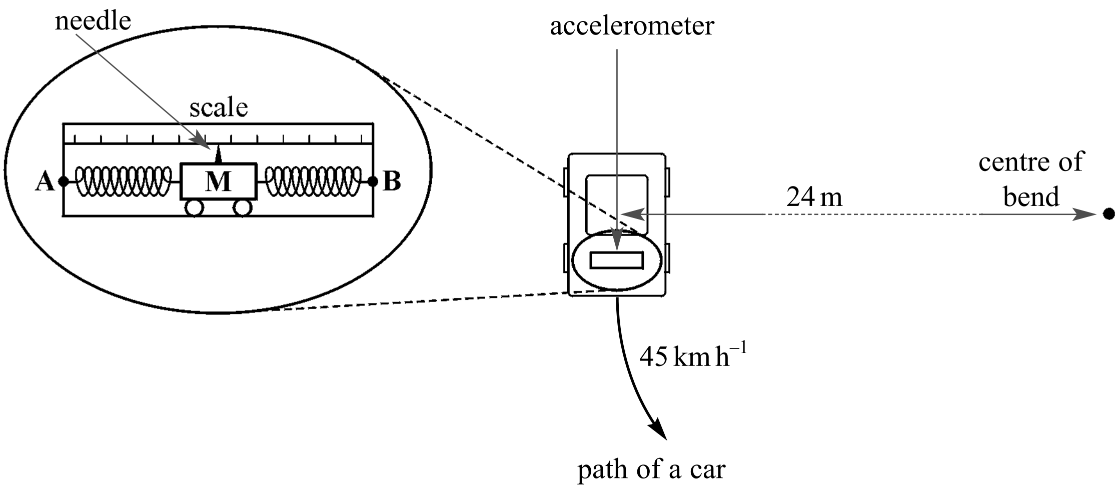

Figure 2

The two ends **A** and **B** are fixed to the car. The mass **M** is free to move between the two springs. The needle attached to the mass moves along a scale to indicate the acceleration.

In one instant a car travels round a bend of radius 24 m in the direction shown in **Figure 2**. The speed of the car is 45 km h^{-1}.

(a) State and explain the direction in which the pointer moves from its equilibrium position.

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(3 marks)

(b) (i) Calculate the acceleration that would be recorded by the accelerometer.

(2 marks)

(ii) The mass **M** between the springs in the accelerometer is 0.35 kg. A test shows that a force of 0.75 N moves the pointer 27 mm.

Calculate the displacement of the needle from the equilibrium position when the car is travelling with the acceleration in part (i).

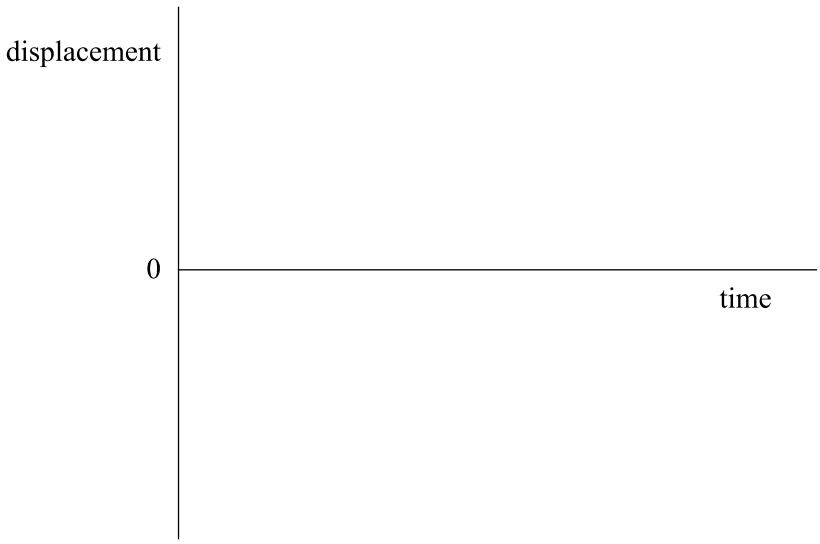
(2 marks)

(c) When the car leaves the bend the accelerometer eventually returns to its zero reading after a few cycles of damped simple harmonic motion.

(i) Calculate the period of the oscillation of the mass **M**.

(3 marks)

(ii) Sketch, on the axes below, a graph showing how the displacement of the mass varies with time from the instant the car leaves the bend. Include appropriate values on the axes of your graph.



(2 marks)

12

Total for this question: *11 marks*

4 (a) Explain why it is usual to quote only one specific heat capacity for a solid but for gases it is necessary to state whether the energy is supplied at constant volume or constant pressure.

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

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(6 marks)

(b) **Figure 3** shows a schematic diagram of a warm air heater.

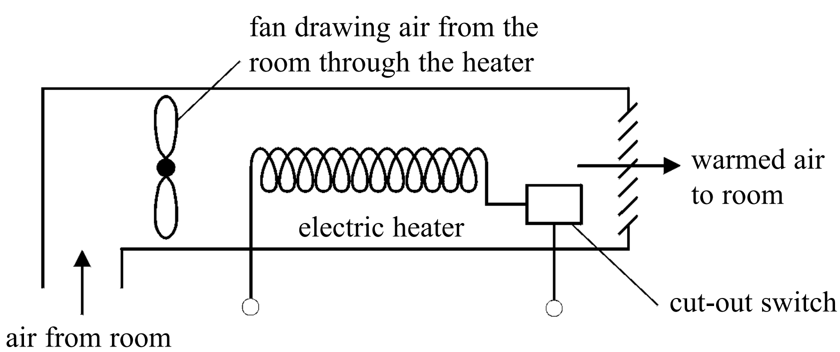

Figure 3

A designer decides that, for safety reasons, the maximum temperature of air leaving the heater should be 45 °C. A cut-out operates when this temperature is achieved. A fan forces air from the room through the heater at a rate of $0.032\,\mathrm{m^3\,s^{-1}}$.

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(i) Calculate the maximum temperature that the air in the room can reach before the cut-out operates when a 750 W heating element is used.

The specific heat capacity of air at constant pressure is 990 J kg^{-1} K^{-1}.
The density of air is 1.3 kg m^{-3}.

(3 marks)

(ii) A higher room temperature is needed using the 750 W element. State and explain how the heater would need to be modified so that the higher room temperature could be reached before the cut-out operates.

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(2 marks)

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11

TURN OVER FOR THE NEXT QUESTION

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Total for this question: ***11 marks***

5 (a) (i) The internal energy of a gas is the sum of the potential and kinetic energies of the molecules of the gas.

Explain why, for an ideal gas, only the kinetic energy changes when the internal energy of the gas is increased either at constant volume or at constant pressure.

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(3 marks)

(ii) Calculate the total kinetic energy of the atoms in 0.025 mol of an ideal gas at a temperature of 290 K.

The Avogrado constant is $6.0 \times 10^{23}\,\text{mol}^{-1}$.
The Boltzmann constant is $1.38 \times 10^{-23}\,\text{J K}^{-1}$.

(2 marks)

(b) The laws of football require the ball to have a circumference between 680 mm and 700 mm. Its pressure should be between 0.61×10^5 and $1.11 \times 10^5\,\text{Pa}$ above atmospheric pressure at sea level.

One ball has a circumference of 690 mm.

The molar mass of air is $0.028\,\text{kg mol}^{-1}$.
The universal gas constant R is $8.3\,\text{J mol}^{-1}\,\text{K}^{-1}$.

(i) The thickness of the material used for the ball is negligible. Show that the volume of air in the football is approximately $5.5 \times 10^{-3}\,\text{m}^3$.

(2 marks)

(ii) Assuming that the temperature is 17 ºC and that the atmospheric pressure at sea level is 1.01×10^5 Pa, calculate the minimum mass of air inside the ball that satisfies the regulation.

(3 marks)

(iii) Calculate the pressure that would exist in the football if the temperature were to fall to 0 ºC. Assume that the volume of the ball remains constant.

(1 mark)

11

TURN OVER FOR THE NEXT QUESTION

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

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

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(2 marks)

(b) **Figure 4** shows a sketch drawn by an accident investigator following a head-on collision between two vehicles.

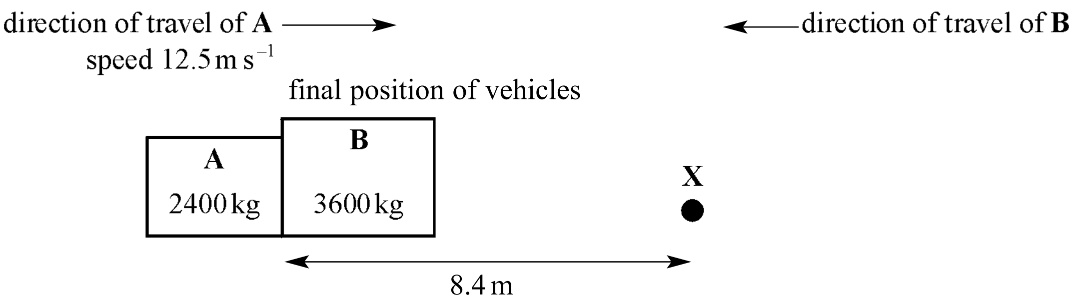

Figure 4

From the skid marks and debris on the road the investigator knows that the collision took place at the point marked **X**. The vehicles locked together on impact and vehicle **A** was pushed backwards a distance of 8.4 m.

For the road conditions and vehicle masses the average frictional force between the road and the vehicles immediately after the collision was known to be 7500 N.

(i) Calculate the work done against friction in bringing the vehicles to rest.

(2 marks)

(ii) Determine the speed of the interlocked vehicles immediately after impact.

(2 marks)

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(iii) Vehicle **A** was known to be moving at $12.5\,m\,s^{-1}$ just before the impact. Calculate the speed of vehicle **B** just before impact.

(3 marks)

(iv) The drivers of both vehicles have the same mass. State and explain which driver is likely to experience the higher force during the impact.

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(4 marks)

13

Total for this question: *11 marks*

7 **Figure 5** shows the energy levels of neon that are involved in the production of laser light from a helium-neon laser. Energies are given relative to the ground state.

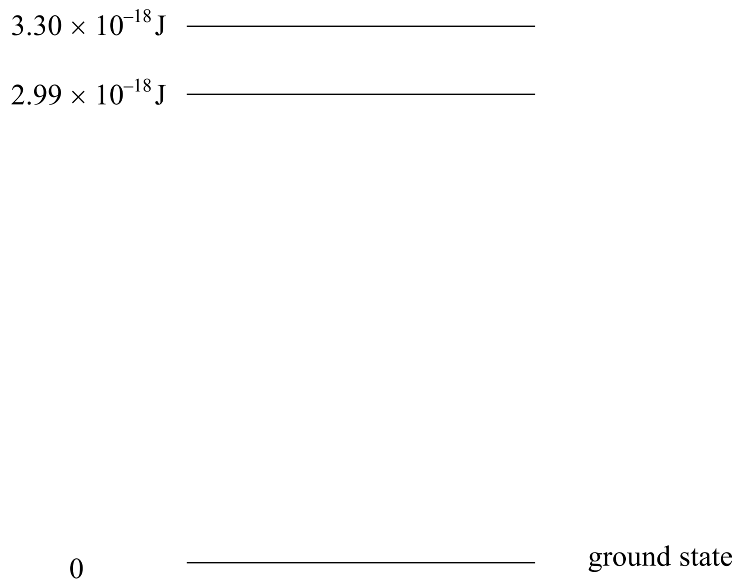

Figure 5

A photon of the laser light has an energy of 3.1×10^{-19} J.

(a) Use an arrow to show on **Figure 5** the energy level transition that produces the photon.

(1 mark)

(b) Calculate the wavelength of the laser light.

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

(3 marks)

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(c) For laser action, atoms of the element which produce the laser light must have *a metastable electron energy level* so that *population inversion* can occur.

Explain the meanings of the terms in italics and explain how laser light is produced.

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

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(7 marks)

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END OF QUESTIONS