| Surname | | Other Names | |
|---|---|---|---|
| Centre Number | | Candidate Number | |
| Candidate Signature | | | |

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General Certificate of Education
January 2002
Advanced Level Examination

AQA
ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Monday 28 January 2002 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 these perforated pages 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 | | | |
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| Number | Mark | Number | Mark |
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Answer **all** questions in the spaces provided.

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

**Figure 1** shows how the kinetic energy of a simple pendulum varies with displacement.

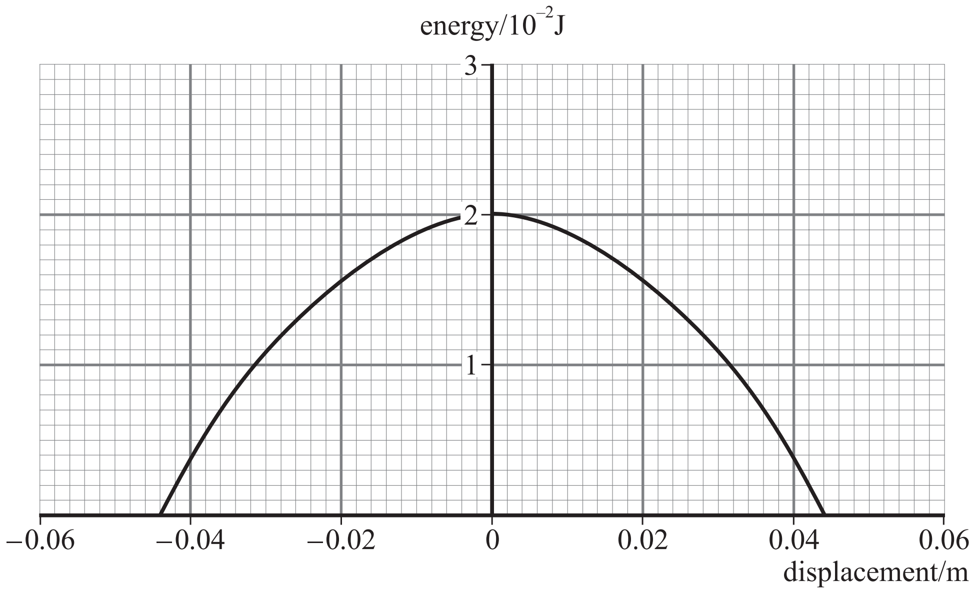


**Figure 1**

(a) Sketch on **Figure 1** a graph to show how the potential energy of the pendulum varies with displacement. *(2 marks)*

(b) (i) State the amplitude of the oscillation.

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*(1 mark)*

(ii) The frequency of vibration of the pendulum is 3.5 Hz. Write down the equation that models the variation of position with time for the simple harmonic motion of **this** pendulum.

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*(1 mark)*

(iii) Calculate the maximum acceleration of the simple pendulum.

*(2 marks)*

6

**Detach this perforated page at the start of the examination.**

## Foundation Physics Mechanics Formulae

$$\text{moment of force} = Fd$$

$$v = u + at$$

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

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

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

$$\text{for a spring, } F = k\Delta l$$

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

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

## Foundation Physics Electricity Formulae

$$I = nAvq$$

$$\text{terminal p.d.} = E - Ir$$

$$\text{in series circuit, } R = R_1 + R_2 + R_3 + .....$$

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

$$\text{output voltage across } R_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times \text{input voltage}$$

## Waves and Nuclear Physics Formulae

$$\text{fringe spacing} = \frac{\lambda D}{d}$$

$$\text{single slit diffraction minimum } \sin\theta = \frac{\lambda}{b}$$

$$\text{diffraction grating } n\lambda = d\sin\theta$$

$$\text{Doppler shift } \frac{\Delta f}{f} = \frac{v}{c} \text{ for } v << c$$

$$\text{Hubble law } v = Hd$$

$$\text{radioactive decay } A = \lambda N$$

### 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 $L$ | | |
|---|---|---|---|
| | $L_e$ | $L_\mu$ | $L_\tau$ |
| $e^-$ | 1 | | |
| $e^+$ | –1 | | |
| $\nu_e$ | 1 | | |
| $\overline{\nu}_e$ | –1 | | |
| $\mu^-$ | | 1 | |
| $\mu^+$ | | –1 | |
| $\nu_\mu$ | | 1 | |
| $\overline{\nu}_\mu$ | | –1 | |
| $\tau^-$ | | | 1 |
| $\tau^+$ | | | –1 |
| $\nu_\tau$ | | | 1 |
| $\overline{\nu}_\tau$ | | | –1 |

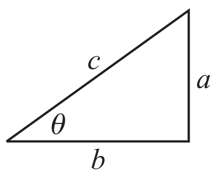
## Geometrical and Trigonometrical Relationships

$$\text{circumference of circle} = 2\pi r$$

$$\text{area of a circle} = \pi r^2$$

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

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




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

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

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

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

**Detach this perforated page at the start of the examination.**

## Circular Motion and Oscillations

$$v = r\omega$$

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

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

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

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

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

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

## 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

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

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

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

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

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

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

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

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

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

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

## Momentum and Quantum Phenomena

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

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

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

(a) State what is meant by the *yield stress* of a material.

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*(3 marks)*

(b) A steel piano wire has a diameter of $1.8 \times 10^{-3}$ m and a length of 1.55 m. When tightened to emit a note of the required frequency it extends by $1.3 \times 10^{-3}$ m. The Young modulus of the steel is $2.1 \times 10^{11}$ Pa.

(i) Calculate the force exerted on the frame of the piano by this wire.

*(3 marks)*

(ii) Calculate the strain energy stored in this stretched wire.

*(2 marks)*

8

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

The photoelectric effect is one piece of evidence that suggests that light behaves like a stream of particles or photons.

(a) State what is meant by the threshold frequency in an experiment to investigate the photoelectric effect.

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*(2 marks)*

(b) State and explain the effect of increasing the intensity of light on the rate at which electrons are emitted.

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*(2 marks)*

(c) In an experiment to investigate the photoelectric effect the radiation incident on the surface caused the emission of electrons of energy $1.5 \times 10^{-19}$ J. The work function of the surface was known to be $3.2 \times 10^{-19}$ J.

The Planck constant $h$ is $6.6 \times 10^{-34}$ J s.
The speed of electromagnetic radiation is $3.0 \times 10^{8}$ m s$^{-1}$.
The mass of an electron is $9.1 \times 10^{-31}$ kg.

(i) Calculate the wavelength of the incident radiation.

*(2 marks)*

(ii) Calculate the de Broglie wavelength of the emitted electrons.

*(3 marks)*

9

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

A student uses the system shown in **Figure 2** to measure the contact time of a metal ball when it bounces on a metal block.

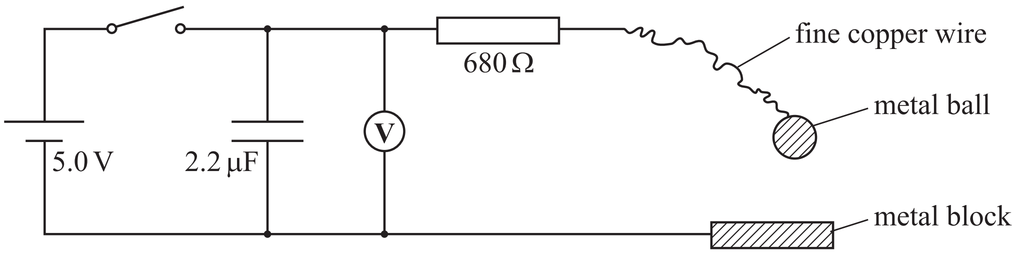


**Figure 2**

The student charges the capacitor by closing the switch, records the voltmeter reading and then opens the switch. The student then releases the ball and measures the voltage after the ball has rebounded from the metal block.

In one test the student records an initial voltage of 5.0 V and a final voltage of 2.2 V.

(a) Calculate the time for which the ball is in contact with the block.

*(3 marks)*

(b) (i) Calculate the energy lost by the capacitor during the discharge.

*(2 marks)*

(ii) State where this energy is dissipated and the form it will take.

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*(2 marks)*

**Turn over ►**

(c) In an attempt to measure **longer** contact times the student decides to place a second capacitor of capacitance 3.3 μF **in series** with the first with the intention that a similar change in voltage will be recorded.

(i) Calculate the combined capacitance of the two capacitors in series.

*(2 marks)*

(ii) Explain whether the adjustment to the circuit will have the desired effect.

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*(1 mark)*

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

The mass of a car and its passengers is 950 kg. When the brakes are applied the car decelerates uniformly from a speed of $25\,\text{m}\,\text{s}^{-1}$ to a speed of $15\,\text{m}\,\text{s}^{-1}$ in 2.5 s.

(a) Calculate the decelerating force developed by the brakes.

*(2 marks)*

(b) Calculate the work done in decelerating the car.

*(3 marks)*

(c) Calculate the rate of energy dissipation by the brakes.

*(2 marks)*

(d) There are four brake discs, each of mass 1.2 kg. The material from which the discs are made has a specific heat capacity of $510\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

(i) Assuming that all the energy dissipated during braking is converted into internal energy of the brake discs equally, calculate the temperature rise of the discs.

*(3 marks)*

(ii) State and explain the effect on the temperature rise of one factor that has not been taken into account in the assumption in part (i).

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*(2 marks)*

*12*

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

**Figure 3** shows the initial path taken by an electron when it is produced as a result of a collision in a cloud chamber.

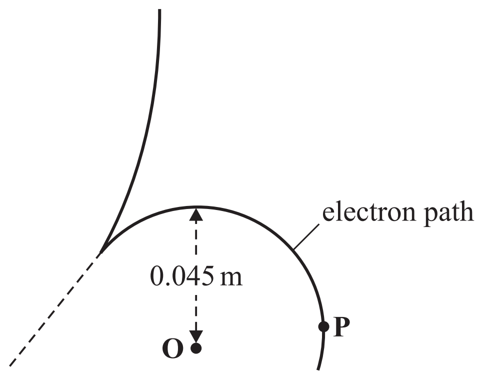


**Figure 3**

The path is the arc of a circle of radius 0.045 m with centre **O**.

(a) The speed of the electron is $4.2 \times 10^{7}\,\mathrm{m\,s^{-1}}$. The mass of an electron is $9.1 \times 10^{-31}$ kg.

(i) Calculate the momentum of the electron.

*(2 marks)*

(ii) Calculate the magnitude of the force acting on the electron that makes it follow the curved path.

*(2 marks)*

(iii) Show on **Figure 3** the direction of this force when the electron is at the point **P**.

*(1 mark)*

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(b) When an electron hits an atom of hydrogen in a cloud chamber, it is possible for any one of the following events to occur. The electron may undergo *an elastic collision*, ionise the hydrogen atom or cause the hydrogen atom to emit light.

In the space and on the lines below, you are to explain these events.

In your answer, include:

- an explanation of the term *an elastic collision*;
- a sketch of the energy levels of an electron in a hydrogen atom, including the ground state ($-13.6\,eV$);
- an explanation of what happens when an electron ionises a hydrogen atom and how an electron can cause a hydrogen atom to emit light.

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

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*(8 marks)*

*13*

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**7** **Total for this question:** ***17 marks***

**Figure 4** shows a bicycle inner tube in which the pressure is being increased using a bicycle pump.

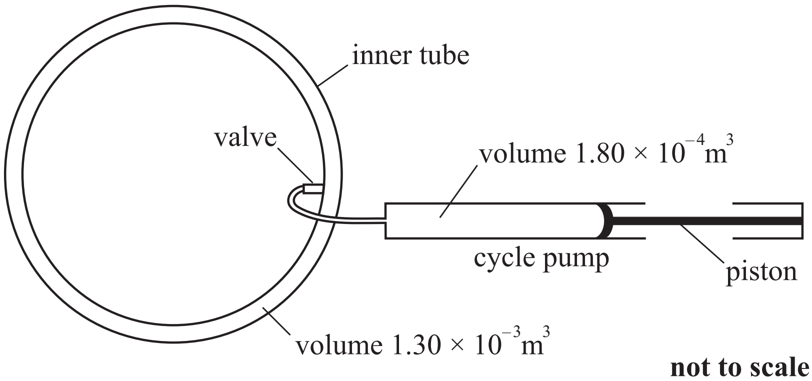


**Figure 4**

The cycle inner-tube has a volume of $1.30 \times 10^{-3}\,\text{m}^3$ which remains constant as more air is pushed into it. When full of air, the pump contains $1.80 \times 10^{-4}\,\text{m}^3$ of air at a pressure of $1.00 \times 10^5\,\text{Pa}$ and a temperature of 300 K.

When the piston is pushed in, all the air molecules from the pump are transferred into the inner tube.

(a) Initially the air in the inner tube has a pressure of $1.50 \times 10^5\,\text{Pa}$ and a temperature of 300 K.

the universal gas constant, $R = 8.31\,\text{J mol}^{-1}\,\text{K}^{-1}$

(i) Calculate the number of moles of gas in the inner tube initially.

*(2 marks)*

(ii) Calculate the number of moles of gas transferred into the inner tube each time air is pushed into the tube.

*(1 mark)*

(iii) Calculate the new pressure in the inner tube after one "pump-full" of air has been transferred to the inner tube.

Assume that the temperature of the air in the pump and the inner tube remains constant at 300 K when the air is pushed into the inner tube and that air behaves like an ideal gas.

*(1 mark)*

(b) Explain how the kinetic theory model of an ideal gas predicts:

– the existence of gas pressure;

– an increase in pressure when more molecules are transferred to the inner tube.

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

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*(7 marks)*

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(c) **Figure 5** shows a graph of the variation of pressure with volume of the air in the pump up to the time when it starts to enter the inner tube.

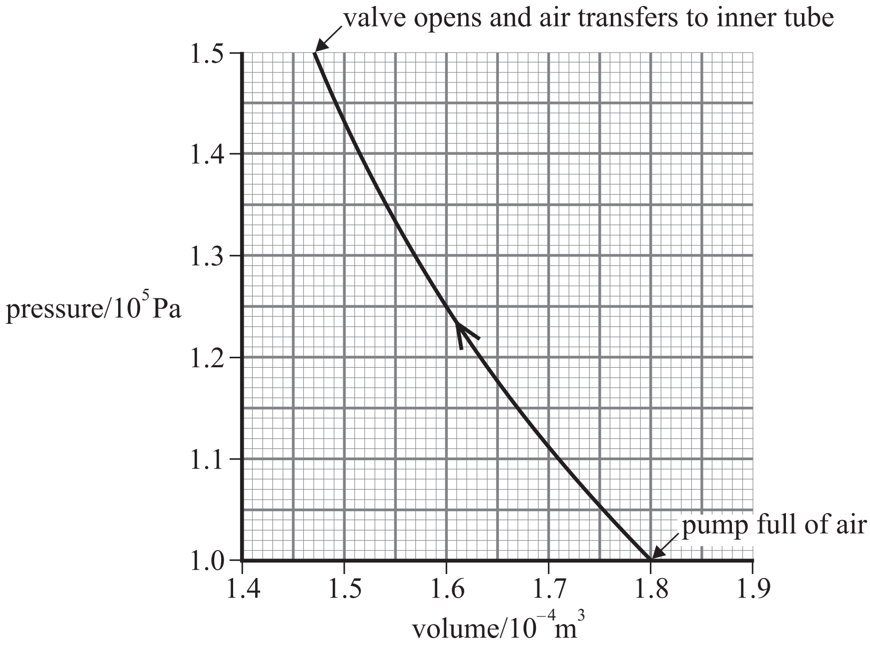


**Figure 5**

(i) Use data from the graph to show that the change is not isothermal.

*(2 marks)*

(ii) Use the graph to estimate the work done on the gas while the gas is being compressed to the point at which the air enters the inner tube. Show your working.

**Notice that neither of the scales on the axes starts at zero.**

*(4 marks)*

17

**END OF QUESTIONS**

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