

**PHYSICS (SPECIFICATION B)  
Unit 6 Exercise 1**

**PHB6/1**

to be conducted between 1 March 2004 and 21 May 2004

**In addition to this paper you will require:**

- an 8-page answer book;
- A4 graph paper;
- a calculator;
- a ruler.

Time allowed: 1 hour 30 minutes

**Instructions**

- Use blue or black ink or ball-point pen.
- Write the information required on the front of the answer book. The *Examining Body* for this unit is AQA. The *Paper Reference* is PHB6/1.
- Answer **all** questions. A separate sheet of graph paper is required.
- *Formulae Sheets* are provided on pages 3 and 4. Detach this perforated page at the start of the examination.
- Show all your working. Do all rough work in the answer book. Cross through any work you do not want marked.

**Information**

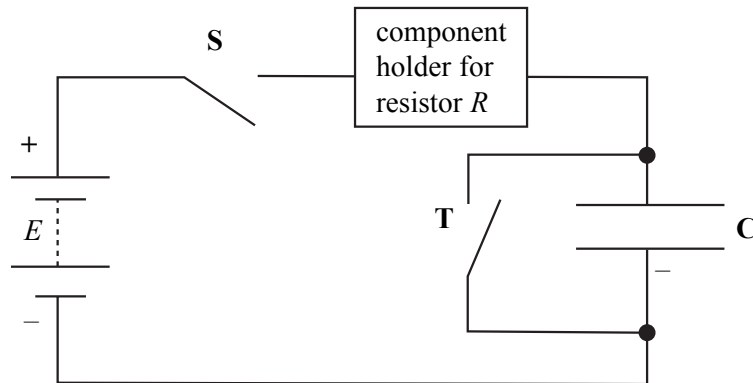
- The maximum mark for this paper is 39.
- Mark allocations are shown in brackets.
- You are expected to use a calculator where appropriate.
- You will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist 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.

**Advice**

- Before commencing the first part of any question, read the question through completely.
- Ensure that **all** measurements taken, including repeated readings, gradients, derived quantities, etc., are recorded to an appropriate number of significant figures with due regard to the accuracy of measurement.
- If an experiment does not operate correctly, you should request assistance from the Supervisor. The Supervisor will give the minimum help necessary to make the experiment operate and will report the action taken to the Examiner. If the fault is due to your inability to make the experiment operate, a deduction of marks will be made, but it will be possible for you to complete the remainder of the question and gain marks for the later parts of that question.

Answer **all** questions.

- 1 You are going to investigate the charging of a capacitor and determine the capacitances of two capacitors. The circuit shown in **Figure 1** has been set up for you.



**Figure 1**

**NOTE**

- 1 **Before making any measurement the capacitor MUST be discharged.**  
**To discharge the capacitor:**

turn switch **S** to **OFF**;  
 turn switch **T** to **ON** for a few seconds;  
 turn switch **T** to **OFF**.

- 2 When using the voltmeter ensure that the terminal marked ‘-’ on the voltmeter lead is connected to the terminal marked ‘-’ on the supply.

- (a) (i) Using the voltmeter, measure and record the emf,  $E$ , of the supply you are using. *(1 mark)*
- (ii) Connect the voltmeter across the capacitor, **C**. Using **one** of the resistors provided, make  $R = 22 \text{ k}\Omega$ .
- Turn switch **S** to **ON** and start the stopwatch at the same time. The capacitor will now charge up.
- Stop the charging after 10 s by turning switch **S** to **OFF**.
- Record the potential difference,  $V$ , across the capacitor at the instant charging was stopped. *(2 marks)*
- (iii) The rate of charging decreases as the capacitor charges. Explain why this happens. *(3 marks)*
- (iv) Calculate the maximum power dissipated in the  $22 \text{ k}\Omega$  resistor during the charging process. The internal resistance of the supply may be ignored. *(2 marks)*
- (v) State when this maximum power dissipation occurs. *(1 mark)*

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### Foundation Physics Mechanics Formulae

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

$$v = u + at$$

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

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

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

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

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

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

### Foundation Physics Electricity Formulae

$$I = nAvq$$

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

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

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

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

### Waves and Nuclear Physics Formulae

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

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

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

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

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

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

### Properties of Quarks

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

### Lepton Numbers

| Particle         | Lepton number $L$ |         |          |
|------------------|-------------------|---------|----------|
|                  | $L_e$             | $L_\mu$ | $L_\tau$ |
| $e^-$            | 1                 |         |          |
| $e^+$            | -1                |         |          |
| $\nu_e$          | 1                 |         |          |
| $\bar{\nu}_e$    | -1                |         |          |
| $\mu^-$          |                   | 1       |          |
| $\mu^+$          |                   | -1      |          |
| $\nu_\mu$        |                   | 1       |          |
| $\bar{\nu}_\mu$  |                   | -1      |          |
| $\tau^-$         |                   |         | 1        |
| $\tau^+$         |                   |         | -1       |
| $\nu_\tau$       |                   |         | 1        |
| $\bar{\nu}_\tau$ |                   |         | -1       |

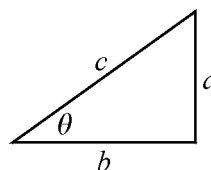
### Geometrical and Trigonometrical Relationships

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

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

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

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



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

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

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

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

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### Circular Motion and Oscillations

$$v = r\omega$$

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

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

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

$$\text{maximum } v = 2\pi f A$$

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

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

### Fields and their Applications

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

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

$$k = \frac{1}{4\pi\epsilon_0}$$

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

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

$$\text{for point masses, } \Delta E_p = GM_1 M_2 \left( \frac{1}{r_1} - \frac{1}{r_2} \right)$$

$$\text{for point charges, } \Delta E_p = kQ_1 Q_2 \left( \frac{1}{r_1} - \frac{1}{r_2} \right)$$

$$\text{for a straight wire, } F = BIl$$

$$\text{for a moving charge, } F = BQv$$

$$\phi = BA$$

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

$$E = mc^2$$

### Temperature and Molecular Kinetic Theory

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

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

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

### Heating and Working

$$\Delta U = Q + W$$

$$Q = mc\Delta\theta$$

$$Q = ml$$

$$P = Fv$$

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

$$\text{work done on gas} = p\Delta V$$

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

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

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

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

### Capacitance and Exponential Change

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

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

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

$$\text{parallel plate capacitance, } C = \frac{\epsilon_0 \epsilon_r A}{d}$$

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

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

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

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

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

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

### Momentum and Quantum Phenomena

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

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

- (b) (i) You are now going to investigate how the potential difference,  $V$ , across the capacitor varies with  $R$ , when the capacitor has been charged for 10 s.

You will be required to plot a graph of  $\ln(E - V)$  against  $\frac{1}{R}$ , where  $R$  is in  $\Omega$ .

You have been provided with two  $22\text{ k}\Omega$  and two  $33\text{ k}\Omega$  resistors. You also have an extra component holder so that you can connect these in the circuit in any combination you choose.

Use the resistors provided to obtain **five further sets** of values for  $R$  and  $V$ .

You should use a maximum of **two** resistors in any combination. You are advised to connect only similar value resistors in parallel. (11 marks)

- (ii) The equation for the charging of the capacitor is

$$(E - V) = E e^{-t/RC}$$

Plot a graph of  $\ln(E - V)$  against  $\frac{1}{R}$ .

(Remember that 'ln' means the logarithm to the base e.) (7 marks)

- (iii) Determine the gradient of your graph. (3 marks)

- (iv) Use the gradient to determine a value for the capacitance of the capacitor. Show clearly how you arrive at your answer. (3 marks)

- (c) You are now going to determine the capacitance of a second capacitor **X**.

Connect the circuit with the second capacitor, **X**, in parallel with the original capacitor, **C**, as shown in **Figure 2**. Ensure that the terminal marked '-' on each capacitor is connected to the terminal marked '-' on the supply.

Make the value of  $R$  equal to  $22\text{ k}\Omega$ .

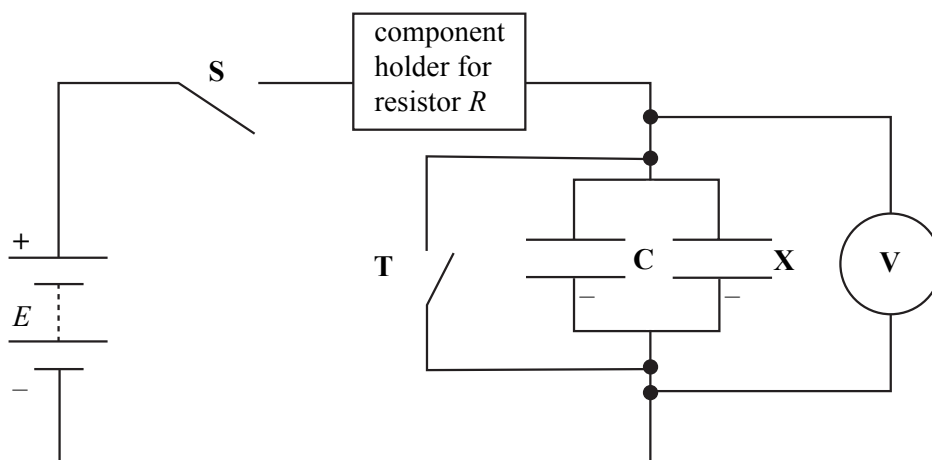


Figure 2

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- (i) Determine the time taken for the potential difference across the combination of capacitors to reach the same value as that which you recorded in part (a)(ii). *(2 marks)*
- (ii) For a given value of  $R$ , the time to reach a given potential difference is directly proportional to the total capacitance in the circuit.
- Calculate the new total capacitance. *(2 marks)*
- (iii) Calculate the capacitance of the second capacitor  $X$ . *(2 marks)*

**END OF QUESTIONS**

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