OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2826/01

Unifying Concepts in Physics

Friday **20 JANUARY 2006** Morning 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator
Ruler (cm/mm)

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	12	
2	19	
3	13	
4	16	
TOTAL	60	

This question paper consists of 12 printed pages.

[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

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

refractive index, $n = \frac{1}{\sin C}$

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

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}<c^2>$

radioactive decay, $x = x_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \frac{3H_0^2}{8\pi G}$

relativity factor, $= \sqrt{(1 - \frac{v^2}{c^2})}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10 \lg \left(\frac{I}{I_0}\right)$

[Turn over

For Examiner's Use

Answer **all** the questions.

1 The following terms are often confused by physics students. State what is meant by each of the following terms so that the differences between them are clear.

(a) speed and velocity

....

....

....

....

....[2]

(b) elastic and plastic

....

....

....

....

....[2]

(c) temperature and heat

....

....

....

....

....[2]

(d) fission and fusion

....

....

....

....

....[2]

For Examiner's Use

(e) kinetic energy and momentum. This should **not** be answered just in terms of the equations $E_k = ½mv^2$ and $p = mv$.

....

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....[4]

[Total: 12]

2 The charge stored in the capacitor **X** of capacitance 5 μF in the circuit given in Fig. 2.1 is 30 μC.

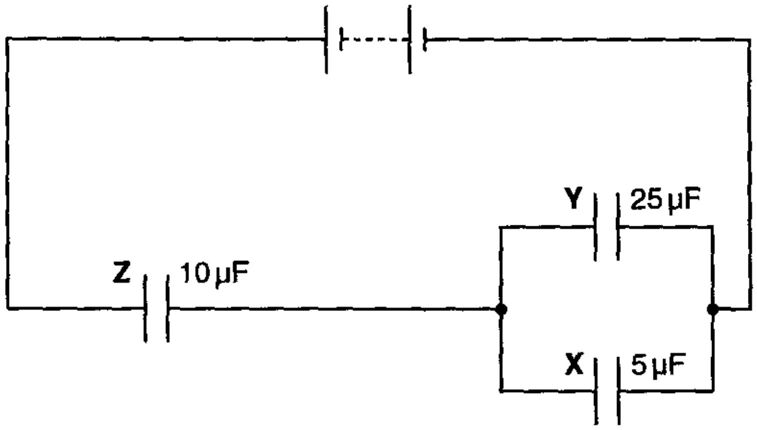

Fig. 2.1

(a) **(i)** Complete the table for this circuit.

capacitor	capacitance / μF	charge / μC	p.d. / V	energy / μJ
X	5	30		
Y	25			
Z	10			

[9]

For Examiner's Use

(ii) Using data from the table find

1 the e.m.f. of the battery

e.m.f. = ... V [1]

2 the total charge supplied from the battery

charge = ... μC [1]

3 the total circuit capacitance

capacitance = ... μF [1]

4 the total energy stored in all the capacitors.

energy = ... μJ [1]

(b) **(i)** What law or principle of physics was used to determine **(a)(ii)1**?

....[1]

(ii) What law or principle of physics was used to determine **(a)(ii)2**?

....[1]

(c) The battery is removed and replaced by a resistor of resistance 200 kΩ. The capacitors now discharge through this resistor. Calculate

(i) the time constant of the circuit

time constant = ... s [2]

(ii) the fraction of the total charge remaining on the capacitors after a time equal to **four** time constants.

fraction remaining = ... [2]

[Total: 19]

[Turn over

3 Efficiency is a word frequently met in physics and in everyday life. It does, however, often have different meanings. The following are all different uses of the word.

X An electric motor has an efficiency of 82%.

Y The efficiency of the insulation of houses should be improved to help reduce global warming.

Z A dictionary definition of efficiency, when applied to a person, is capability or competence.

(a) How is efficiency defined in physics, as used in example **X**?

....

....[1]

(b) Explain the use of the word efficiency in example **Y**. In your answer, state how the efficiency can be improved and why the improvement could bring about a reduction in global warming.

....

....

....

....

....

....[3]

(c) The efficiency ε of a steam turbine in a power station is given by the equation

$$\varepsilon = \frac{\text{work done by turbine}}{\text{heat supplied to turbine in the same time}}.$$

It can be shown that the maximum theoretical efficiency ε_{max} of the turbine is related to the high temperature T_H of the steam entering the turbine and the low temperature T_C of the water cooling the turbine. The equation relating these quantities, with all temperatures in kelvin, is

$$\varepsilon_{max} = \frac{T_H - T_C}{T_H}.$$

(i) Calculate the actual efficiency of a turbine being supplied with heat at a rate of 120 MW and producing an output power of 42 MW.

efficiency = ... [2]

For Examiner's Use

(ii) The turbine in **(i)** is supplied with steam at a temperature of 750 K and is cooled by water at 290 K. What is its maximum theoretical efficiency?

maximum theoretical efficiency = ... [2]

(iii) In order to increase the maximum theoretical efficiency, the temperatures T_H and T_C need to be altered. Which way, raised or lowered, does each need to be changed?

T_H needs to be ....

T_C needs to be .... [1]

(iv) Describe a problem which would arise in practice if

1 T_H was changed in the way you suggest

....

....[1]

2 T_C was changed in the way you suggest.

....

....[2]

(v) What value would T_C need to have in order to get a theoretical efficiency of 1 (100%)?

T_C = ... [1]

[Total: 13]

[Turn over

For Examiner's Use

4 The following is adapted from an article about superconducting devices written by Archie M. Campbell for "Physics World". Read the following paragraphs and answer the questions which follow.

> The electrical resistance of a material suddenly vanishes when it becomes superconducting. This remarkable transition takes place at a critical temperature, which is within a few degrees of absolute zero for most superconducting materials. Certain materials have critical temperatures which are appreciably above absolute zero. Yttrium barium copper oxide (YBCO) has a critical temperature of 92 K and below this temperature it is superconducting. Such materials are extremely useful for electrical devices. For example, the very high currents that can be passed through superconducting materials can be used to generate large magnetic fields, such as those used in magnetic separation of charged particles or in making powerful electric motors.
>
> A problem is that heat will enter into such a cold device. The rate at which work needs to be done to remove the heat leaking into the device increases as the operating temperature is lowered. At 77 K heat leaking in at the rate of 1 W requires 30 W of power to be supplied to the cooling mechanism to maintain a constant temperature. At 4.2 K the power supplied needs to increase to 300 W for each watt leaking in.

(a) State the resistance of a superconducting material below the critical temperature.

Ω ....[1]

(b) Calculate the power required by the cooling mechanism at 4.2 K if heat is leaking into a superconducting device at a rate of 20 W.

power = ... W [1]

(c) Suggest why a superconducting device using YBCO will be run at a temperature of, say, 77 K when its critical temperature is 92 K.

....

....

....[2]

(d) A large electromagnet is made out of superconducting wire of square cross-section having area 1.0 mm^2. It is a circular coil containing 3200 turns of average radius 0.30 m. A cut-away diagram is shown in Fig. 4.1. The wire, when superconducting, has current density through it of 2.0×10^8 amperes per square metre (A m^{-2}) of cross-section.

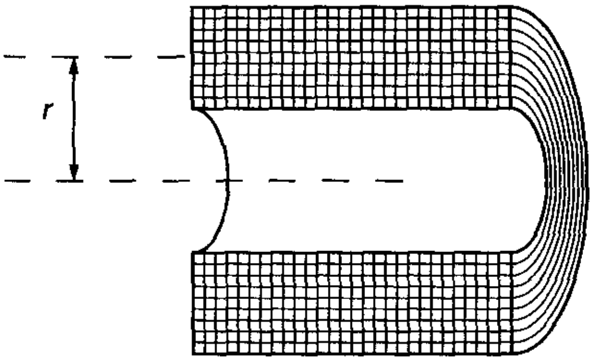

Fig. 4.1

(i) Show that the current in the wire is 200 A.

[2]

(ii) The magnetic flux density B caused by such a coil can be estimated using the equation

$$B = \frac{\mu_0 I N}{2r}$$

where I is the current, N the number of turns, r the average radius of the coil and μ_0 is a constant equal to 1.26×10^{-6} T m A^{-1}.
Calculate the resulting magnetic flux density.

magnetic flux density = ... T [2]

(e) Isotopes of an element can be separated by first ionising them and then firing them into a magnetic field. For example, if singly ionised atoms of U-235 and U-238 are fired into a magnetic field they are deflected into circular paths of different radii.

(i) State the equation for the force F acting on a charge Q moving with velocity v at right angles to a magnetic field of flux density B.

.... [1]

This question continues on the next page.

[Turn over

(ii) Calculate the radius of the circular path of a singly-charged U-235$^+$ ion when it is fired with a velocity of $8.3 \times 10^5\,m\,s^{-1}$ at right angles into the magnetic field caused by the superconducting coil in **(d)(ii)**. Assume that the charge on this ion is $+1.60 \times 10^{-19}$C.

radius of path = ... m [4]

(iii) A beam containing singly ionised U-235$^+$ and U-238$^+$ ions, all travelling at the same speed, enters a region of uniform magnetic field. Sketch the paths of these ions in the region of the magnetic field in Fig. 4.2. Label the diagram clearly. No calculation is required.

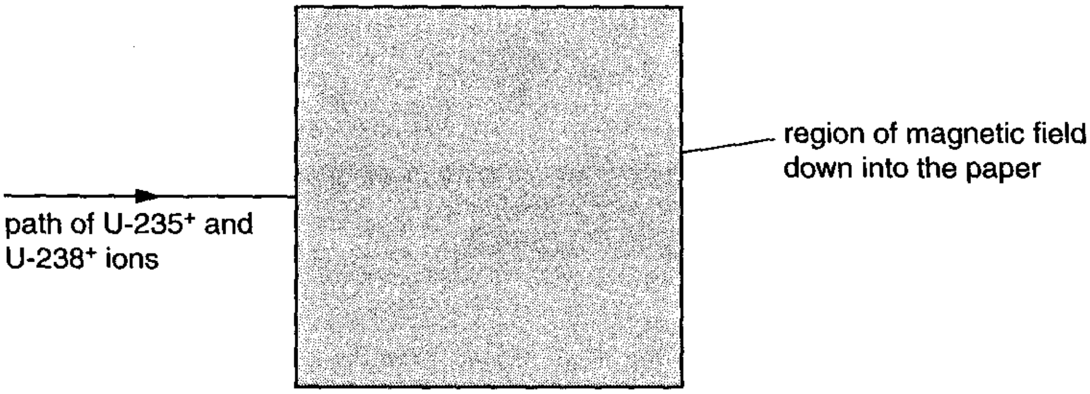

Fig. 4.2

[3]

[Total: 16]

END OF QUESTION PAPER