| Centre No. | | | | | | Paper Reference | Surname | Initial(s) |
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| Candidate No. | | | | | | 6 7 3 6 / 0 1 | Signature | |

Paper Reference(s)

**6736/01**

# Edexcel GCE

## Physics

## Advanced Level

Unit Test PHY6

Thursday 21 June 2007 – Afternoon

Time: 2 hours

Examiner's use only

Team Leader's use only

| Question Number | Leave Blank |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| Total | |

| Materials required for examination | Items included with question papers |
|---|---|
| Nil | Insert |

**Instructions to Candidates**

In the boxes above, write your centre number, candidate number, your signature, your surname and initials.
Answer **ALL** questions in the spaces provided in this question paper.
In calculations you should show all the steps in your working, giving your answer at each stage.
Calculators may be used.
Include diagrams in your answers where these are helpful.

**Information for Candidates**

This question paper is designed to give you the opportunity to make connections between different areas of physics and to use skills and ideas developed throughout the course in new contexts.
You should include in your answers relevant information from the whole of your course, where appropriate.
You should have an insert that is the passage for use with Section I.
The marks for individual questions and the parts of questions are shown in round brackets.
There are four questions in this paper. The total mark for this paper is 80.
**The list of data, formulae and relationships is printed at the end of this booklet.**

**Advice to Candidates**

You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, taking account of your use of grammar, punctuation and spelling.



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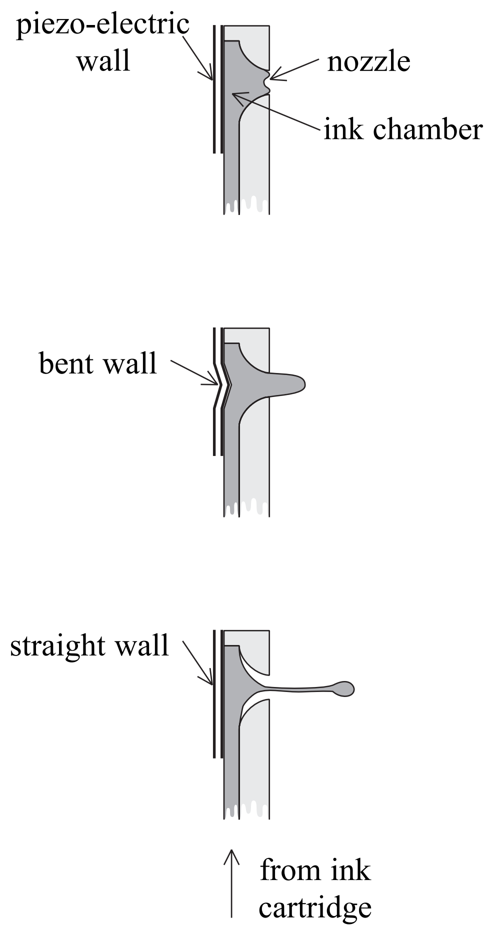
## SECTION I

**1.** Read the passage on the separate insert and then answer the Section I questions.

(a) The diagram shows three stages in the production of a droplet by a piezo-electric driven drop generator.




(i) What is meant by a piezo-electric material?

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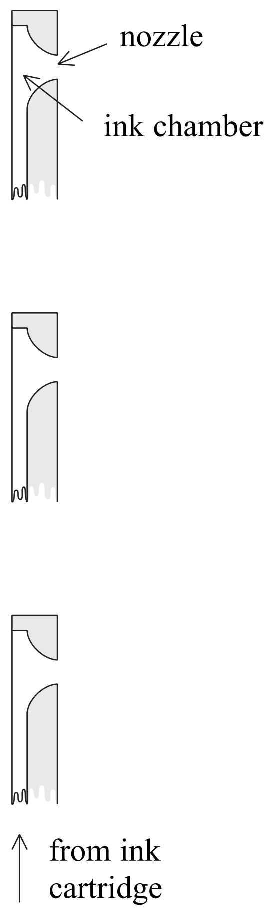
**(2)**



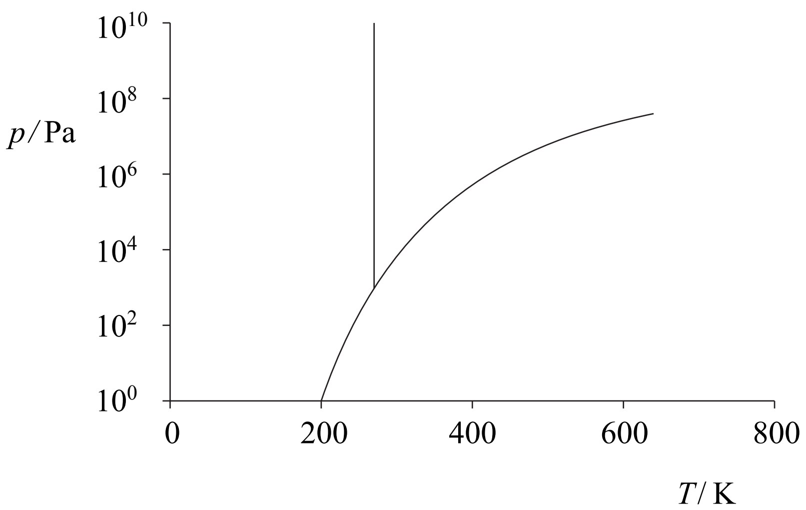
N 2 6 1 4 9 A 0 2 2 0

(ii) Complete the diagram below to show the equivalent stages in the production of a droplet by a heater element drop generator.




**(3)**

(b) The graph below is a phase diagram, showing a range of temperatures and pressures. The lines separate regions in which water is in either a liquid, a solid, or a gaseous state.




(i) Label the regions to indicate where water is a liquid, a solid and a gas.

**(2)**

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(ii) What is meant by the critical point of water?

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**(1)**

(c) (i) What role does surface tension play in the operation of inkjet printers?

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(ii) Describe how ink droplets are steered to their place on the page.

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(d) (i) Show that the '100 000 drops per second' (paragraph 2) is consistent with the 'few microseconds' of heating (paragraph 4).

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(ii) An inkjet printer drop generator operating at 620 kHz produces drops of diameter 11 μm.

What volume of ink is projected from such a generator when working for 3.0 minutes?

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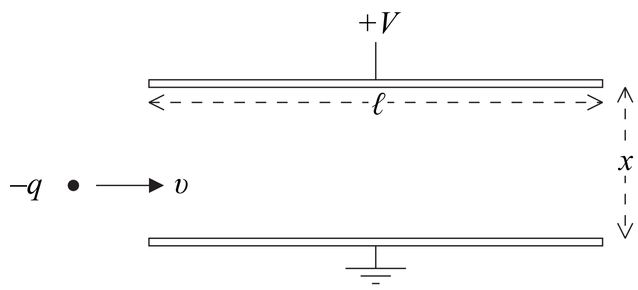
**(3)**

(e) A droplet of mass *m* carrying a charge $-q$ reaches the deflection plates at a speed $v$. The potential difference between the plates is $V$ and their dimensions are as shown in the diagram.




(i) By considering the electric force on the droplet in the electric field between the plates, show that the acceleration of the droplet is $qV/mx$.

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(ii) State the direction of this acceleration and give any assumption you made in your proof.

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**(2)**

(iii) Describe the shape of the path of a charged droplet in an inkjet printer:

1. as it moves between the plates,

..........

2. as it moves beyond the plates.

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**(3)**

(f) In one printer $\ell = 1.5$ cm and $\upsilon = 220$ m s$^{-1}$. While the droplet is between the plates it accelerates at $2.0 \times 10^5$ m s$^{-2}$ perpendicular to its initial direction of motion.

(i) Calculate the time the droplet takes to travel through the deflection plates.

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(ii) Calculate the displacement of the droplet perpendicular to its motion while moving between the plates.

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**(3)**

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(g) The pressure $p$ in a water droplet of radius $r$ can be shown to be

$$p = p_A + 2\gamma/r$$

where $p_A$ is atmospheric pressure and $\gamma$ is the surface tension of water.

(i) Calculate the pressure above atmospheric in a water droplet of diameter 11 μm. Take the surface tension of water to be $7.3 \times 10^{-2}$ J m$^{-2}$.

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(ii) Express this excess pressure as a percentage of normal atmospheric pressure.

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**(4)**

**Q1**

**(Total 31 marks)**

**TOTAL FOR SECTION I: 31 MARKS**

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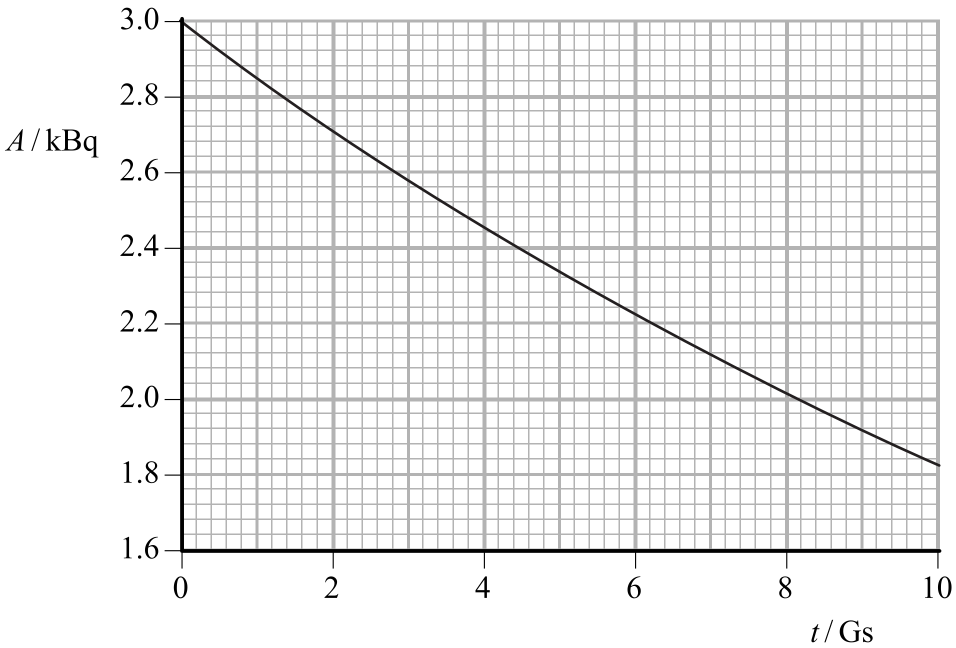
## SECTION II

**(Answer ALL questions)**

**2.** The graph shows the predicted change in the activity $A$ over a period of just over 300 years of $^{241}_{95}Am$, an isotope of americium used in smoke alarms. One gigasecond, Gs, is equal to $10^9$ s.




(a) (i) Show that the graph is part of an exponential decay curve.

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(ii) Use the graph to determine the half-life of this isotope in years. (Do *not* attempt to extrapolate the graph.)

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(iii) In fact, the graph was drawn using the known half-life of this isotope. Outline how in principle the half-life of such a very long-lived isotope can be measured.

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**(3)**

(b) A graph similar in shape to the graph opposite could represent the rate at which charge is leaking from an imperfectly insulated capacitor.

(i) Suggest what would replace the $A$/kBq and the $t$/Gs on the axes of such a capacitor decay graph.

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(ii) State one way in which the discharge of a capacitor and the decay of a radioactive sample are *not* analogous.

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**(3)**



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(c) Americium-241 decays by α-emission into an isotope of neptunium (Np). Two decays are possible. One emits α-particles of energy 5.44 MeV; the other emits α-particles of energy 5.49 MeV.

(i) Complete the nuclear equation for the decay of americium-241.

$$^{241}_{95}\text{Am} \longrightarrow$$

(ii) The 5.44 MeV decay leaves an excited nucleus that then emits a photon of energy 50 keV.

By calculating the wavelength of this photon, deduce the part of the electromagnetic spectrum to which it belongs.

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**(5)**

**Q2**

**(Total 17 marks)**

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**3.** (a) Manganin is a metal alloy whose resistivity does not vary with temperature. It can be used to make wire-wound resistors.

(i) Describe, with the aid of a circuit diagram, how you would determine the resistivity of manganin given a reel of the wire with a resistance per unit length of about $10\,\Omega\,m^{-1}$.

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**(5)**

(ii) In manufactured wire-wound resistors, the wire is covered with an insulating material and a coil is formed from a number of layers of the wire.

Explain why manganin is a suitable alloy for use in such resistors.

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**(2)**

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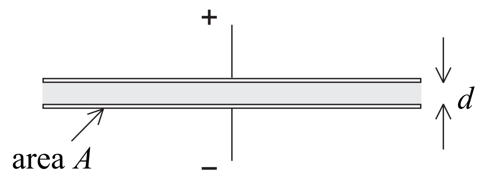
(b) Mica is a mineral that can be split into uniform thin sheets. It can be used as an insulating material between the plates of a capacitor.




After charging and isolating this capacitor, the charge is found to leak very slowly between the plates through the insulating mica.

(i) The resistivity of mica is $\rho$. Write an expression for the resistance $R$ between the plates of this capacitor.

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(ii) The capacitance of this capacitor is $C = \varepsilon A/d$, where $\varepsilon$ is a constant called the permittivity of mica.

1. The decay of charge is exponential. Show that the time for half the charge to leak is dependent on the product of the values of $\rho$ and $\varepsilon$, and is independent of the thickness $d$ or cross-sectional area $A$ of the mica sheet.

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2. Half the charge is found to leak in 30 minutes. Taking $\rho$ to be $5.0 \times 10^{13}\ \Omega$ m, determine a value for $\varepsilon$, the permittivity of mica.

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**(5)**



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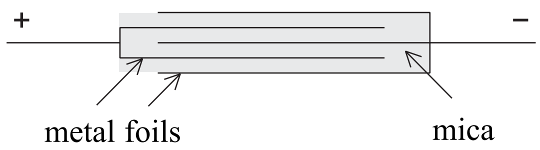
(iii) In practice mica capacitors are made up of sandwiches of metal foil and mica connected as shown.




Explain whether these metal foils are connected electrically in series or in parallel.

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State the capacitance of this capacitor if the capacitance of one pair of foils is $C$.

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**(3)**

**Q3**

**(Total 15 marks)**

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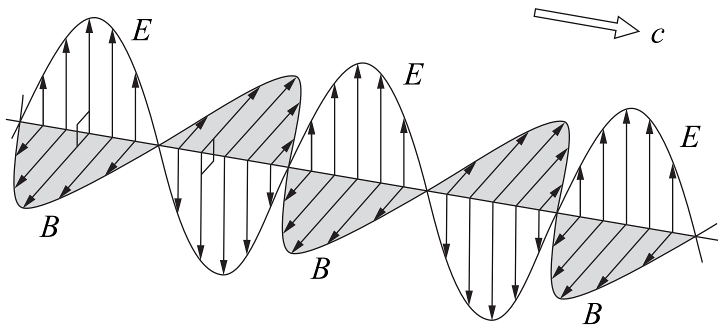
**4.** (a) Electromagnetic waves travelling in space at a speed of $3.00 \times 10^8\,m\,s^{-1}$ consist of oscillating electric and magnetic fields. The diagram shows a plane polarised electromagnetic wave. The plane of polarisation is that of the electric field oscillations.




(i) Explain why this wave is called a transverse wave.

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(ii) How would you place a coil in order to detect the oscillations of the magnetic field in this plane polarised electromagnetic wave?

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(iii) Describe the difference between a polarised and a non-polarised electromagnetic wave.

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**(3)**

(b) The intensity $I$, that is the power passing per unit area, of an electromagnetic wave in which the amplitude of the electric field is $E_0$ is given by

$$I = \tfrac{1}{2} acE_0^2$$

where $a$ is a constant equal to $8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$.

(i) Show that the above equation is homogeneous with respect to units.

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(ii) Calculate a value for $E_0$ in a wave of intensity $1.40 \times 10^3\,\mathrm{W\,m^{-2}}$, the Sun's intensity at Earth.

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(iii) What would be the value of the intensity of the Sun's radiation at a distance from the Sun equal to 20 times the Sun-Earth distance?

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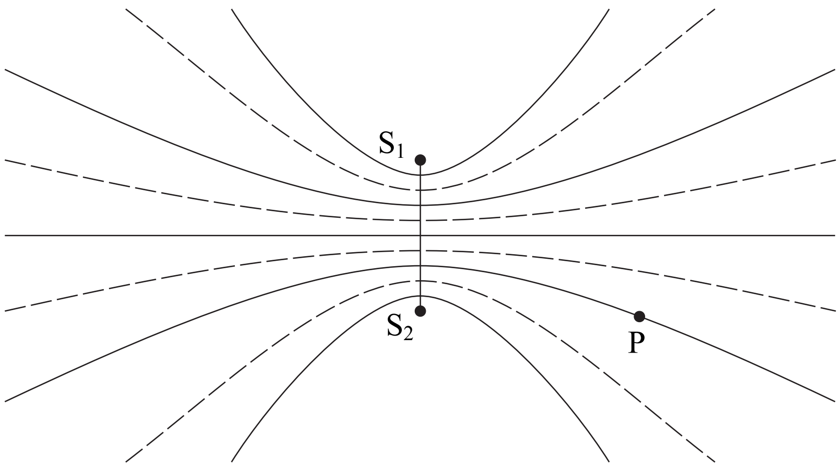
**(4)**

(c) Two in-phase microwave sources of wavelength 7.0 mm placed at $S_1$ and $S_2$ produce the interference pattern shown in the diagram. The full lines are lines of constructive superposition (maxima) and the dashed lines are lines of destructive superposition (minima).
The diagram is to scale.




(i) Explain what is meant by constructive superposition in this situation.

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(ii) Use a ruler to confirm that at P there is a maximum.

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(iii) Explain why the distance between the minima on the line $S_1S_2$ is 3.5 mm.

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**(6)**

Q4

**(Total 17 marks)**

**TOTAL FOR SECTION II: 49 MARKS**

**TOTAL FOR PAPER: 80 MARKS**

**END**





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## List of data, formulae and relationships

***Data***

| | | |
|---|---|---|
| Speed of light in vacuum | $c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$ | |
| Gravitational constant | $G = 6.67 \times 10^{-11}\ \mathrm{N\ m^{2}\ kg^{-2}}$ | |
| Acceleration of free fall | $g = 9.81\ \mathrm{m\ s^{-2}}$ | (close to the Earth) |
| Gravitational field strength | $g = 9.81\ \mathrm{N\ kg^{-1}}$ | (close to the Earth) |
| Elementary (proton) charge | $e = 1.60 \times 10^{-19}\ \mathrm{C}$ | |
| Electronic mass | $m_{\mathrm{e}} = 9.11 \times 10^{-31}\ \mathrm{kg}$ | |
| Electronvolt | $1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$ | |
| Planck constant | $h = 6.63 \times 10^{-34}\ \mathrm{J\ s}$ | |
| Unified atomic mass unit | $\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$ | |
| Molar gas constant | $R = 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$ | |
| Permittivity of free space | $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$ | |
| Coulomb law constant | $k = 1/4\pi\varepsilon_0$ <br> $= 8.99 \times 10^{9}\ \mathrm{N\ m^{2}\ C^{-2}}$ | |
| Permeability of free space | $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N\ A^{-2}}$ | |

***Rectilinear motion***

For uniformly accelerated motion:

$$v = u + at$$

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

$$v^2 = u^2 + 2ax$$

***Forces and moments***

Moment of $F$ about O = $F \times$ (Perpendicular distance from $F$ to O)

Sum of clockwise moments about any point in a plane = Sum of anticlockwise moments about that point

***Dynamics***

Force $\quad F = m\dfrac{\Delta v}{\Delta t} = \dfrac{\Delta p}{\Delta t}$

Impulse $\quad F\Delta t = \Delta p$

***Mechanical energy***

Power $\quad P = Fv$

***Radioactive decay and the nuclear atom***

Activity $\quad A = \lambda N \quad$ (Decay constant $\lambda$)

Half-life $\quad \lambda t_{\frac{1}{2}} = 0.69$

***Electrical current and potential difference***

Electric current $I = nAQv$

Electric power $P = I^2R$

***Electrical circuits***

Terminal potential difference $V = \mathcal{E} - Ir$ (E.m.f. $\mathcal{E}$; Internal resistance $r$)

Circuit e.m.f. $\Sigma\mathcal{E} = \Sigma IR$

Resistors in series $R = R_1 + R_2 + R_3$

Resistors in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

***Heating matter***

Change of state: energy transfer $= l\Delta m$ (Specific latent heat or specific enthalpy change $l$)

Heating and cooling: energy transfer $= mc\Delta T$ (Specific heat capacity $c$; Temperature change $\Delta T$)

Celsius temperature $\theta/°\text{C} = T/\text{K} - 273$

***Kinetic theory of matter***

Temperature and energy $T \propto$ Average kinetic energy of molecules

Kinetic theory $p = \frac{1}{3}\rho\langle c^2\rangle$

***Conservation of energy***

Change of internal energy $\Delta U = \Delta Q + \Delta W$ (Energy transferred thermally $\Delta Q$; Work done on body $\Delta W$)

Efficiency of energy transfer $= \frac{\text{Useful output}}{\text{Input}}$

Heat engine maximum efficiency $= \frac{T_1 - T_2}{T_1}$

***Circular motion and oscillations***

Angular speed $\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r}$ (Radius of circular path $r$)

Centripetal acceleration $a = \frac{v^2}{r}$

Period $T = \frac{1}{f} = \frac{2\pi}{\omega}$ (Frequency $f$)

Simple harmonic motion:

displacement $x = x_0 \cos 2\pi ft$

maximum speed $= 2\pi f x_0$

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

For a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

For a mass on a spring $T = 2\pi\sqrt{\frac{m}{k}}$ (Spring constant $k$)

***Waves***

| | | |
|---|---|---|
| Intensity | $I = \dfrac{P}{4\pi r^2}$ | (Distance from point source $r$; Power of source $P$) |

***Superposition of waves***

| | | |
|---|---|---|
| Two slit interference | $\lambda = \dfrac{xs}{D}$ | (Wavelength $\lambda$; Slit separation $s$; Fringe width $x$; Slits to screen distance $D$) |

***Quantum phenomena***

| | | |
|---|---|---|
| Photon model | $E = hf$ | (Planck constant $h$) |
| Maximum energy of photoelectrons | $= hf - \varphi$ | (Work function $\varphi$) |
| Energy levels | $hf = E_1 - E_2$ | |
| de Broglie wavelength | $\lambda = \dfrac{h}{p}$ | |

***Observing the Universe***

| | | |
|---|---|---|
| Doppler shift | $\dfrac{\Delta f}{f} = \dfrac{\Delta\lambda}{\lambda} \approx \dfrac{v}{c}$ | |
| Hubble law | $v = Hd$ | (Hubble constant $H$) |

***Gravitational fields***

| | | |
|---|---|---|
| Gravitational field strength | $g = F/m$ | |
| for radial field | $g = Gm/r^2$, numerically | (Gravitational constant $G$) |

***Electric fields***

| | | |
|---|---|---|
| Electric field strength | $E = F/Q$ | |
| for radial field | $E = kQ/r^2$ | (Coulomb law constant $k$) |
| for uniform field | $E = V/d$ | |
| For an electron in a vacuum tube | $e\Delta V = \Delta(\frac{1}{2}m_e v^2)$ | |

***Capacitance***

| | | |
|---|---|---|
| Energy stored | $W = \frac{1}{2}CV^2$ | |
| Capacitors in parallel | $C = C_1 + C_2 + C_3$ | |
| Capacitors in series | $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$ | |
| Time constant for capacitor discharge | $= RC$ | |

***Magnetic fields***

| | | |
|---|---|---|
| Force on a wire | $F = BIl$ | |
| Magnetic flux density (Magnetic field strength) | | |
| in a long solenoid | $B = \mu_0 nI$ | (Permeability of free space $\mu_0$) |
| near a long wire | $B = \mu_0 I/2\pi r$ | |
| Magnetic flux | $\Phi = BA$ | |
| E.m.f. induced in a coil | $\varepsilon = -\dfrac{N\Delta\Phi}{\Delta t}$ | (Number of turns $N$) |

***Accelerators***

| | |
|---|---|
| Mass-energy | $\Delta E = c^2 \Delta m$ |
| Force on a moving charge | $F = BQv$ |

***Analogies in physics***

| | |
|---|---|
| Capacitor discharge | $Q = Q_0 e^{-t/RC}$ |
| | $\dfrac{t_{\frac{1}{2}}}{RC} = \ln 2$ |
| Radioactive decay | $N = N_0 e^{-\lambda t}$ |
| | $\lambda t_{\frac{1}{2}} = \ln 2$ |

***Experimental physics***

$$\text{Percentage uncertainty} = \frac{\text{Estimated uncertainty} \times 100\%}{\text{Average value}}$$

***Mathematics***

$$\sin(90° - \theta) = \cos\theta$$

$$\ln(x^n) = n \ln x$$

$$\ln(e^{kx}) = kx$$

| | | |
|---|---|---|
| Equation of a straight line | $y = mx + c$ | |
| Surface area | cylinder $= 2\pi rh + 2\pi r^2$ | |
| | sphere $= 4\pi r^2$ | |
| Volume | cylinder $= \pi r^2 h$ | |
| | sphere $= \frac{4}{3}\pi r^3$ | |
| For small angles: | $\sin\theta \approx \tan\theta \approx \theta$ | (in radians) |
| | $\cos\theta \approx 1$ | |

Paper Reference(s)

**6736/01**

# Edexcel GCE

## Physics

## Advanced Level

Unit Test PHY6: Synoptic Paper

Thursday 21 June 2007 – Afternoon

## Insert for use with Question 1.

## This insert must NOT be returned to Edexcel with the question paper

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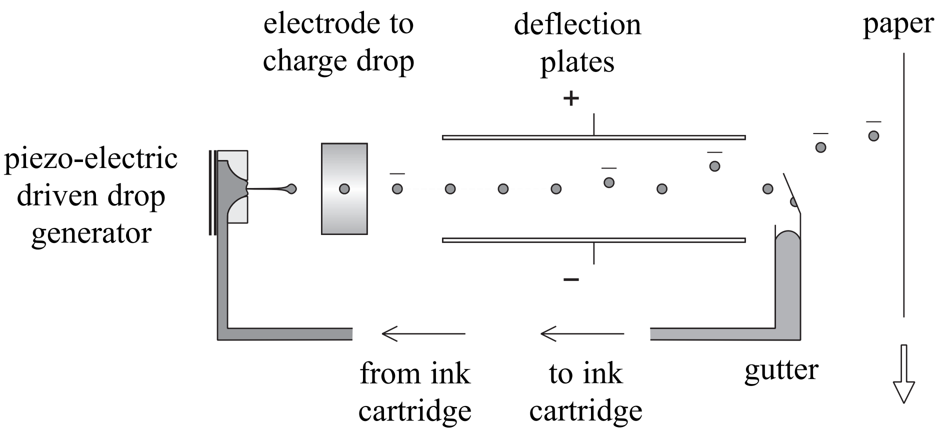
## PASSAGE FOR SECTION I

### Inkjet printing

Most people today have access to an inkjet printer that can print high-quality documents at the touch of a button. The essence of an inkjet printer is that it forms an image from a stream of fine ink droplets that travel from the print head to the paper. The first inkjet printers were based on the observation that a fine liquid jet will break naturally into a stream of moving droplets under the action of surface tension. Directing the path of each drop as it travels between the print head nozzle and the paper creates the inkjet image.

How is this done? First, the drop break-off is stabilised by using a transducer to oscillate the ink pressure in the drop generator at the required drop creation rate. This can be over 100 000 drops per second. Next, a controlled charge is applied to each drop just as it breaks from the main jet. The drop then passes through an electric field and feels a deflection force that is proportional to its charge. Depending on whether the image requires a dot or a white space, the drops are deflected either onto the paper or travel straight on into a collection gutter. The diagram, not to scale, shows the layout of a typical inkjet printer.




The transducer in the drop generator in the diagram is a piezo-electric driver element. Piezo-electrics are materials that deform or bend when an electric potential difference is applied across them. Here the wall of the drop generator is made of a piezo-electric material and drops are ejected by applying electrical pulses that bend the wall inwards and shrink the volume of the ink chamber. Surface tension pulls the ink ejected from the nozzle into a spherical droplet, which heads towards the paper.

Another type of drop generator uses a heater element in place of the piezo-electric driver. To eject a drop a current is passed through the heater for a few microseconds, heating a thin film of water-based ink. The ink close to the element is heated above its critical point and forms a single, high-pressure bubble of water vapour. The bubble expands, pushing ink out of the nozzle. The heater cools, the bubble of water vapour collapses and more ink flows into the chamber. To create the next drop the heater again raises the temperature of the ink above the critical point of water, which is 374 °C. At this temperature, where there is no distinction between the liquid and gas state, a single stable steam bubble forms reliably, time after time.

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[Adapted from ‘Inkjet printing’ by Guy Newcombe: *Physics Review*, February 2005]