Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2009

Physics A PHYA1

Unit 1 Particles, Quantum Phenomena and Electricity

Tuesday 13 January 2009 1.30 pm to 2.45 pm

For this paper you must have:
- a pencil and a ruler
- a calculator
- a Data and Formulae book.

Time allowed
- 1 hour 15 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.
- You are expected to use a calculater where appropriate.
- A *Data and Formulae Book* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

There are no questions printed on this page

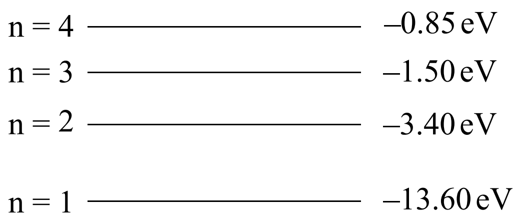
DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Areas outside the box will not be scanned for marking

Answer **all** questions in the spaces provided.

1 **Figure 1** shows part of an energy level diagram for a hydrogen atom.

Figure 1



1 (a) The level, n = 1, is the ground state of the atom.
State the ionisation energy of the atom in eV.

answer = ... eV
(1 mark)

1 (b) When an electron of energy 12.1 eV collides with the atom, photons of three different energies are emitted.

1 (b) (i) On **Figure 1** show with arrows the transitions responsible for these photons.
(3 marks)

1 (b) (ii) Calculate the wavelength of the photon with the smallest energy. Give your answer to an appropriate number of significant figures.

answer =............................. m
(5 marks)

9

Turn over ▸

2 When light of a certain frequency is shone on a particular metal surface, electrons are emitted with a range of kinetic energies.

2 (a) Explain

- in terms of photons why electrons are released from the metal surface, and
- why the kinetic energy of the emitted electrons varies upto a maximum value.

The quality of your written communication will be assessed in this question.

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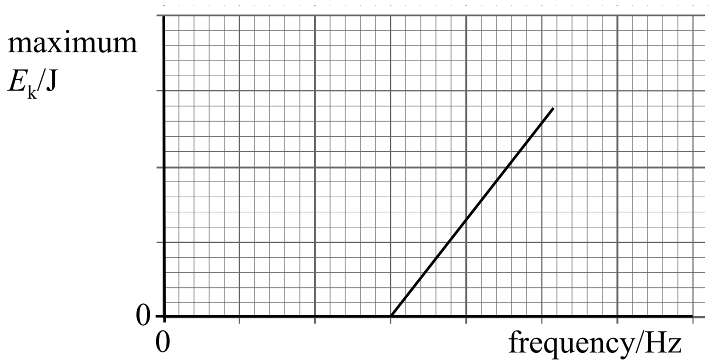
(6 marks)

2 (b) The graph below shows how the maximum kinetic energy of the electrons varies with the frequency of the light shining on the metal surface.



2 (b) (i) On the graph mark the *threshold frequency* and label it f_0.

(1 mark)

2 (b) (ii) On the graph draw a line for a metal which has a higher threshold frequency.

(2 marks)

2 (b) (iii) State what is represented by the gradient of the graph.

....

(1 mark)

2 (c) The threshold frequency of a particular metal surface is 5.6×10^{14} Hz. Calculate the maximum kinetic energy of emitted electrons if the frequency of the light striking the metal surface is double the threshold frequency.

answer = ... J

(3 marks)

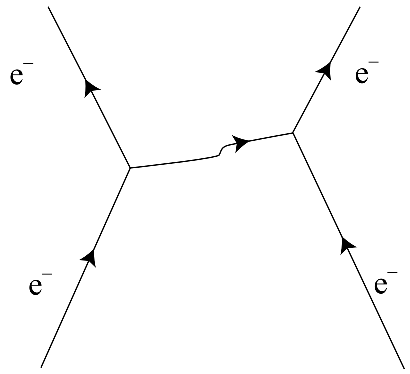
13

Turn over ▸

Areas outside the box will not be scanned for marking

3 (a) **Figure 2** shows the Feynman diagram for a particular interaction.

Figure 2



3 (a) (i) State the type of interaction involved and name the exchange particle.

....

....
(2 marks)

3 (a) (ii) State **two** quantities other than energy and momentum, that are conserved in this interaction.

....

....
(2 marks)

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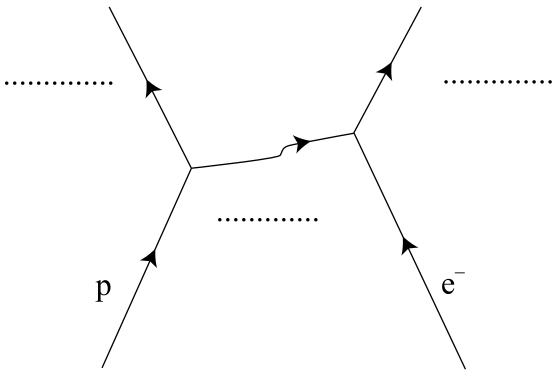
3 (b) **Figure 3** shows the Feynman diagram for another type of interaction.

Figure 3



3 (b) (i) Complete the diagram to show the two particles formed in the interaction and the exchange particle. *(3 marks)*

3 (b) (ii) Name the type of interaction responsible for this exchange particle.

....
(1 mark)

3 (b) (iii) Energy and momentum are conserved in this interaction.
State **two** other quantities that must be conserved and show that they are conserved in this interaction.

....

....

....
(4 marks)

3 (b) (iv) The exchange particle in this interaction was discovered by experiment with a rest mass that had been predicted. Why is it important to test by experiment the prediction of a scientific theory?

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....
(2 marks)

14

4 (a) State what is meant by the wave-particle duality of electrons.

....

....

....

(1 mark)

4 (b) Electrons of wavelength 1.2×10^{-10} m are required to investigate the spacing between planes of atoms in a crystal.

4 (b) (i) Calculate the momentum of an electron of this wavelength stating an appropriate unit.

momentum of electron = ...

(3 marks)

4 (b) (ii) Calculate the speed of such an electron.

speed of electron = ... m s^{-1}

(2 marks)

4 (b) (iii) Calculate the kinetic energy of such an electron.

kinetic energy of electron = ... J

(2 marks)

8

Areas outside the box will not be scanned for marking

5 (a) Some materials exhibit the property of *superconductivity* under certain conditions.

- State what is meant by superconductivity.
- Explain the required conditions for the material to become superconducting.

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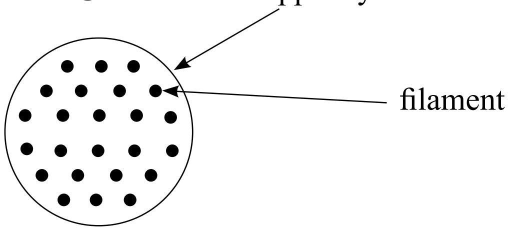
(3 marks)

5 (b) **Figure 4** shows the cross-section of a cable consisting of parallel filaments that can be made superconducting, embedded in a cylinder of copper.

Figure 4



5 (b) (i) The cross-sectional area of the copper in the cable is $2.28 \times 10^{-7}\,m^2$. The resistance of the copper in a 1.0m length of the cable is $0.075\,\Omega$. Calculate the resistivity of the copper, stating an appropriate unit.

answer = ...

(3 marks)

5 (b) (ii) State and explain what happens to the resistance of the cable when the embedded filaments of wire are made superconducting.

....

....

....

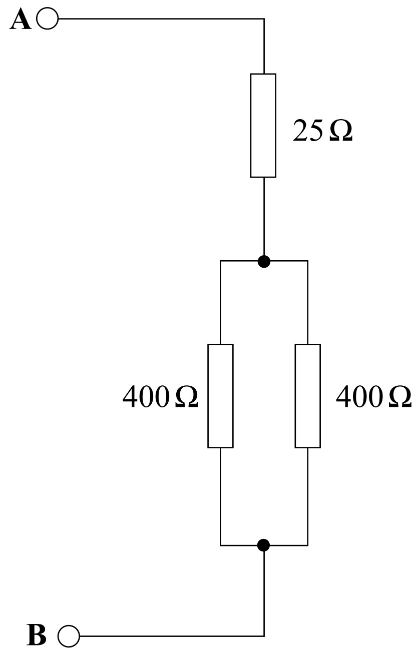
(3 marks)

9

Turn over ▸

6 **Figure 5** shows an arrangement of resistors.

Figure 5



6 (a) Calculate the total resistance between terminals **A** and **B**.

answer = ... Ω
(2 marks)

6 (b) A potential difference is applied between the two terminals, **A** and **B**, and the power dissipated in each of the 400 Ω resistors is 1.0 W.

6 (b) (i) Calculate the potential difference across the 400 Ω resistors.

answer = ... V

6 (b) (ii) Calculate the current through the 25 Ω resistor.

answer = ...A

6 (b) (iii) Calculate the potential difference applied to terminals **A** and **B**.

answer = ... V

(6 marks)

8

Turn over for the next question

7 A car battery has an *emf* of 12 V and an *internal resistance* of $5.0 \times 10^{-3}\,\Omega$.

7 (a) (i) Explain what is meant by the emf of the battery.

....

....

(1 mark)

7 (a) (ii) Explain what is meant by the internal resistance of the battery.

....

....

(1 mark)

7 (b) The battery is used to provide the starting motor of a car with a current of 800 A.

7 (b) (i) Calculate the potential difference across the terminals of the battery.

answer = ... V

(2 marks)

7 (b) (ii) Calculate the rate of dissipation of energy due to its internal resistance stating an appropriate unit.

answer = ...

(3 marks)

7 (c) State and explain the effect of attempting to use a battery with a much higher internal resistance to start the car.

....

....

....

....

(2 marks)

END OF QUESTIONS

9

General Certificate of Education
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Physics A PHYA1

Unit 1 Particles, Quantum Phenomena and Electricity

Data and Formulae Booklet

DATA
FUNDAMENTAL CONSTANTS AND VALUES

Quantity	*Symbol*	*Value*	*Units*
speed of light in vacuo	c	3.00×10^{8}	$m\ s^{-1}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$H\ m^{-1}$
permittivity of free space	ε_0	8.85×10^{-12}	$F\ m^{-1}$
charge of electron	e	-1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$N\ m^{2}\ kg^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$J\ K^{-1}\ mol^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	$J\ K^{-1}$
the Stefan constant	σ	5.67×10^{-8}	$W\ m^{-2}\ K^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	$C\ kg^{-1}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	e/m_p	9.58×10^{7}	$C\ kg^{-1}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$N\ kg^{-1}$
acceleration due to gravity	g	9.81	$m\ s^{-2}$
atomic mass unit (1u is equivalent to 931.3 MeV)	u	1.661×10^{-27}	kg

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
surface area of cylinder	$= 2\pi rh$
volume of cylinder	$= \pi r^2 h$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

ASTRONOMICAL DATA

Body	*Mass/kg*	*Mean radius/m*
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.98×10^{24}	6.37×10^{6}

This insert page should **not** be sent to the examiner

AS FORMULAE

PARTICLE PHYSICS

Rest energy values

class	*name*	*symbol*	*rest energy /MeV*
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

type	*charge*	*baryon number*	*strangeness*
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

	Lepton number
particles: e^-, ν_e ; μ^-, ν_μ	+1
antiparticles: e^+, $\overline{\nu_e}$; μ^+, $\overline{\nu_\mu}$	–1

Photons and Energy Levels

photon energy $E = hf = hc/\lambda$

photoelectricity $hf = \phi + E_{K\,(max)}$

energy levels $hf = E_1 - E_2$

de Broglie Wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

ELECTRICITY

current and pd $I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$ $R = \frac{V}{I}$

emf $\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$

resistors in series $R = R_1 + R_2 + R_3 + \ldots$

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

resistivity $\rho = \frac{RA}{L}$

power $P = VI = I^2R = \frac{V^2}{R}$

alternating current $I_{rms} = \frac{I_0}{\sqrt{2}}$ $V_{rms} = \frac{V_0}{\sqrt{2}}$

MECHANICS

moments moment = Fd

velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

equations of motion $v = u + at$ $s = \frac{(u+v)}{2}t$

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

force $F = ma$

work, energy and power $W = F\,s\cos\theta$

$E_K = \frac{1}{2}m v^2$ $\Delta E_P = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

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

MATERIALS

density $\rho = \frac{m}{V}$ Hooke's law $F = k\,\Delta L$

Young modulus = $\frac{\text{tensile stress}}{\text{tensile strain}}$ tensile stress = $\frac{F}{A}$

tensile strain = $\frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

WAVES

wave speed $c = f\lambda$ *period* $T = \frac{1}{f}$

fringe spacing $w = \frac{\lambda D}{s}$ *diffraction grating* $d\sin\theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 *and* n_2,

law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

critical angle $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$