Centre Number						Candidate Number				
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Other Names										
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For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
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TOTAL	

AQA

General Certificate of Education
Advanced Subsidiary Examination
June 2014

Physics A PHYA1

Unit 1 Particles, Quantum Phenomena and Electricity

Tuesday 20 May 2014 9.00 am to 10.15 am

For this paper you must have:
- a pencil and a ruler
- a calculator
- a Data and Formulae Booklet (enclosed).

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. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* 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.

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

1 (a) The positive kaon, K^+, has a strangeness of $+1$.

1 (a) (i) What is the quark structure of the K^+?

[1 mark]

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1 (a) (ii) What is the baryon number of the K^+?

[1 mark]

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1 (a) (iii) What is the antiparticle of the K^+?

[1 mark]

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1 (b) The K^+ may decay into a neutrino and an antimuon in the following way.

$$K^+ \rightarrow \nu_\mu + \mu^+$$

1 (b) (i) Complete **Table 1** using ticks and crosses as indicated in the first row.

[3 marks]

Table 1

Classification	K^+	ν_μ	μ^+
lepton	✗	✓	✓
charged particle			
hadron			
meson			

1 (b) (ii) In this decay, charge, energy and momentum are conserved.
Give another quantity that is conserved in this decay and one that is not conserved.

[2 marks]

Conserved ....

Not conserved ....

1 (c) Another possible decay of the K^+ is shown in the following equation,

$$K^+ \rightarrow \pi^+ + X$$

1 (c) (i) Identify X by ticking **one** box from the following list.

[1 mark]

electron	
muon	
negative pion	
neutral pion	
neutrino	
neutron	
positron	

1 (c) (ii) Give **one** reason for your choice in part (c)(i).

[1 mark]

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10

Do not write outside the box

2 (a) **Table 2** contains data for four different nuclei, P, Q, R and S.

Table 2

Nuclei	Number of neutrons	Nucleon number
P	5	11
Q	6	11
R	8	14
S	9	17

2 (a) (i) Which nucleus contains the fewest protons?

[1 mark]

nucleus ....

2 (a) (ii) Which **two** nuclei are isotopes of the same element?

[1 mark]

nuclei .... and ....

2 (a) (iii) State and explain which nucleus has the smallest specific charge.

[2 marks]

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2 (a) (iv) Complete the following equation to represent β^- decay of nucleus R to form nucleus X.

[3 marks]

$$ {}^{14}_{6}\mathrm{R} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{X} + {}^{\cdots\cdots}_{\cdots\cdots} \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots $$

Do not write outside the box

2 (b) (i) The strong nuclear force is responsible for keeping the protons and neutrons bound in a nucleus.
Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons, quoting suitable values for separation.

[3 marks]

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2 (b) (ii) Another significant interaction acts between the protons in the nucleus of an atom.
Name the interaction and name the exchange particle responsible for the interaction.

[2 marks]

Interaction ....

Exchange particle ....

12

Turn over for the next question

Do not write outside the box

3 (a) What phenomenon can be used to demonstrate the wave properties of electrons?

[1 mark]

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3 (b) Calculate the wavelength of electrons travelling at a speed of $2.5 \times 10^5\ \mathrm{m\,s^{-1}}$.

Give your answer to an appropriate number of significant figures.

[3 marks]

wavelength .... m

3 (c) Calculate the speed of muons with the same wavelength as these electrons.

mass of muon = 207 × mass of electron

[2 marks]

speed .... $\mathrm{m\,s^{-1}}$

6

Turn to page 8 for the next question

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

4 (a) A fluorescent tube is filled with mercury vapour at low pressure. After mercury atoms have been excited they emit photons.

4 (a) (i) In which part of the electromagnetic spectrum are these photons?

[1 mark]

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4 (a) (ii) What is meant by an excited mercury atom?

[1 mark]

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4 (a) (iii) How do the mercury atoms in the fluorescent tube become excited?

[2 marks]

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4 (a) (iv) Why do the excited mercury atoms emit photons of characteristic frequencies?

[3 marks]

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Do not write outside the box

4 (b) The wavelength of some of the photons emitted by excited mercury atoms is 254 nm.

4 (b) (i) Calculate the frequency of the photons.

[2 marks]

frequency .... Hz

4 (b) (ii) Calculate the energy of the photons in electron volts (eV).

[2 marks]

energy .... eV

4 (c) Explain how the coating on the inside of a fluorescent tube emits visible light.

[2 marks]

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13

Turn over for the next question

5 A student investigates how the power dissipated in a variable resistor, Y, varies as the resistance is altered.
Figure 1 shows the circuit the student uses. Y is connected to a battery of emf ε and internal resistance r.

Figure 1

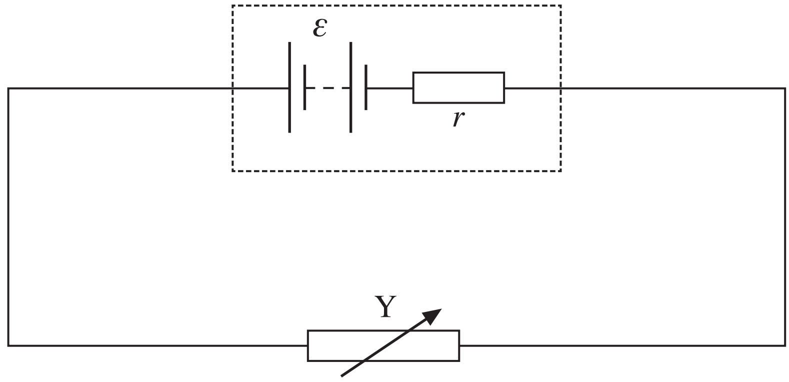
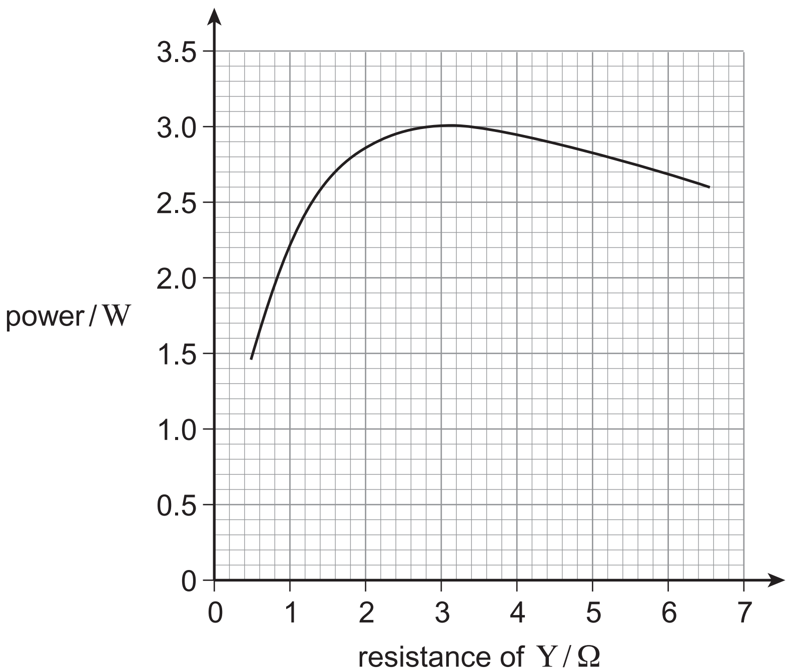


Figure 2 shows the results obtained by the student as the resistance of Y is varied from $0.5\,\Omega$ to $6.5\,\Omega$.

Figure 2



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5 (a) Describe how the power dissipated in Y varies as its resistance is increased from $0.5\ \Omega$ to $6.5\ \Omega$.

[2 marks]

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5 (b) The emf of the battery is $6.0\ \mathrm{V}$ and the resistance of Y is set at $0.80\ \Omega$.

5 (b) (i) Use data from **Figure 2** to calculate the current through the battery.

[3 marks]

current .... A

5 (b) (ii) Calculate the voltage across Y.

[2 marks]

voltage V

5 (b) (iii) Calculate the internal resistance of the battery.

[2 marks]

internal resistance .... Ω

Question 5 continues on the next page

Turn over ▶

Do not write outside the box

5 (c) The student repeats the experiment with a battery of the same emf but negligible internal resistance. State and explain how you would now expect the power dissipated in Y to vary as the resistance of Y is increased from $0.5\ \Omega$ to $6.5\ \Omega$.

[3 marks]

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12

6 The critical temperature of tin is $-269\,^{\circ}\mathrm{C}$. The resistivity of tin increases as its temperature rises from $-269\,^{\circ}\mathrm{C}$.

6 (a) (i) Define resistivity.

[2 marks]

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6 (a) (ii) State the significance of the critical temperature of a material.

[2 marks]

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6 (b) A sample of tin in the form of a cylinder of diameter $1.0\,\mathrm{mm}$ and length $4.8\,\mathrm{m}$ has a resistance of $0.70\,\Omega$.

Use these data to calculate a value of the resistivity of tin.
State an appropriate unit for your answer.

[4 marks]

resistivity .... unit ....

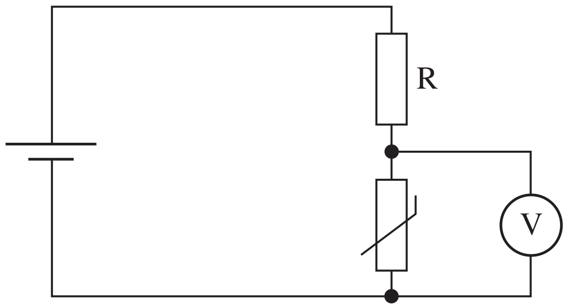
8

Turn over for the next question

Do not write outside the box

7 A thermistor is to be used as a temperature sensor. In order to find out how the voltage across the thermistor varies with temperature the circuit shown in **Figure 3** is set up.

Figure 3



7 (a) Data have to be obtained so that a graph can be plotted to show how the reading on the voltmeter varies with temperature between $0\,^{\circ}\mathrm{C}$ and $100\,^{\circ}\mathrm{C}$. Design an experiment, using this circuit, to obtain enough data to plot the graph. Your answer should include:

- details of the measurements taken
- details of how the temperature of the thermistor can be varied
- an explanation of the need for resistor R
- an explanation of how the thermistor can then be used to measure the temperature of a room.

The quality of your written communication will be assessed in your answer.

[6 marks]

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7 (b) The experiment you designed in part (a) is repeated with the voltmeter connected across R instead.
State and explain how the readings on the voltmeter would be different.

[3 marks]

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9

END OF QUESTIONS

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Physics A

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_o	$4\pi \times 10^{-7}$	$H\ m^{-1}$
permittivity of free space	ε_o	8.85×10^{-12}	$F\ m^{-1}$
magnitude of the 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 931.5 MeV)	u	1.661×10^{-27}	kg

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}

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	$= \frac{4}{3}\pi r^3$

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 $hf = \phi + E_k$

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 $R = R_1 + R_2 + R_3 + \dots$

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

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

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

force $F = ma$

work, energy and power $W = Fs\cos\theta$

$E_K = \frac{1}{2}mv^2$ $\Delta E_p = mg\Delta h$

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

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 $n_1 > n_2$