AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

AS
PHYSICS

Paper 1

Tuesday 15 May 2018 Morning Time allowed: 1 hour 30 minutes

Materials

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

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 scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

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

AS Physics data and formulae

For use in exams from the June 2016 Series onwards

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}
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}	$\text{N m}^2\ \text{kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1}\ \text{mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2}\ \text{K}^{-4}$
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	$\frac{e}{m_e}$	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	$\frac{e}{m_p}$	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

ALGEBRAIC EQUATION

quadratic equation $\quad x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.97×10^{24}	6.37×10^{6}

GEOMETRICAL EQUATIONS

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

Particle Physics

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 $E = hf = \frac{hc}{\lambda}$

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

energy levels $hf = E_1 - E_2$

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

Waves

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

first harmonic $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

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 $n_1 > n_2$

Mechanics

moments moment $= Fd$

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

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

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

force $F = ma$

force $F = \frac{\Delta(mv)}{\Delta t}$

impulse $F\,\Delta t = \Delta(mv)$

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

$E_k = \frac{1}{2}\,m\,v^2$ $\Delta E_p = mg\Delta h$

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

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

Materials

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

Young modulus $= \frac{tensile\ stress}{tensile\ strain}$ *tensile stress* $= \frac{F}{A}$ *tensile strain* $= \frac{\Delta L}{L}$

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

Electricity

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

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

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

resistors in parallel $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

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

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

Answer **all** questions.

0 1 . 1 Describe the interaction that is responsible for keeping protons and neutrons together in a stable nucleus.
You should include details of the properties of the interaction in your answer.

[3 marks]

0 1 . 2 Nuclei can decay by alpha decay and by beta decay.

In alpha decay only one particle is emitted but in beta decay there are two emitted particles.

Explain how baryon number is conserved in alpha and beta decay.

[3 marks]

0 1 . 3 Kaons are mesons that can be produced by the strong interaction between pions and protons.

The equation shows a reaction in which a kaon and a lambda particle are produced.

$$\pi^- + p \rightarrow K^0 + \Lambda^0$$

Deduce the quark structure of the Λ^0

[2 marks]

quark structure = _____

0 1 . 4 The kaon decays by the weak interaction.

The equation shows an example of kaon decay.

$$K^0 \rightarrow \pi^+ + \pi^-$$

State **one** feature of this decay that shows it is an example of the weak interaction.

[1 mark]

_____

_____

0 1 . 5 There have been considerable advances in our understanding of particle physics over the past 100 years.

Explain why it is necessary for many teams of scientists and engineers to collaborate in order for these advances to be made.

[2 marks]

_____

_____

_____

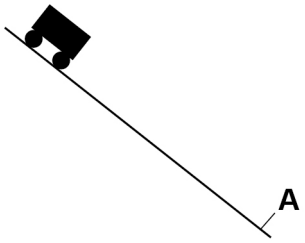
_____

_____

11

0 2 . 1 **Figure 1** shows a truck moving freely down a ramp inclined at an angle to the horizontal.

Figure 1



The truck starts from rest at the top of the ramp and reaches point **A**. Friction and air resistance are negligible.

As the truck moves down the ramp to point **A**, its centre of mass has a total vertical displacement of $8.0\ \text{m}$

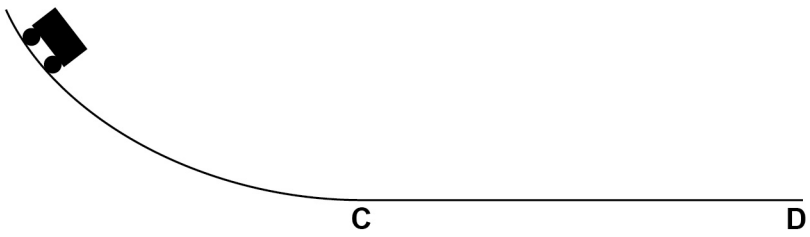
Calculate the speed of the truck at point **A**.

[2 marks]

speed = _____ m s^{-1}

0 2 . 2 **Figure 2** shows the truck moving down a ramp with a varying slope.

Figure 2



The truck starts from rest and moves freely down the ramp. It reaches point **C** and then moves along the horizontal runway to **D**. Friction and air resistance are negligible.

Discuss how the acceleration of the truck in **Figure 2** differs from the acceleration of the truck in **Figure 1**.

[3 marks]

Question 2 continues on the next page

0 2 . 3 The total vertical displacement of the centre of mass of the truck in **Figure 2** is also $8.0\ \text{m}$

The speed of the truck when it reaches the horizontal runway is the same as the speed of the truck in **Figure 1** when it reaches point **A**.

Explain why.

[1 mark]

0 2 . 4 The horizontal runway in **Figure 2** has negligible friction and air resistance. As the truck moves along the runway, it starts to rain. The rain falls vertically and water collects in the truck.

Discuss whether there are any changes in the momentum of the truck and collected water.

[3 marks]

9

Turn over for the next question

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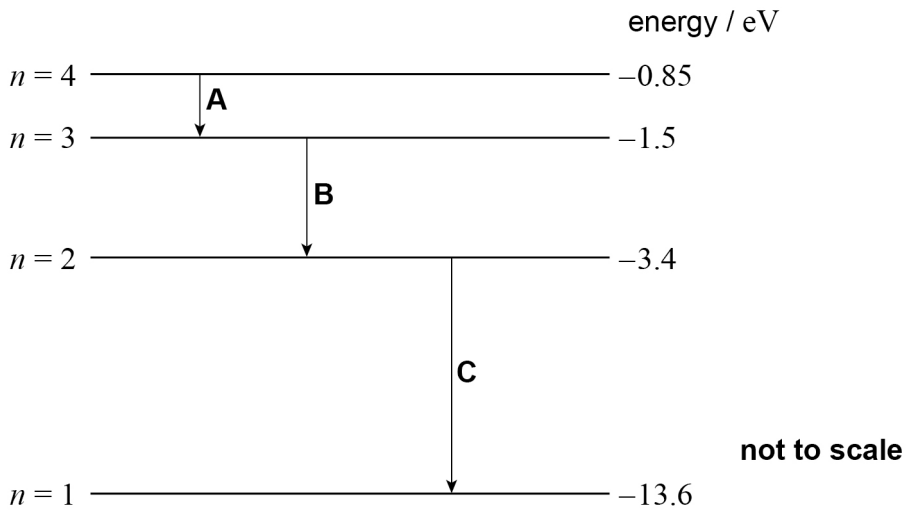
ANSWER IN THE SPACES PROVIDED

0 3 **Figure 3** shows some of the energy levels for a hydrogen atom.

Figure 3



An excited hydrogen atom can emit photons of certain discrete frequencies. Three possible transitions are shown in **Figure 3**.

0 3 . 1 The transitions shown in **Figure 3** result in photons being emitted in the ultraviolet, visible and infrared regions of the electromagnetic spectrum.

To which region of the spectrum do the emitted photons belong?

Tick (✓) the correct box for each transition, **A**, **B** and **C**.

[1 mark]

Transition	Ultraviolet	Visible	Infrared
A	☐	☐	☐
B	☐	☐	☐
C	☐	☐	☐

0 3 . 2 Two ways to excite a hydrogen atom are by collision with a free electron or by the absorption of a photon.

Explain why, for a particular transition, the photon must have an exact amount of energy whereas the free electron only needs a minimum amount of kinetic energy.

[3 marks]

0 3 . 3 The surface of a sample of caesium is exposed to photons emitted in each of the three transitions shown in **Figure 3**.

The threshold frequency of caesium is 5.1×10^{14} Hz

Determine whether any of these transitions would produce photons that would cause electrons to be emitted from the surface of caesium.

[3 marks]

Question 3 continues on the next page

0 3 . 4 Photons each with energy $12.1\ \text{eV}$ are incident on the surface of the caesium sample.

Calculate the maximum speed of electrons emitted from the caesium.

[3 marks]

maximum speed = _____ m s^{-1}

10

Turn over for the next question

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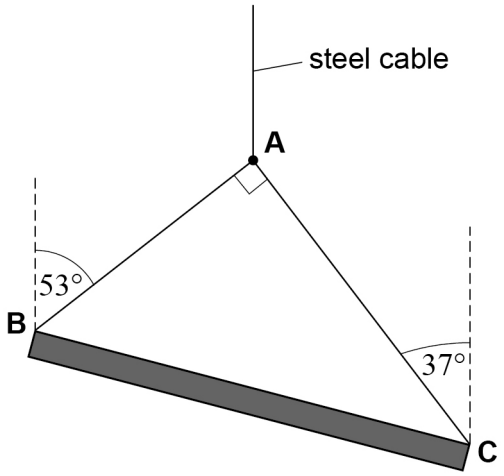
0 4 **Figure 4** shows a uniform beam supported by two light cables, **AB** and **AC**, which are attached to a single steel cable from a crane. The beam is stationary and in equilibrium.

Figure 4



0 4 . 1 State **two** necessary conditions for the beam to be in equilibrium.

[2 marks]

Condition 1 _____

_____

_____

Condition 2 _____

_____

_____

0 4 . 2 State what is meant by the centre of mass.

[1 mark]

_____

_____

0 4 . 3 Explain why the centre of mass of the beam in **Figure 4** must be vertically below **A**.

[2 marks]

0 4 . 4 The weight of the beam is $12\ 000$ N

Calculate the tension T_1 in cable **AB** and the tension T_2 in cable **AC**.

[4 marks]

T_1 = _____ N

T_2 = _____ N

Question 4 continues on the next page

0 4 . 5 The steel cable from the crane has a circular cross-section of diameter $1.5 \times 10^{-2}\,\text{m}$ The cable is $12\,\text{m}$ long.

Calculate the extension of the cable caused by the weight of the beam. You can assume that the weights of **all cables** are negligible.

Young modulus of steel = $2.0 \times 10^{11}\,\text{Pa}$

[3 marks]

extension = _____ m

12

0 5 . 1 Calculate the weight of an ice cube that has volume $4.0 \times 10^{-6}\ \text{m}^3$

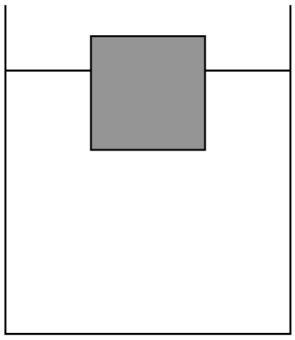
density of ice = $920\ \text{kg m}^{-3}$

[2 marks]

weight = _____ N

0 5 . 2 **Figure 5** shows the ice cube floating in a beaker of water.

Figure 5



When the ice cube is placed in the beaker, it displaces a volume of water causing the water level to rise.
The weight of water displaced is equal to the weight of the ice cube.

Calculate the volume of water displaced by the ice cube.

density of water = $1000\ \text{kg m}^{-3}$

[1 mark]

volume = _____ m^3

Question 5 continues on the next page

0 5 . 3 The ice cube in **Figure 5** is replaced by another cube also with volume $4.0 \times 10^{-6}\ \text{m}^3$
This cube is made of ice containing a small piece of iron.
The mass of water now displaced is $3.9 \times 10^{-3}\ \text{kg}$

Calculate the volume of the piece of iron.

density of iron = $7800\ \text{kg m}^{-3}$

[3 marks]

volume = _____ m^3

6

Turn over for the next question

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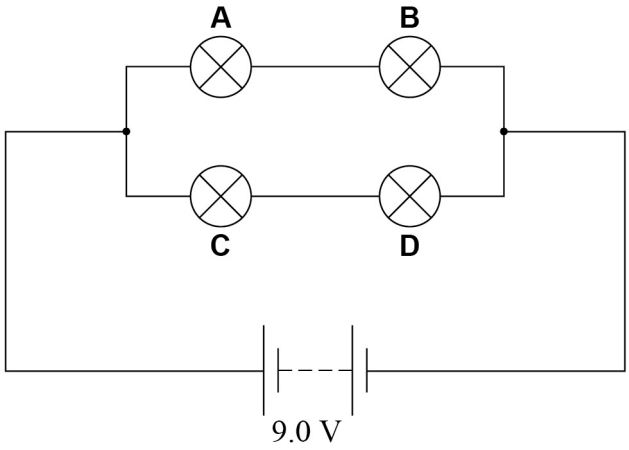
0 6 A student connects four lamps **A**, **B**, **C** and **D** in the circuit shown in **Figure 6**. The battery has an emf of $9.0\ \text{V}$ and negligible internal resistance.

Figure 6



0 6 . 1 **Table 1** shows the operating conditions for the lamps when they are at normal brightness.

Table 1

Lamps	Operating voltage / V	Power / W
A and **C**	6.0	6.0
B and **D**	3.5	4.1

The student observes that **two** of the lamps are at their normal brightness.
Assume that any changes in resistance of the lamps are negligible.

Determine which **two** lamps are at their normal brightness.

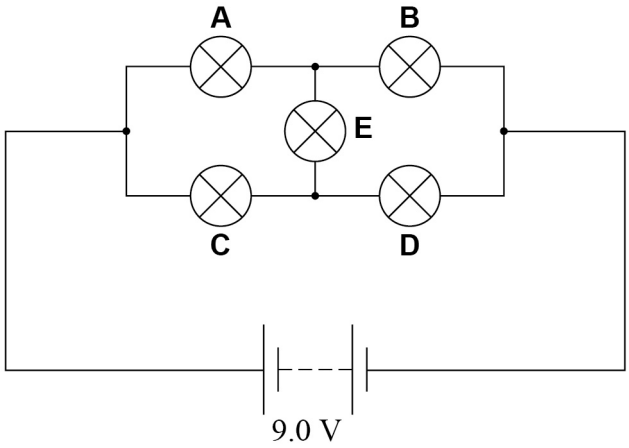
Use calculations to support your answer.

[4 marks]

Question 6 continues on the next page

0 6 . 2 The student connects another lamp **E** in the circuit as shown in **Figure 7**.
Lamp **E** is identical to lamps **A** and **C**.

Figure 7



Explain what the student would observe regarding the brightness of the lamps.

Refer to potential differences across lamp **E** in your answer.

[3 marks]

0 6 . 3 Lamp **B** in **Figure 7** fails so that it no longer conducts. This change does not affect the resistance of the other lamps.

Deduce the effect on the current in the battery.

Use calculations to support your answer.

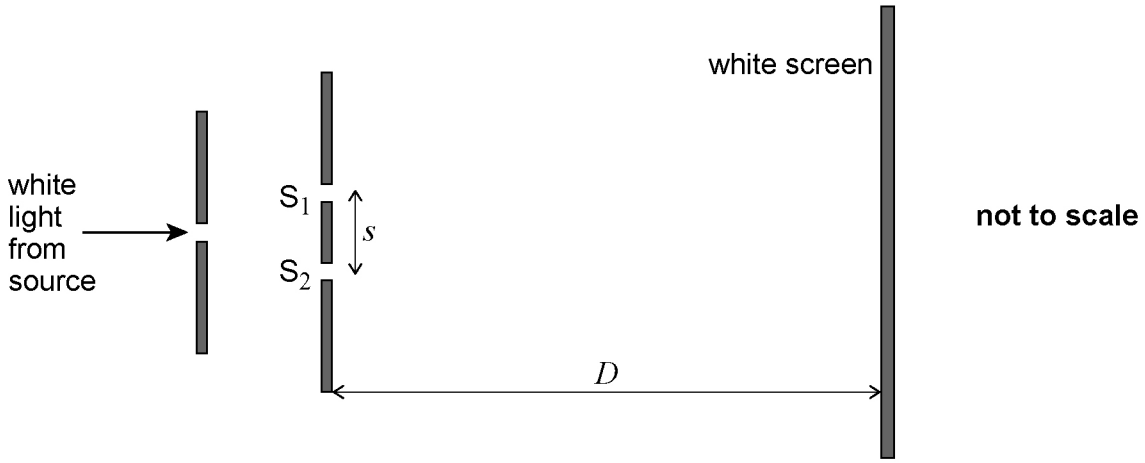
[3 marks]

10

Turn over for the next question

0 7 **Figure 8** shows a diagram of apparatus used to demonstrate the formation of interference fringes using a white light source in a darkened room. Light from the source passes through a single slit and then through two narrow slits S_1 and S_2.

Figure 8



0 7 . 1 Describe the interference pattern that is seen on the white screen.

[2 marks]

0 7 . 2 A filter transmits only green light of wavelength λ and red light of wavelength 1.2λ
This filter is placed between the light source and the single slit.

Describe the interference pattern now seen on the white screen.

Use a calculation to support your answer.

[4 marks]

Question 7 continues on the next page

0 7 . 3 A student decides to use the apparatus shown in **Figure 8** to determine the wavelength of red light using a filter that transmits only red light.

The student suggests the following changes:

- decrease slit separation s
- decrease D, the distance between the slits and the screen.

The student decides to make each change independently.

Discuss the effects each independent change has on the interference pattern, and whether this change is likely to reduce uncertainty in the determination of the wavelength.

[6 marks]

END OF QUESTIONS

12

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