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ADVANCED
General Certificate of Education
2016

Centre Number

Candidate Number

Physics

Assessment Unit A2 1
assessing
Momentum, Thermal Physics,
Circular Motion, Oscillations
and Atomic and Nuclear Physics

AY211

[AY211]

TUESDAY 24 MAY, MORNING

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete in blue or black ink only. **Do not write with a gel pen.**
Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **2(a)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.
Question **9** contributes to the synoptic assessment required of the specification.

If you need the values of physical constants to answer any questions in this paper they may be found in the Data and Formulae Sheet.

Answer **all nine** questions

1 (a) Define momentum.

____

____

____ [1]

(b) A rugby player, mass 120 kg, is running with the ball at a speed of 28.8 km h^{-1}.

(i) Calculate the momentum of the rugby player in S.I. units.

Momentum = ____________________ kg m s^{-1} [2]

(ii) The rugby player is tackled head-on by an opponent of mass 100 kg running at 2.0 m s^{-1}. The tackling player holds onto the first player. Calculate the resultant velocity of the players in m s^{-1} and state its direction.

Resultant velocity = ____________________ m s^{-1}

Direction = ____________________ [4]

9871

(iii) Later in the match the same player running with the ball at the same speed of 28.8 km h^{-1} is tackled head-on but this time by two opponents each of mass 100 kg and each running at a speed of 2.0 m s^{-1}.

With reference to your answer to **(ii)**, describe what happens under these conditions.

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____

____

____ [2]

Where appropriate in this question you should answer in continuous prose. You will be assessed on the quality of your written communication.

2 **(a)** The law relating the pressure of a fixed mass of gas at constant temperature to its volume is called Boyle's Law.

(i) Describe the method you would use to investigate this relationship. Give an indication of the results that should be taken to establish the relationship.

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____ [3]

(ii) State how you would ensure that, as far as possible, the sample of gas remains at constant temperature.

____

____

____ [1]

Quality of written communication [2]

(b) On a day when the atmospheric pressure is 102 kPa and the temperature is 8 °C, the pressure in a car tyre is 190 kPa above atmospheric pressure. After a long journey the temperature of the air in the tyre rises to 29 °C.

(i) Calculate the pressure of the air in the tyre at 29 °C. Assume that the volume of the tyre remains constant.

Pressure = _________ kPa [3]

(ii) Calculate the percentage increase in the root-mean-square speed $\left(\sqrt{<C^2>}\right)$ of the molecules of air in the tyre when the temperature rises from 8 °C to 29 °C.

Percentage increase = ______________ % [3]

3 **(a)** State the relationship between the linear velocity, v, radius, r, and the angular velocity, ω, for a body moving at constant speed in a circle.

____

____ [1]

(b) The high bar is one of the six pieces of equipment used in men's artistic gymnastics. The basic movement is the giant vertical circle in which the gymnast tries to remain extended in the handstand position whilst circling the bar.

A photograph of the athlete at various positions in his path is shown in **Fig. 3.1**.

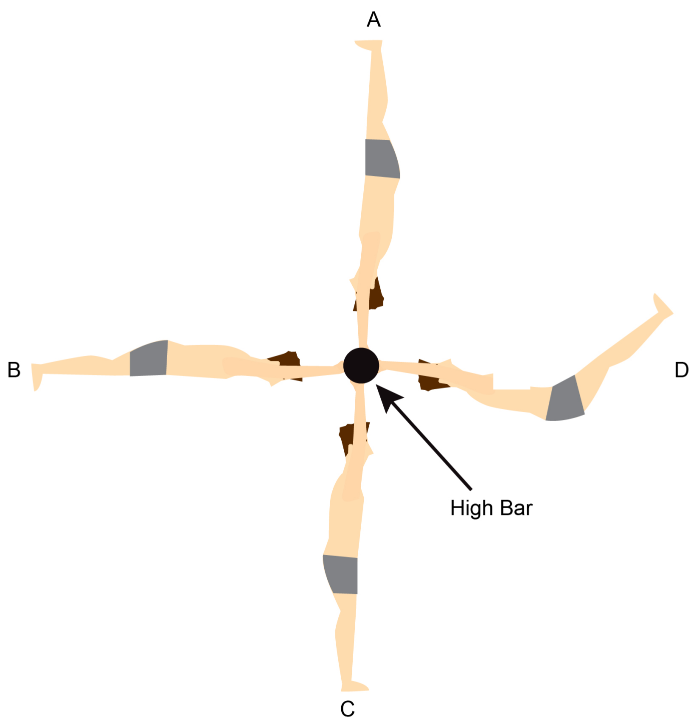

Fig. 3.1

The high bar is made of steel and is flexible. The degree to which the bar will flex or deform will vary as the gymnast performs the giant vertical circle.

(i) For a gymnast moving with a constant angular velocity, at which point **A**, **B**, **C** or **D** in the motion would maximum bar deformation occur? Explain your answer.

Point in motion: ____________________

Explanation:

____

____

____ [3]

(ii) There exists a set of circumstances during the giant vertical circle which results in **no deformation** of the high bar.

(1) Identify at what point in the gymnast's circular motion this will occur. Explain your answer.

Point in motion: ____________________

Explanation:

____

____

____ [3]

(2) Calculate the angular velocity of the gymnast at which this will occur. Take the centre of gravity of the gymnast to be 1.8 m from the bar.

Angular velocity = ____________________ rad s^{-1} [2]

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(Questions continue overleaf)

4 **(a)** An object of mass 0.060 kg vibrates with simple harmonic motion of amplitude 0.68 m and period 4.1 s.

(i) Calculate the acceleration of the object

(1) at an extreme point of its motion,

Acceleration = ______________ m s^{-2} [2]

(2) at the centre of its motion.

Acceleration = ______________ m s^{-2} [1]

(ii) The kinetic energy of the object varies during the motion.

(1) What is the minimum value of the kinetic energy?

Kinetic energy = ______________ J [1]

(2) At what point in the motion does this minimum value occur?

____

____ [1]

(b) A pendulum is an example of an oscillating system that is lightly damped.

(i) How could you tell that a pendulum is lightly damped?

____

____ [1]

(ii) What is the cause of the damping in a pendulum?

____ [1]

(iii) "Because of damping, the energy of the oscillating pendulum is not conserved." State with a reason whether this statement is **true** or **false**.

____

____

____ [1]

5 Geiger and Marsden performed experiments which consisted of firing alpha particles at thin sheets of gold.

(a) Outline two experimental observations which came from these experiments.

1. ______________________________

____

____

2. ______________________________

____

______________________________ [2]

(b) Rutherford compared one of the observations "to shooting an artillery shell at a piece of tissue paper and seeing it bounce back". Which of the observations was Rutherford referring to and how did he explain this observation?

____

____

____

______________________________ [3]

(c) The chemical symbol for gold is $^{197}_{79}\text{Au}$. Calculate the density of the gold nucleus.

Take r_o to be equal to 1.2×10^{-15} m, and the average mass of a nucleon to be 1.66×10^{-27} kg.

Density of the gold nucleus = ______________ kg m^{-3} [4]

6 **(a)** The iridium-168 isotope, Ir, is known to go through alpha decay to give rhenium, Re. If a nucleus of iridium has 77 protons find the number of neutrons and protons in the rhenium nucleus.

Number of protons = ____________

Number of neutrons = ____________ [2]

(b) **(i)** Define the half-life of a radioactive material.

____

____ [1]

(ii) Describe an experiment to measure the half-life of a radioactive isotope. Your description should include a list of readings to be taken, any necessary safety precautions and how the results are to be processed to find the half-life of the isotope.

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____ [6]

[Turn over

7 **(a)** Write down Einstein's mass–energy relationship. Identify any symbols used.

____

____

____ [1]

(b) (i) The helium atom has a mass of 4.00260 u. The atom consists of a nucleus which contains two protons each of mass 1.00728 u, two neutrons each of mass 1.00867 u, and two orbiting electrons each of mass 0.00055 u. What is the mass defect of the helium atom?

Mass defect = __________________ kg [3]

(ii) What is the energy equivalence of this mass defect in MeV?

Energy equivalence = __________________ MeV [2]

(iii) This energy equivalence is referred to as the **binding energy**. What is meant by the **binding energy**?

____

____

____ [1]

(c) A neutron of mass 1.00867 u is fired at the helium atom. What speed would the neutron have to acquire if it were to break the helium atom into its component parts, assuming all the KE of the neutron is absorbed by the helium atom?

Speed = ____________________ $m\,s^{-1}$ [2]

8 **(a)** What is nuclear fusion?

____

____

____ [1]

(b) **(i)** Complete the deuterium–tritium reaction given below.

$^{2}_{1}D + ^{3}_{1}T \rightarrow$

[1]

(ii) Give two reasons why this reaction is the most suitable reaction for terrestrial fusion.

____

____

____ [2]

(c) In order to produce a self-sustaining fusion reaction, the tritium deuterium plasma must be heated to over 100 million °C.

(i) Why is such a high temperature needed?

____

____

____ [2]

(ii) To sustain such a temperature the hot plasma must be kept away from the walls of the reactor. In the JET fusion reactor how is this achieved and what is used to achieve it?

____

____

____

____ [3]

Data Analysis Question
This question contributes to the synoptic requirement of the specification. In your answer you will be expected to bring together and apply principles and concepts from different areas of physics, and to use the skills of physics in the particular situation described.

9 When a converging lens is placed, curved side down, on top of a flat piece of glass and illuminated from above with monochromatic light, a pattern called Newton's Rings is observed. The rings are caused by interference of light waves. The pattern formed is shown in **Fig. 9.1** below. Diagram not to scale.

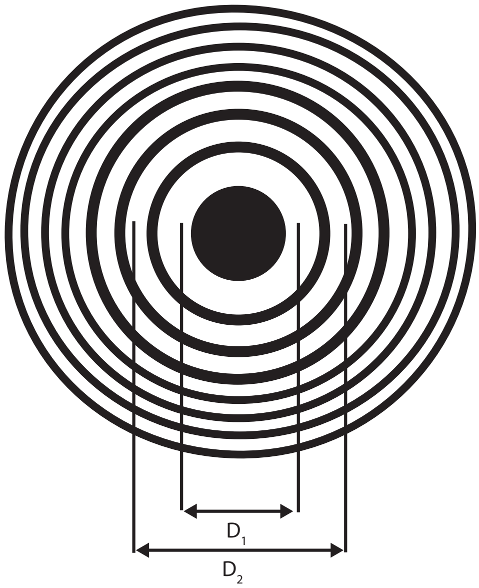

Fig. 9.1

The graph below, **Fig. 9.2**, shows how the ring diameter *D* varies with the ring number *n.* The innermost ring corresponds to *n* = 1. The corresponding diameter D_1 is labelled in **Fig. 9.1**.

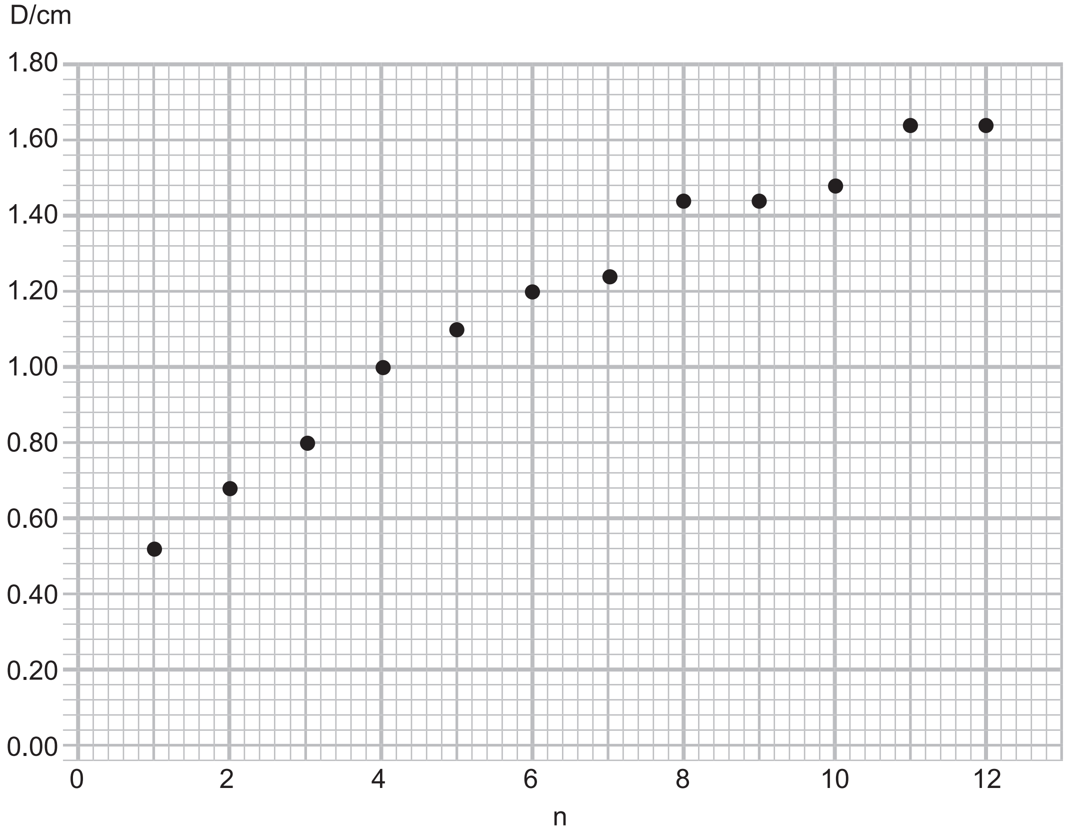

Fig. 9.2

(a) State one piece of evidence that shows that *D* is not proportional to *n*.

____

____ [1]

[Turn over

(b) It is suggested that the relationship between D and n is of the form

$$D = an^p$$

where a and p are constants.

Explain what graph you would plot and how it is used in order to determine the values of a and p.

[3]

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(Questions continue overleaf)

(c) Theory suggests that $p = \frac{1}{2}$ and so

$$D^2 = cn \text{ (where } c = a^2\text{).}$$

(i) Complete **Table 9.1** by inserting values for D^2.

Table 9.1

D/cm	0.52	0.68	0.80	1.00	1.08	1.20	1.26
D^2/cm^2							
n	1	2	3	4	5	6	7

[2]

(ii) Plot a graph of D^2 against n in **Fig. 9.3**.

(iii) Use the graph in **Fig. 9.3** to determine the value of the constant c.

Value of c = ______________________ [2]

(iv) Determine the percentage uncertainty of the constant a.

Percentage uncertainty of a = ____________ % [3]

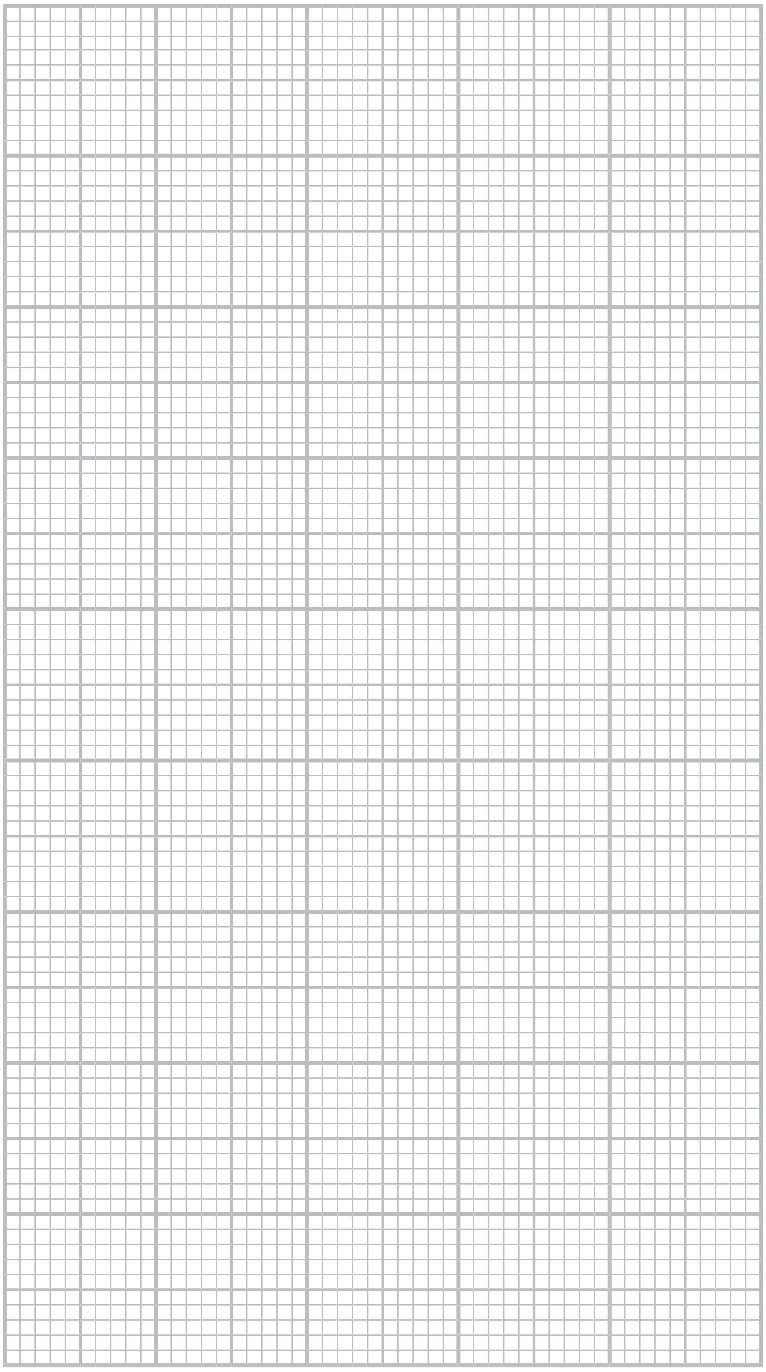

Fig. 9.3

[5]

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For Examiner's use only		
Question Number	Marks	Remark
1		
2		
3		
4		
5		
6		
7		
8		
9		

Total Marks		

GCE Physics

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{F^{-1}\,m}\right)$
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 unit	$1\ \mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
mass of electron	$m_\mathrm{e} = 9.11 \times 10^{-31}\,\mathrm{kg}$
mass of proton	$m_\mathrm{p} = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_\mathrm{A} = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall on the Earth's surface	$g = 9.81\,\mathrm{m\,s^{-2}}$
electron volt	$1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$

The following equations may be useful in answering some of the questions in the examination:

Mechanics

Conservation of energy	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$	for a constant force
Hooke's Law	$F = kx$	(spring constant k)

Simple harmonic motion

Displacement	$x = \mathrm{A}\cos\omega t$

Sound

Sound intensity level/dB	$= 10\,\mathrm{lg}_{10}\dfrac{I}{I_0}$

Waves

Two-source interference	$\lambda = \dfrac{ay}{d}$

Thermal physics

Average kinetic energy of a molecule	$\frac{1}{2}m\left\langle c^2\right\rangle = \frac{3}{2}kT$
Kinetic theory	$pV = \frac{1}{3}Nm\left\langle c^2\right\rangle$
Thermal energy	$Q = mc\Delta\theta$

Capacitors

Capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$
Capacitors in parallel	$C = C_1 + C_2 + C_3$
Time constant	$\tau = RC$

Light

Lens formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

Magnification $m=\frac{v}{u}$

Electricity

Terminal potential difference $V=E-Ir$ (e.m.f. E; Internal Resistance r)

Potential divider $V_{\text{out}}=\frac{R_1 V_{\text{in}}}{R_1+R_2}$

Particles and photons

Radioactive decay $A=\lambda N$

$A=A_0 e^{-\lambda t}$

Half-life $t_{\frac{1}{2}}=\frac{0.693}{\lambda}$

de Broglie equation $\lambda=\frac{h}{p}$

The nucleus

Nuclear radius $r=r_0 A^{\frac{1}{3}}$