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General Certificate of Education
January 2014

Centre Number

71	

Candidate Number

Physics

Assessment Unit A2 1

assessing

Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

[AY211]

AY211

MONDAY 20 JANUARY, AFTERNOON

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.
Answer **all eleven** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **10**.
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 **11** contributes to the synoptic assessment required of the specification.

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
Total Marks	

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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.

Examiner Only	
Marks	Remark

Answer **all eleven** questions

1 **(a)** An explosion splits an object, initially at rest, into two pieces of unequal mass. A student observes that the less massive of the two pieces moves with a faster speed than the heavier piece and in the opposite direction. Explain these observations.

____

____

____ [2]

(b) **(i)** During a ten pin bowling game a player has one pin left to knock down. The player rolls a 7.26 kg bowling ball down the lane and it hits the stationary pin, of mass 1.47 kg, head on at a speed of 8.15 $m\,s^{-1}$. After the collision the pin moved forwards at a speed of 13.32 $m\,s^{-1}$. Calculate the speed of the ball after the collision.

Speed of ball = ____________ $m\,s^{-1}$ [2]

(ii) 1. State what is meant by an inelastic collision.

____

____ [1]

2. Show, **by calculation**, that the collision between the bowling ball and the pin was inelastic.

[2]

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Examiner Only	
Marks	Remark

2 **(a)** State the difference between a real gas and an ideal gas in terms of the internal energy of the gas molecules.

____

____ [2]

(b) The coldest known place in the universe is the Boomerang Nebula, 5000 light years away from us in the constellation Centaurus. Scientists reported in 1997 that gases blowing out from a central dying star have expanded and rapidly cooled to a temperature of 1.0 K. Usually, gas clouds in space are at a temperature of 2.7 K.

Calculate the difference between the average kinetic energy of a gas molecule at a temperature of 1.0 K compared to 2.7 K.

Kinetic energy difference = ____________ J [2]

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Marks	Remark

(c) **Fig. 2.1** shows a graph of pressure against mean square speed of a fixed mass of carbon dioxide molecules trapped inside a 50 cm^3 container of fixed volume.

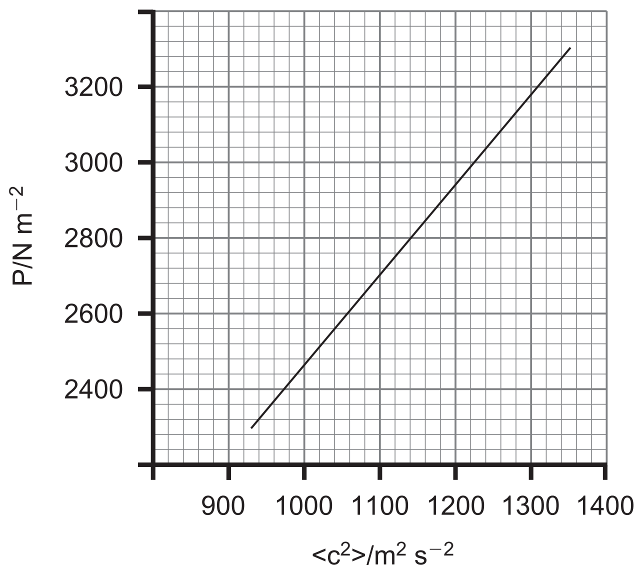

Fig. 2.1

(i) Write down an equation for the gradient of the line of **Fig. 2.1** in terms of N the number of molecules, m the molecular mass and V the gas volume.

Gradient = ____________ [2]

(ii) The molar mass of carbon dioxide is 44.01 g mol^{-1}. Use the graph of **Fig. 2.1** to calculate the number of carbon dioxide molecules in the container.

Number of carbon dioxide molecules = ____________ [4]

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Examiner Only: Marks | Remark

3 **(a)** An electrical method to determine the specific heat capacity of iron is carried out using the apparatus shown in **Fig. 3.1**.

(i) Complete **Fig. 3.1** by drawing a suitable circuit containing an ammeter and voltmeter that will allow the energy input to the heater to be calculated. [2]

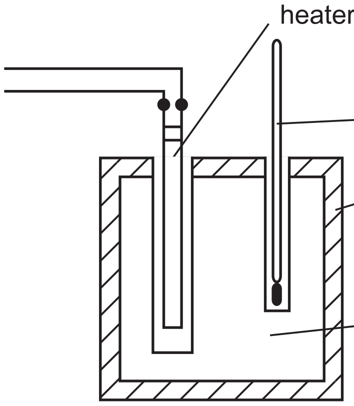

Fig. 3.1

(ii) The circuit is turned on at the same time as a stopclock is started. After a considerable time the circuit is switched off and the time and temperature recorded immediately.

Explain why this procedure will result in a value for the specific heat capacity of iron that is higher than the accepted value and state how the procedure should be adapted to improve the value obtained. Assume the insulation is perfect and that there is no energy loss to the surroundings.

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____ [3]

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(b) In a non-electrical method to determine the specific heat capacity of iron, a student took a 15 g piece of the iron and placed it into boiling water until it reached a temperature of 100.00 °C. The iron was then removed from the boiling water and immediately plunged into 100 g of water at 25.00 °C.

The hot iron cools down and the water heats up until both reach the same end temperature, which was measured to be 26.36 °C. If the specific heat capacity of water is 4184 J kg^{-1} °C^{-1} and energy losses to the container holding the water at 25.00 °C are negligible, calculate the specific heat capacity of the iron.

Specific heat capacity = ____________ J kg^{-1} °C^{-1} [3]

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Examiner Only	
Marks	Remark

4 Two examples of objects that move with circular motion are the Earth, which rotates once on its axis every 24 hours and the blade of a fan, which completes 24 revolutions per minute. The radius of the Earth is 6400 km and the fan blade has a radius of 40 cm.

(a) The angular velocity of a point on the edge of the fan is much greater than the angular velocity of a point on the surface of the Earth at the equator, while the linear velocity of these same points is much greater on the Earth than on the fan.

Carry out appropriate calculations and complete **Table 4.1** to show that the above statement is true.

Table 4.1

	Point on edge of fan	**Point on surface of Earth at the equator**
Angular velocity/rad s^{-1}		
Linear velocity/m s^{-1}		

[4]

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Marks	Remark

(b) (i) Explain why the linear velocity of a point on the Earth's surface at the equator is so much larger than at the edge of the fan, even though it has a much smaller angular velocity.

____ [1]

(ii) **Fig. 4.1** shows a circle representing the Earth. Explain why it is necessary to know that the point on the surface of the Earth is at the equator when calculating the linear velocity. Draw on **Fig. 4.1** to help explain your answer.

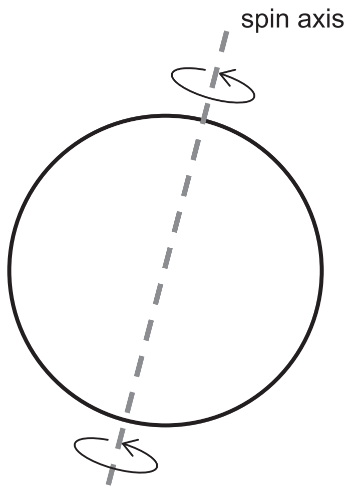

Fig. 4.1

____

____ [2]

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Examiner Only	
Marks	Remark

5 **(a)** Simple harmonic motion and circular motion have some similarities. The period is one example.

(i) Define the period of an object moving in circular motion.

____

____ [1]

(ii) Define the period of an object moving in simple harmonic motion.

____

____ [1]

(iii) One difference between circular motion and simple harmonic motion is due to the force that causes the motion. Describe the differences in the magnitude and direction of the forces that act to keep an object moving with circular motion and an object moving with simple harmonic motion. In both cases the period of the object is constant.

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____

____ [4]

(b) Describe how the amplitude and period of oscillation change over time for a lightly damped system and explain how and why the average speed of the object oscillating must also change.

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____ [3]

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Examiner Only	
Marks	Remark

6 **(a)** An iron nucleus contains 56 nucleons of which 26 are protons. Calculate the density of the nucleus of an iron atom.

Take $r_0 = 1.2$ fm and the volume of a sphere as $\frac{4}{3}\pi r^3$

Density = ____________ $\mathrm{kg\,m^{-3}}$ [4]

(b) An iron cube with 5 cm sides has a mass of 0.984 kg. Calculate the density of iron metal.

Density = ____________ $\mathrm{kg\,m^{-3}}$ [1]

(c) What does the difference in your answers to **(a)** and **(b)** tell you about the composition of iron atoms?

____

____ [1]

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Examiner Only	
Marks	Remark

7 A large number of dice can be used to model the radioactive decay process. When the dice are thrown, any that land as a "6" are said to have decayed and are removed from the pile before the next throw.

(a) In this model, the "throw number" is equivalent to the "time taken" in radioactive decay. What does the number of dice remaining after each throw represent?

____ [1]

(b) A teacher carries out the experiment in class and records the results in **Table 7.1**. The initial number of dice was 250.

(i) Calculate the missing values from **Table 7.1** and enter them into the table. [1]

Table 7.1

throw number	number of 6s	number of dice remaining, N
1	38	212
2	32	180
3	29	
4	23	128
5	21	107
6	15	92
7	15	
8	11	66
9	6	60
10	7	53

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Examiner Only | Marks | Remark

(ii) Plot a graph of the number of dice remaining against throw number on the grid of **Fig. 7.1** [2]

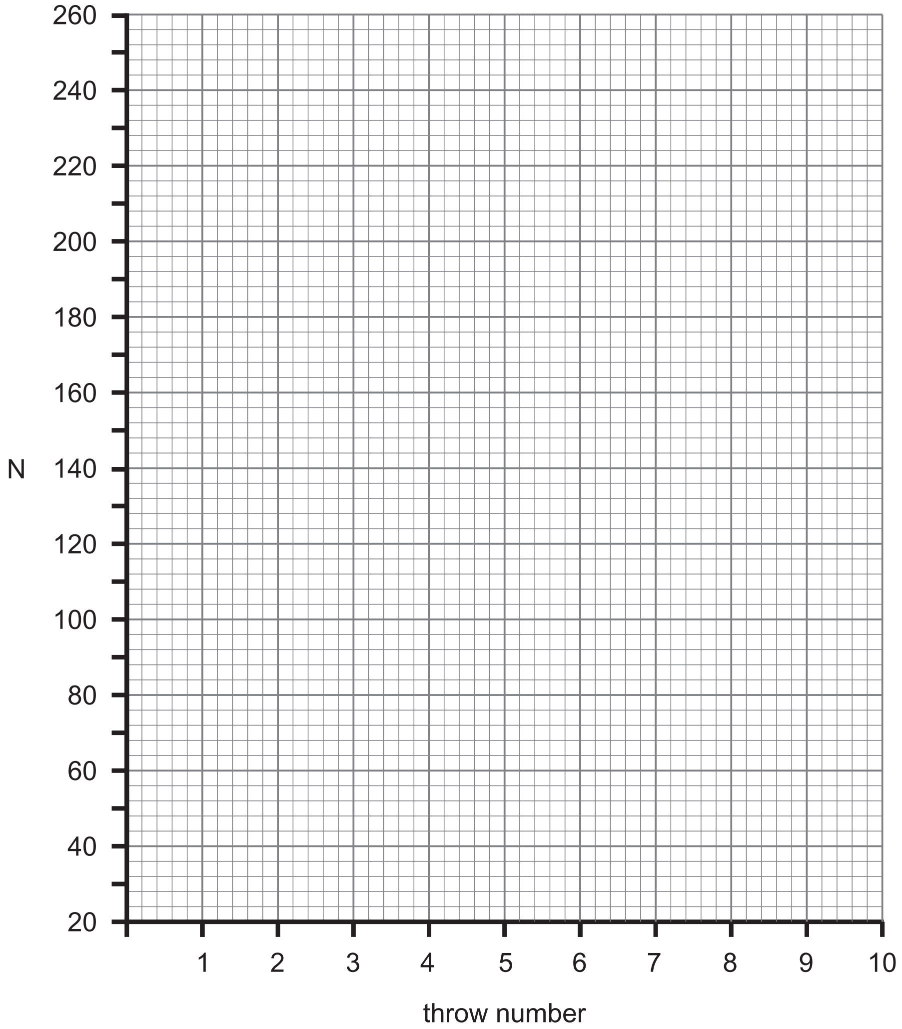

Fig. 7.1

(iii) From your graph, calculate a value equivalent to the half-life of the dice. Give your answer to 1 decimal place.

Half-life equivalent = ____________ throws [2]

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Examiner Only	
Marks	Remark

(iv) Calculate the hypothetical decay constant from your answer to **(iii)**.

Decay constant = ____________ $throw^{-1}$ [1]

(v) How does this compare to the actual probability of throwing a 6?

____

____ [1]

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Examiner Only	
Marks	Remark

8 **(a)** Einstein's equation relating mass and energy states that if energy is added into a system the mass of the system will increase.

If a 1 kg bar of gold is heated so that its temperature rises by 20 °C, it gains 2.58×10^3 J of energy. Calculate the mass increase in the bar of gold when it is heated by 20 °C.

Mass increase = ____________ kg [2]

(b) The mass increase in a 1 kg bar of gold is so small that it can be considered negligible. Einstein's equation can be more usefully applied in nuclear reactions. Explain how the equation applies in nuclear reactions.

____

____

____ [2]

(c) Draw the curve showing how the binding energy per nucleon varies with mass number on the axes in **Fig. 8.1.** Indicate clearly on the diagram the region where nuclei undergo fission and the region where nuclei undergo fusion. [4]

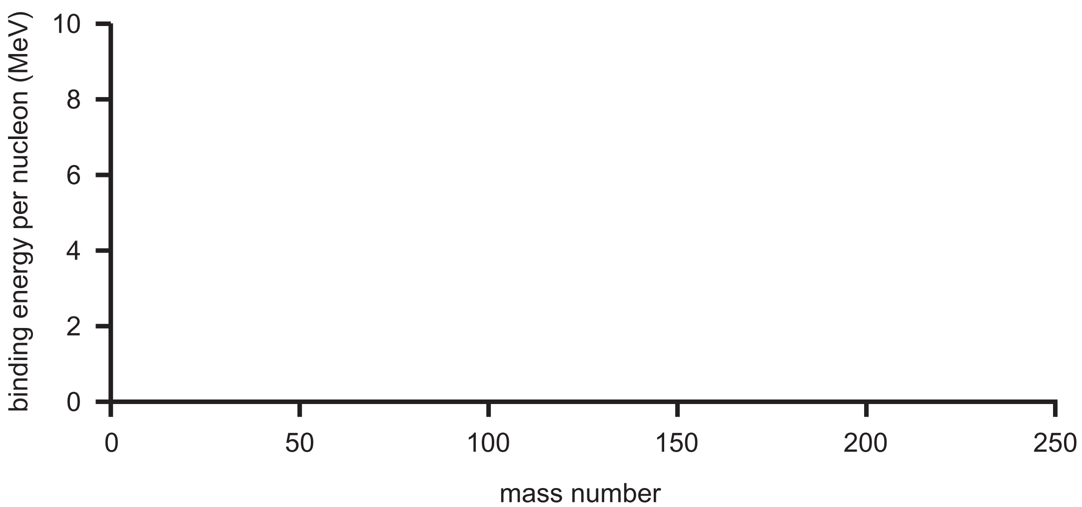

Fig. 8.1

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Examiner Only	
Marks	Remark

9 The fate of the neutrons produced in the fission process is the key to understanding the difference between a controlled nuclear reaction, which takes place inside a nuclear reactor, and an uncontrolled nuclear reaction, which leads to the explosion of an atomic bomb.

(a) Why is there the possibility of an uncontrolled nuclear reaction when nuclear fission occurs? Describe the process by which this would happen.

____

____

____

____

____ [3]

(b) **(i)** All nuclear reactors have a Self-Controlled Remote Automatic Mechanism (SCRAM): in the case of an accident, it inserts the control rods completely into the core of the reactor in a very short time.

Explain how this will stop the nuclear reactions taking place and in as short a time as possible.

____

____

____ [2]

(ii) Name another safety feature of a fission reactor and state its function.

____

____ [2]

(c) "When a Nuclear Reactor Dies, $98 Million is a Cheap Funeral," is a quote from *Smithsonian Magazine*, in October 1989. Explain why this quote is relevant to a fission reactor.

____

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____ [1]

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Examiner Only	
Marks	Remark

In this question you will be assessed on the quality of your written communication. You are advised to answer in continuous prose.

10 Discuss the possibility of using nuclear fusion in a power station as a useful energy resource in the 21st century. Include in your answer:

- The equation for the most suitable terrestrial fusion reaction.
- The advantages associated with nuclear fusion.
- The problems associated with achieving nuclear fusion.
- One method being used to try to overcome some of the practical difficulties.

_____ [6]

Quality of written communication [2]

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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.

11 The volume of fluid that passes through a narrow tube in one second is the volume flow rate, Q in $m^3\,s^{-1}$. This is given by Poiseuille's Law, **Equation 11.1**

$$Q = \frac{\pi r^4 P}{8\eta L} \quad \textbf{Equation 11.1}$$

where r is the radius of the tube, P the pressure difference between the ends of the tube, L the length of the tube and η, a constant known as the viscosity of the fluid.

(a) Use **Equation 11.1** to work out the base units of viscosity, η.

Base units = ______________ [2]

(b) In an experiment to verify Poiseuille's Law, a fluid was passed down tubes of different lengths and the fluid that moved through the tube in one minute was collected in a measuring cylinder.
The results of the experiment are shown in **Table 11.1**.

Table 11.1

L/m	Q/m^3 s^{-1}	$\frac{1}{L}$ /m^{-1}
0.20	3.22×10^{-4}	5.0
0.25	2.60×10^{-4}	4.0
0.30	2.14×10^{-4}	3.3
0.35	1.76×10^{-4}	2.9
0.40	1.63×10^{-4}	2.5

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Marks	Remark

(i) Values of the volume flow rate, Q, have been calculated. Describe how they would have been found from the method used and results taken.

____

____ [2]

(ii) Explain how a graph of Q against $1/L$ can be used to verify Poiseuille's Law if the constant values for r and η are known and the pressure difference P is maintained at the same known value throughout.

____

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____

____ [2]

(c) **Fig. 11.1** shows the plotted graph of the results.

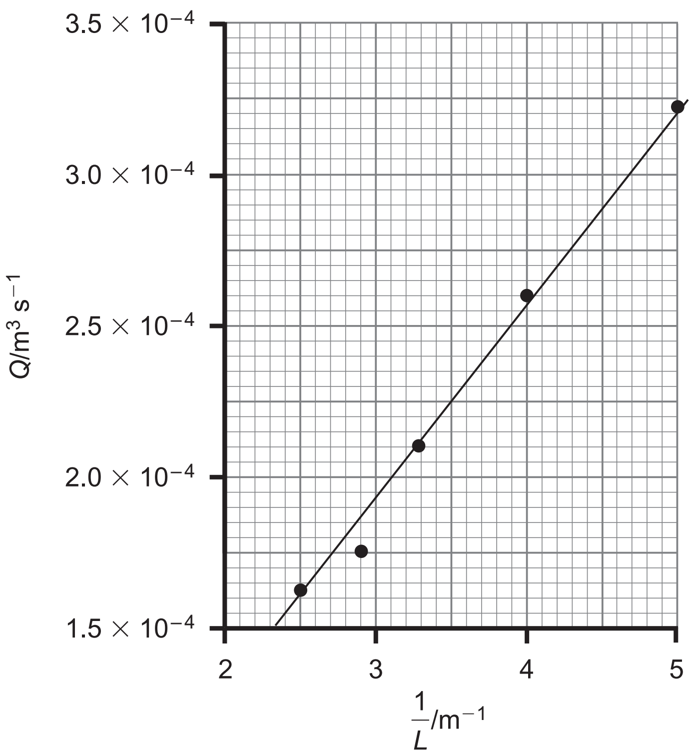

Fig. 11.1

(i) One result appears to be anomalous. Identify at which length the anomalous result occurred and state the correct value of Q assuming the graph is correct.

L at which the anomalous result occurred = ____________ m

Correct value of Q = ____________ $m^3 s^{-1}$ [2]

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(ii) Calculate the gradient of the graph and state the units of the gradient.

Gradient = ______________

Units of gradient = ______________ [3]

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Marks	Remark

THIS IS THE END OF THE QUESTION PAPER

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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	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
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	$1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$

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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 — $x = A\cos\omega t$

Sound

Sound intensity level/dB — $= 10\lg_{10}\frac{I}{I_0}$

Waves

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

Thermal physics

Average kinetic energy of a molecule — $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

Kinetic theory — $pV = \frac{1}{3}Nm\langle c^2\rangle$

Thermal energy — $Q = mc\Delta\theta$

Capacitors

Capacitors in series — $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Capacitors in parallel — $C = C_1 + C_2 + C_3$

Time constant — $\tau = RC$

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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	$V_{out}=\frac{R_1V_{in}}{R_1+R_2}$

Particles and photons

Radioactive decay	$A=\lambda N$
	$A=A_0e^{-\lambda t}$
Half-life	$t_{\frac{1}{2}}=\frac{0.693}{\lambda}$
de Broglie equation	$\lambda=\frac{h}{p}$

The nucleus

Nuclear radius	$r=r_0A^{\frac{1}{3}}$

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