SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

NAME			
CG		**INDEX NO.**	

PHYSICS — **9646**
Preliminary Examination — **18 August 2011**
Paper 2 Structured Questions — **1 hour 45 minutes**

Candidates answer on the Question Paper.
No additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in bracket [ ] at the end of each question or part question.

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Total	

This document consist of **19** printed pages and **1** blank page

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DATA AND FORMULAE

Data

speed of light in free space,	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}
			$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos\omega t$
	v	=	$\pm\omega\sqrt{(x_0^2 - x^2)}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_0 \sin\omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
			where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

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Answer all questions

1 A SRJC student who intends to major in Physics in university attempted to recall Bernoulli's equation, widely used in the field of fluid dynamics. Based on his recollection during H3 lectures, he was able to come up with the following equation:

$$k = p + h\rho g + \frac{1}{2}\rho v^a$$

where p is pressure, h is height, ρ is density, v is velocity and k is a constant. However, he was unable to recall the value of a.

(a) Based on dimensional analysis (ie. comparison of units of terms in the equation), determine the value of a.

$[p] = \left[\frac{1}{2}\rho v^a\right]$

$Nm^{-2} = (kgm^{-3})(ms^{-1})^a$

$(kgms^{-2})m^{-2} = kgm^{-3+a}s^{-a}$ [M1]

$kgm^{-1}s^{-2} = kgm^{a-3}s^{-a}$

By comparing coefficients, a = 2 [A1]

a = ... [2]

(b) Under certain conditions, the equation reduces to $k = \frac{1}{2}\rho v^a$. Calculate the percentage uncertainty in k, given the values of the quantities as listed below.

ρ = (1000 ± 2%) kg m^{-3}
v = (20.0 ± 0.2) m s^{-1}

$k = \frac{1}{2}\rho v^2$

$\frac{\Delta k}{k} = \frac{\Delta \rho}{\rho} + 2\frac{\Delta v}{v}$ [M1]

$= 0.02 + 2\left(\frac{0.2}{20.0}\right) = 0.04$

Percentage uncertainty = 0.04 x 100% = 4% [A1]

percentage uncertainty = ... % [2]

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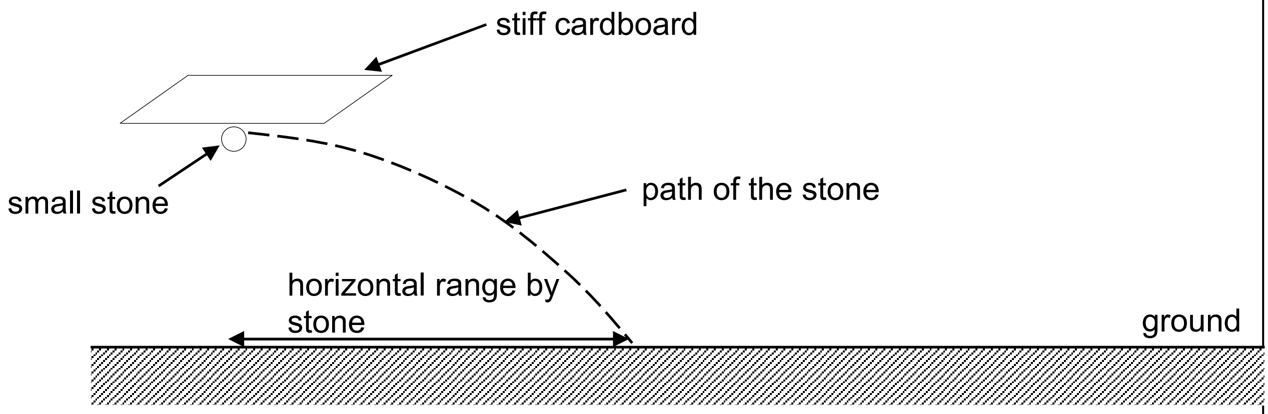
2 **(a)** Derive, from the definitions of velocity and acceleration, the expression

$$v^2 = u^2 + 2as.$$ [2]

(b) In an experiment to test the effect of air resistance on different objects, a small stone and a thin piece of stiff cardboard are separately projected horizontally from the same vertical height, at the same initial speed. The figure below shows the path taken by the stone.



The plane of the paper remains parallel to the ground during its journey.

(i) Explain, why the horizontal range covered by the path of the paper is observed to be further than that of the stone.

Since there is no air resistance experienced in the horizontal direction, the horizontal velocity of paper and stone are the same [M1]. ……………………………...

Due to the surface area of the paper, air resistance is experienced in the vertical direction. Hence duration of flight for paper is longer [M1]. …………………………...

With a longer flight duration for the same horizontal velocity, the horizontal range covered in longer [A0]. ...

…………………………………………………………………………………...

……………………………………………………………………………………[2]

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(ii) Describe and explain, if the final velocity of the paper before hitting the ground, is higher, lower or the same, than that for the stone.

With the same vertical distance covered, the longer flight duration of the paper would mean that its final vertical velocity is lower. [M1]

Since the horizontal velocity for both are the same, the final velocity of the paper would be lower. [A1]

[2]

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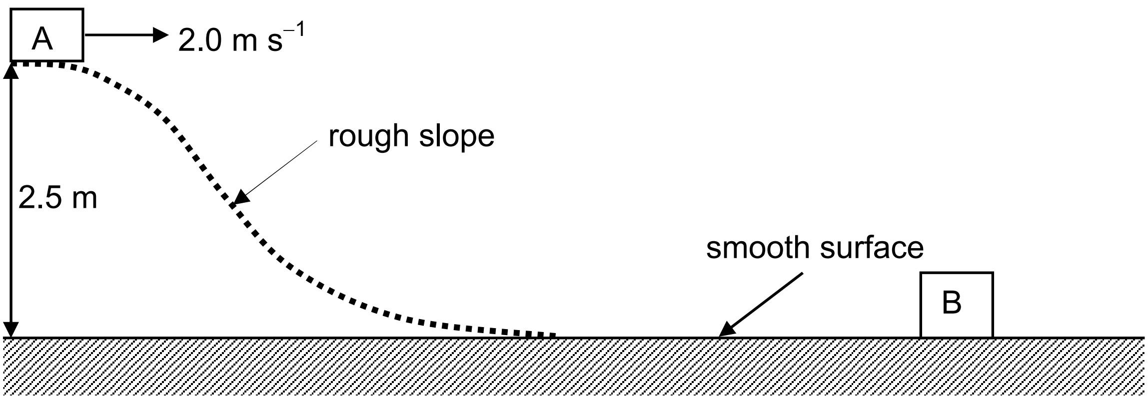
3 **(a)** State the *Principle of Conservation of Linear Momentum*.

The total momentum for a system of colliding bodies remains constant provided that no external force acts on the system.

……………………………………………………………………………………………...

……………………………………………………………………………………………[1]

(b) Box A, of mass 1.5 kg, slides down a rough slope with an initial velocity of 2.0 m s^{-1}. The vertical height of the slope is 2.5 m and the work done against friction by Box A is 5.0 J.



(i) Calculate the velocity of Box A at the bottom of the slope.

Loss in GPE = Gain in KE + Work done against friction

$$(1.5)(9.81)(2.5) = \frac{1}{2}(1.5)\left(v_A{}^2 - 2.0^2\right) + 5 \quad [M1]$$

$$v_A = 6.81 \text{ m s}^{-1} \quad [A1]$$

velocity of Box A at bottom of slope = ………………… m s^{-1} [2]

(ii) At the bottom of the slope, Box A travels along a smooth surface before colliding elastically with a stationary Box B of mass 3.0 kg.

Calculate the final velocities of Box A and Box B immediately after separation.

By COLM,

$1.5(6.81) = 1.5v_A + 3.0v_B$ ......(Eqn1)

By RSA = RSS

$6.81 - 0 = v_B - v_A$ ....(Eqn2) [M1 for Eqn 1 and 2]

Solving Eqn 1 and Eqn 2,

$v_A = -2.27$ m s^{-1} [*A*1]

$v_B = 4.54$ m s^{-1} [*A*1]

velocity of Box A = …………………….. m s^{-1}

velocity of Box B = ……………………… m s^{-1} [3]

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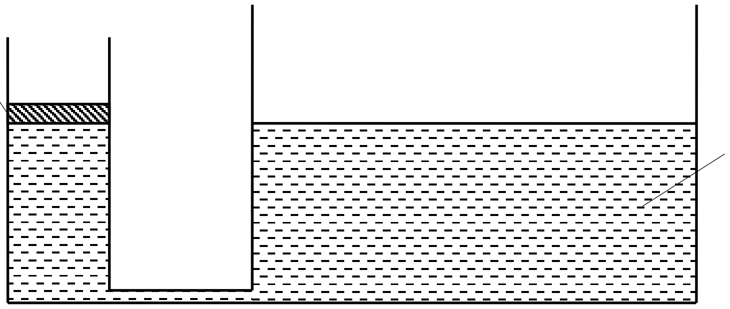
4 A tank with an L-shaped pipe is to be used as a weighing scale. A light airtight frictionless piston is in the pipe, and is in contact with the water. The cross-sectional area of the tank is 4 times that of the piston. The connecting pipe has negligible volume.



Initially, the water levels in the pipe and tank are equal. An object is placed gently on the piston and the piston descends to a new height. It is observed that the piston descends by 2.0 cm.

(a) **(i)** Calculate the difference in water levels within the pipe and tank.

Decrease in volume of water within pipe = Increase in volume of water within tank [M1]
Let Cross-sectional area of pipe be A.
(2.0 cm) (A) = (Increase in height of water in tank) (4A)
Increase in height of water in tank = 0.5 cm
Difference in water levels = 2.0 + 0.5 cm = 2.5 cm [A1]

difference in water levels = …………………… cm [2]

(ii) Hence calculate the mass of the object. The cross-sectional area of the piston is 0.01 m^2, and the density of water is 1000 kg m^{-3}.

Pressure at level of piston, within L-shaped pipe = mg/A -----(1)
Pressure within tank, at level of piston = ρgh -----(2)
[M1 for both expressions]
Equating two expressions, m = Aρh = (0.01)(1000)(0.025) = 0.25 kg [A1]

mass of object = ………………… kg [2]

(b) "Friction always causes energy to be dissipated." With reference to a suitable example, suggest why this statement is not true.

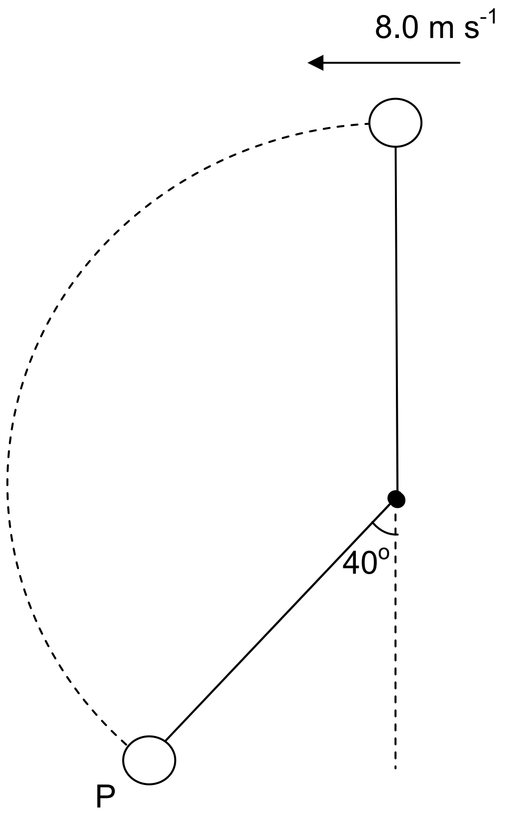
....

....

....[2]

Energy is only lost due to kinetic friction, no negative work is done by static friction.
or Energy is only lost when friction opposes motion. [B1]
Possible examples: Rolling of object, object resting on inclined slope. [B1]

5 A pendulum bob of mass 5.00 kg is projected at a speed of 8.0 m s^{-1} at the top of a vertical circle as shown in the diagram below. The radius of the circular path is 1.50 m.



(a) Calculate the speed of the bob when it reaches point P.

$$\frac{1}{2}mv_i^2 + mgh = \frac{1}{2}mv^2$$

$$\frac{1}{2}(8.0)^2 + (9.81)(1.50 + 1.50\cos 40) = \frac{1}{2}v^2$$ [M1]

$$v = 10.8\,ms^{-1}$$ [A1]

speed = ... ms^{-1} [2]

(b) Determine the tension at point P.

$$F = ma$$

$$F = m\frac{v^2}{r}$$

$$T - (5.00)(9.81)\cos 40 = \frac{(5.00)(10.77)^2}{1.50}$$ [1]

$$T = 424N$$ [1]

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tension = ... N [2]

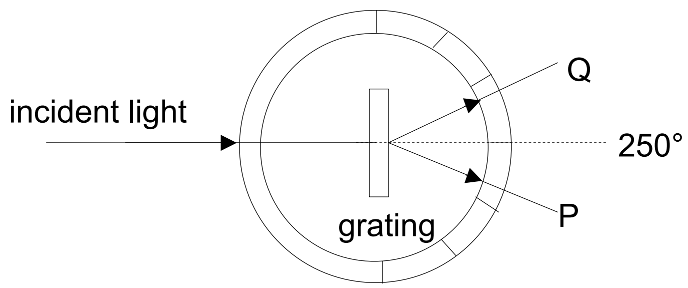
(c) State and explain where the string is most likely to break.

.... [2]

At the bottom, tension has to be larger than the entire weight so that the resultant force is towards the centre of the circle. [B1]

Hence, the string is most likely to break at the bottom. [B1]

6 A narrow beam of coherent light of wavelength 589 nm falls normally on a diffraction grating having 500 lines per millimetre. The diffraction grating is situated at the centre of a circular scale.



The straight through direction is at the reading of 250° on the scale. A detector is placed at P, where the reading on the scale is 210°. The detector is then moved towards Q, where the reading on the scale is 290°.

(a) Determine the number of spectral lines detected as the detector moves from P to Q.

$d \sin \theta = n\lambda$

$(1 \times 10^{-3} \div 500) \sin (290 - 250)° = n (589 \times 10^{-9})$ [M1]

$n = 2.18$

Total no. of spectral lines detected = 2 × 2 + 1 = 5 [A1]

number of spectral lines detected = ………………….. [2]

(b) Explain how the angular separation between two spectral lines of the same order can be increased.

....

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……………………………………………………………………………………………...

……………………………………………………………………………………………[2]

Since *d* sin *θ* = *nλ*, by reducing the slit separation in the diffraction grating / increasing the number of lines per milimeter / increasing the wavelength [B1], the smaller the slit separation / the larger the wavelength, the larger the angle *θ* . [B1]

(c) State and explain the problem that is likely to arise when observing the spectral lines at a higher order.

....

……………………………………………………………………………………………...

....

……………………………………………………………………………………………[2]

Higher order diffracted light has a lower intensity compared to the lower orders (due to envelope constraint resulting from diffraction of light from each individual silt). [B1]

This makes the spectal lines less distinguishable / harder to observe / dimmer. [B1]

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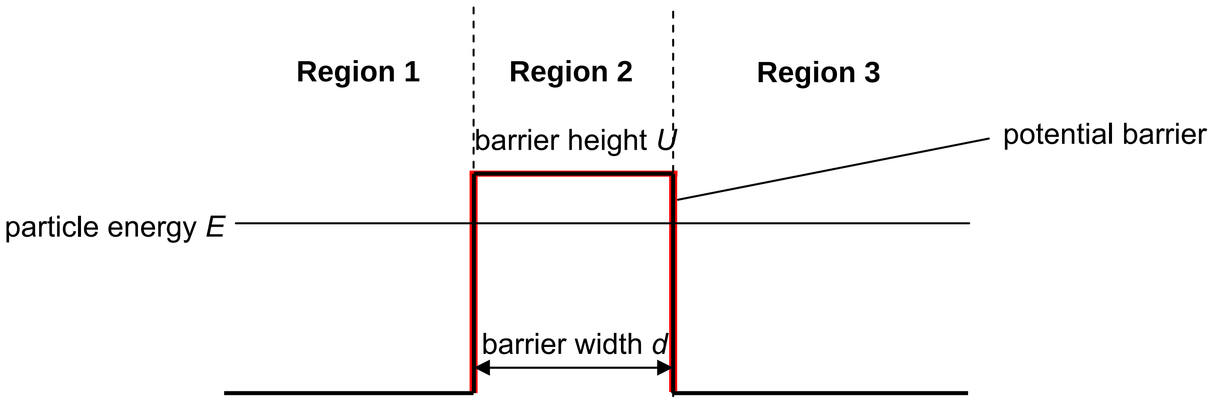
7 **(a)** Show, with the aid of a diagram, what is meant by a *potential barrier*.

....

....

....

....[2]



[Diagram B1]

A potential barrier is a region of maximum potential that prevents an atomic particle on one side of it passing through the other side / where the potential energy U of a particle is higher than its total energy. [B1]

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(b) Using classical mechanics, explain why it is impossible for the particle to penetrate a potential barrier.

....

....

....

....

....

....[1]

For the particle to move from Region 1 to exist in Region 2, it must have total energy of *U*. [B1]
Since total energy *E* = PE + KE, if the particle exists in Region 2,
$E = U + KE_2$
$KE_2 = E - U$
This value of KE_2 is negative, which is classically impossible. [B1]
OR
It does not have enough total energy to overcome *U*. [B1]

(c) Discuss how the wave nature of particles allows particles to tunnel through such a barrier.

....

....

....

....

....

....[2]

The particle has a wave function Ψ associated with it. The amplitude of the wave function is non-zero in all 3 regions / the wave function is smooth and continuous, hence $|\Psi|^2$ at any point is also non-zero.[B1]
Because the probability of locating the particle is proportional to $|\Psi|^2$, there is a finite probability of locating the particle in all 3 regions, regardless of its energy.[B1]

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8 A radioactive sample contains an isotope of Iodine-124. A Geiger Muller tube is placed at a distance from the source to obtain a count rate.

(a) (i) Explain what is meant by the term *isotope*.

Isotopes are atoms with the same number of protons but different number of neutrons. ....

....[1]

(ii) The activity of the radioactive sample is much higher than the count rate (per second) registered by the Geiger Muller tube. Suggest a reason for this.

Since the radioactive particles are emitted in all directions, the GM tube will always receive only a fraction of the total number of emitted particles. Hence the count rate is lower than the activity rate. ....[1]

(b) (i) The sample has a mass of 50 g. Iodine accounts for 0.3% of the sample mass and only 0.116% of this belongs to the Iodine-124 isotope.

Calculate,

1. the number of moles of Iodine-124 present in the sample,

No of I-124 nuclei = $0.3/100 \times 0.116/100 \times 50 \div 124$
$= 1.40 \times 10^{-6}$ [A1]

number of moles of Iodine-124 = ... [2]

2. the number of Iodine-124 atoms present in the sample.

No of I-124 nuclei = $1.40 \times 10^{-6} \times 6.02 \times 10^{23}$
$= 8.45 \times 10^{17}$ [A1]

number of Iodine-124 atoms = ... [2]

(ii) The background radiation count rate was found to be 5.0% of the initial total count rate.

After a period of time, the count rate fell to 70.0% of the initial count rate. Assuming that the background radiation remains constant, calculate the number of Iodine-124 nuclides remaining in the sample.

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For the count rate measured initially, 95% is contributed by the radioactive sample. To decay to 70% of the count rate measured initially, the present count rate due to radioactive source must have decayed to 65% of the initial source, whist the background radiation still accounts for 5% of the initial count rate.

Hence the ratio of nuclides remaining = 65/95 [M1]

Number of I-124 nuclides remaining = 65/95 $\times$ 8.45 $\times$ 10^{17}

= 5.78 $\times$ 10^{17} [A1]

number of nuclides remaining = …………………….. [2]

(iii) The half-life of Iodine-124 is 4.2 days. Calculate the time taken, in days, for the fall in count rate mentioned in **(b)(ii)**.

$C = C_o e^{-\lambda t}$

$$\ln\frac{C}{C_o} = -\frac{\ln 2}{t_{1/2}}t$$

$$t = -\frac{\ln\frac{65}{95}}{\frac{\ln 2}{4.2}} \quad \text{[M1]}$$

$= 2.29$ days [A1]

time taken = …………………….. days [2]

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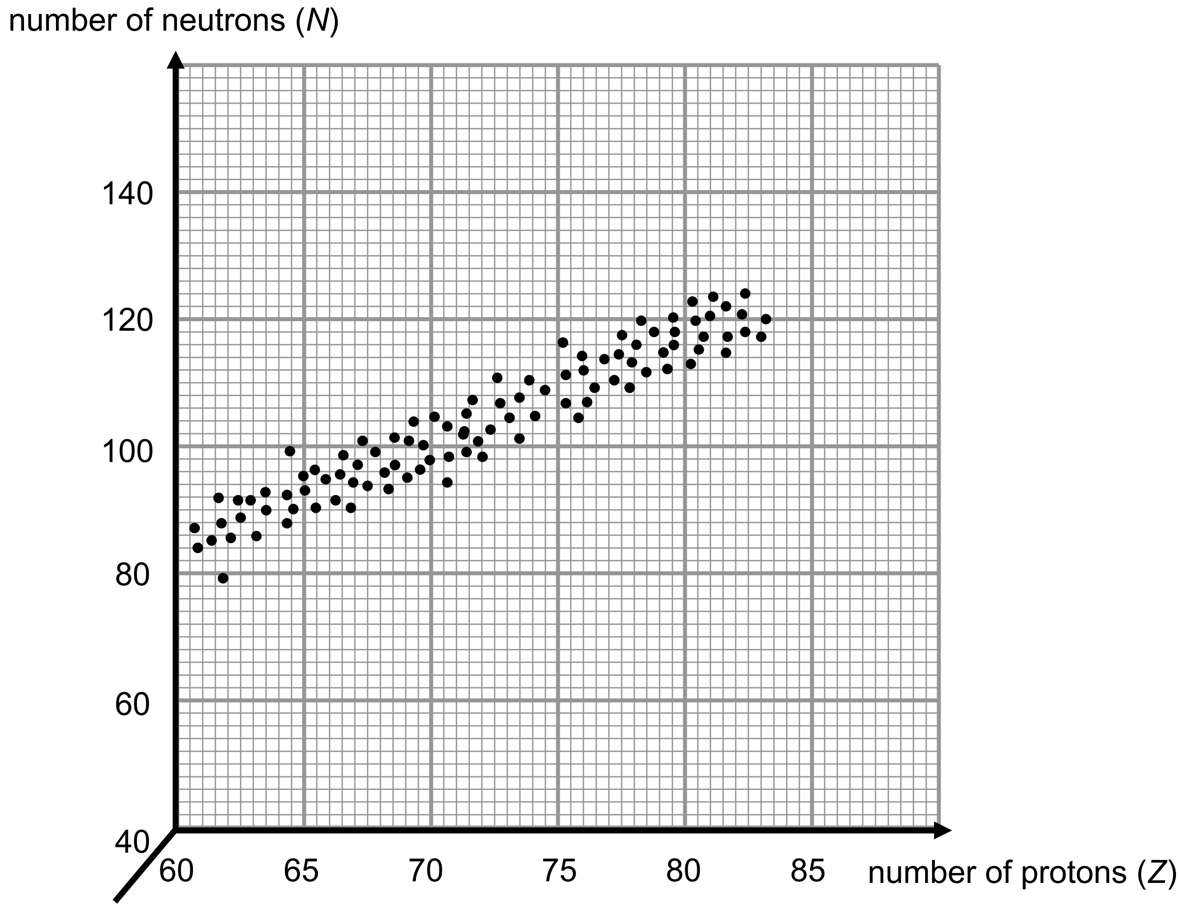
9 One particular model of an atom which was developed in the early 1900s suggested that the core of an atom consists of a massive nucleus. The nucleus is made up of nucleons – the protons (charge of $+1.6 \times 10^{-19}$ C) and neutrons (chargeless) – giving its net positive charge. Charged particles interact via the long-range Coulomb force. In the case of like charges such as protons, the electrostatic force between them is repulsive and varies inversely with the square of the distance between them,

$$F = k\frac{Q_1 Q_2}{r^2}$$

where Q_1 and Q_2 = magnitude of charges [C]
k = 8.99×10^9 [F^{-1} m]
r = distance between the charges [m]

All the nucleons also undergo another force known as the nuclear force. This is an attractive force which is strong enough to overcome the Coulomb force between protons in the short range, i.e. comparable to the spacing between nucleons in a nucleus.

As a result of the forces which the nucleons undergo within each nucleus, nuclei have different extents of stability. Each plot on the graph below represents one nucleus.



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(a) The electrostatic force between like charges is a repulsive force.

State two other types of repulsive force.

Magnetic force between like poles;
electromagnetic force between 2 long straight conductors carrying currents in opposite directions. [2]

(b) Small nuclei which have less than 40 nucleons have approximately equal numbers of neutrons (N) and protons (Z). For large nuclei, the values of N and Z vary according to the equation:

$$N = mZ$$

where m is a constant.

(i) Sketch the graph of $N = Z$ in the graph above. [1]

(ii) Determine an approximate value for m. Show your working clearly.

m = ... [2]

(c) Using the information provided, explain why the existence of the long-range Coulomb force and the short-range nuclear force causes instability in large nuclei if the number of neutrons (N) is equal to the number of protons (Z).

The attractive short range nuclear force acts on all nucleons, so in a small nucleus, the protons are bounded together despite the weaker repulsive electrostatic force acting on them. [1]

In a large nucleus, the attractive short range nuclear force does not extend to the protons which are at the edge of the nucleus. The repulsive electrostatic force is dominant and causes the nucleus to be unstable. [1]

[2]

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(d) Consider 2 protons which are positioned at 2 furthest possible distance apart in a large spherical nucleus of radius 7.5 × 10^{-15} m. Calculate the electrostatic force of repulsion experienced by one charge due to the other.

$r = 2 \times 7.2 \times 10^{-15} = 1.5 \times 10^{-14}$ m [1]

$F = 8.99 \times 10^{9} \times \dfrac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{\left(1.5 \times 10^{-14}\right)^{2}} = 1.02$ N [1]

F = ……………………….N [2]

(e) Suggest, with explanation, if this value of electrostatic force is higher or lower than the actual force experienced by the same charge.

This value is smaller because a large nucleus contains many protons. [1]

A proton at the boundary of the nucleus will experience repulsion from all other protons. [1]

…………………………………………………………………………………[2]

(f) For large nuclei which are unstable, suggest one way they can become more stable.

Radioactive decay; nuclear fission

…………………………………………………………………………………[1]

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10 Noise reduces productivity and is a common problem in cities. In general, other than loudness, noise can be characterized by pitch – for example, road noise and the noise produced by heavy rain is considered low-pitched while sirens are high-pitched noises. Some noises consist of sounds of different pitch, such as the noise produced by military aircraft flying overhead.

Researchers have developed a new kind of lightweight curtain that can absorb sound waves while still letting light through. The material absorbs a portion of the sound energy that strikes it, and only a portion is transmitted. The curtains have been proposed as a method of reducing the amount of noise entering a room through open windows.

Design an experiment to determine how effective the curtain is for different types of noise.

You should draw labelled diagrams to show the arrangement of your apparatus.

In your account you should pay particular attention to

(a) how you would determine the effectiveness of the curtain,

(b) the equipment you would use for the investigation,

(c) the procedure to be followed,

(d) the control of variables,

(e) any safety precautions,

(f) any precautions that you would take to improve the accuracy of the experiment.

[12]

Diagram

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Answer Scheme

Basic procedure [max 2]

Sound waves from speaker directed at curtain

Microphone (detector) on other side

Measurement [max 3]

Use of signal generator and speakers to produce sinusoidal sound waves

Use of signal generator to vary frequency of sound

Use of CRO to measure amplitude of sound

Control of variables [max 2]

Distances of speakers to curtain, curtain to detector etc. kept constant

Amplitude of sound wave produced should be kept constant throughout

Safety procedure [max 1]

Using suitable ear protection to prevent damage to hearing (frequency and amplitude of sound can be high)

Using suitable stand to hold curtain so as to prevent toppling

Additional detail [max 4]

Use of CRO to measure frequency of sound

Size of curtain should be substantial

Curtain should be kept slightly taut to ensure that thickness of curtain is kept constant (or any other method to minimize wrinkling)

Measurement of amplitude of sound without curtain to determine baseline amplitude

Repeat experiment with different amplitude of incident sound

Speakers should be directed normal to curtain

Microphone directed in same line as speakers

Conducting experiment in a quiet sound-proof room to minimize background noise

Conducting experiment in a relatively large room to minimize effect of reflected sound from walls of room

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