JURONG JUNIOR COLLEGE

2013 Preliminary Examination

Name		Class	12S

PHYSICS **9646/2**

Higher 2

Structured Questions **4 Sep 2013**

1 hour 45 minutes

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

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the space provided at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use highlighters, glue or correction fluid.

There are **eight** questions in this paper.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/5
2	/6
3	/10
4	/7
5	/10
6	/8
7	/14
8	/12
Total	/72

(This question paper consists of 20 printed pages)

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ 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	$= \rho gh$
gravitational potential,	ϕ	$= -\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	$= x_o \sin \omega t$
velocity of particle in s.h.m.,	v	$= v_o \cos \omega t$
	v	$= \pm\,\omega\sqrt{(x_o^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	E	$= \frac{3}{2}kT$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$
electric potential,	V	$= \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	$= x_o \sin \omega t$
transmission coefficient,	T	$\propto \exp(-2kd)$
		where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	$= x_o \exp(-\lambda t)$
decay constant	λ	$= \dfrac{0.693}{t_{1/2}}$

1 The period of oscillation of a pendulum is given by the equation

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where l is the length of the pendulum and g is acceleration of free fall.

To determine g, a student obtained the following data:

Period of oscillation = (0.910 $\pm$ 0.005) s

Length of pendulum = (20.6 $\pm$ 0.1) cm

(a) Determine the percentage uncertainty in g.

percentage uncertainty = ______________________ % [2]

(b) Express g together with its associated uncertainty.

g = ($\pm$) m s^{-2} [3]

2 A person supports a load of 20 N in his hand as shown in Fig 2.1. The system of the hand and load is represented by Fig 2.2. The rod represents the forearm and T represents the tension exerted in the biceps. The forearm weighs 60 N.

Fig. 2.1

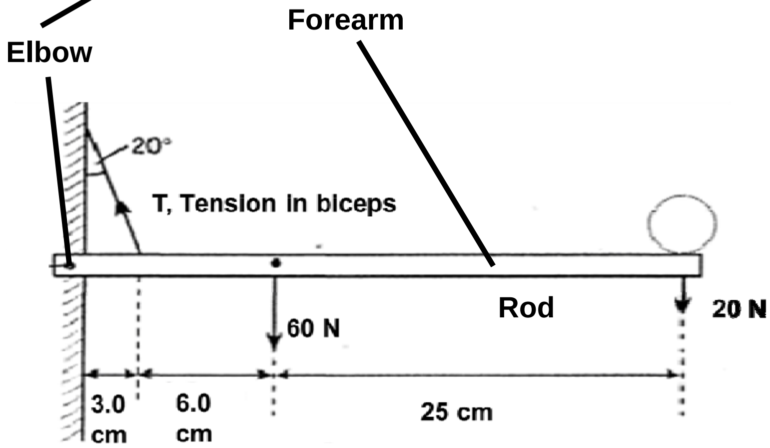

Fig. 2.2

(a) Show that the tension T in the biceps is 433 N. [2]

(b) Determine the magnitude and direction of the force acting at the elbow.

magnitude of force = ... N [3]

direction of force = ... [1]

3 **(a)** In one type of C.R.O., the electrostatic deflection system consists of two parallel metal plates with a separation of 0.50 cm, as shown in Fig. 3.1.

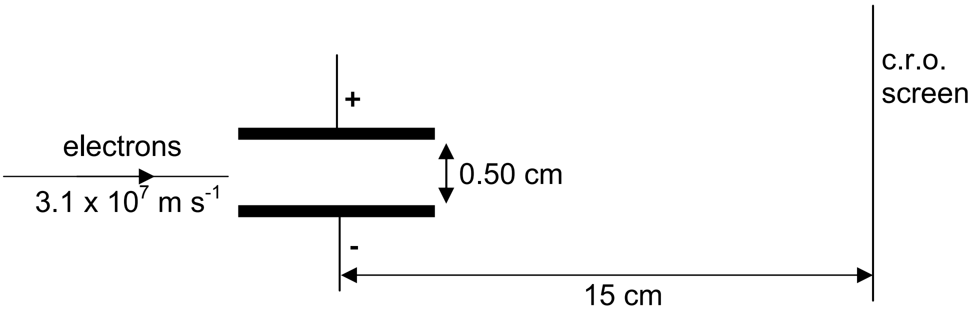

Fig. 3.1

The centre of the plates is situated 15 cm from a screen. A potential difference of 80 V between the plates provides a uniform electric field in the region between the plates. Electrons of speed 3.1×10^7 m s^{-1} enter this region at right angles to the field. The electron takes a time of 6.5×10^{-10} s to pass between the plates.

Calculate

(i) the force on an electron due to the electric field,

force = ... N [2]

(ii) the acceleration of the electron along the direction of the electric field,

acceleration = ... m s^{-2} [1]

(iii) the speed of the electron at right angles to its original direction of motion as it leaves the region between the plates.

speed = ______________________ m s^{-1} [2]

(b) Hence, by considering your answer to **(a)(iii)** and the original speed of the electron, estimate the deflection of the electron beam on the screen.

deflection = ______________________ cm [2]

(c) **(i)** Figure 3.2 represents the front of the screen of the c.r.o.

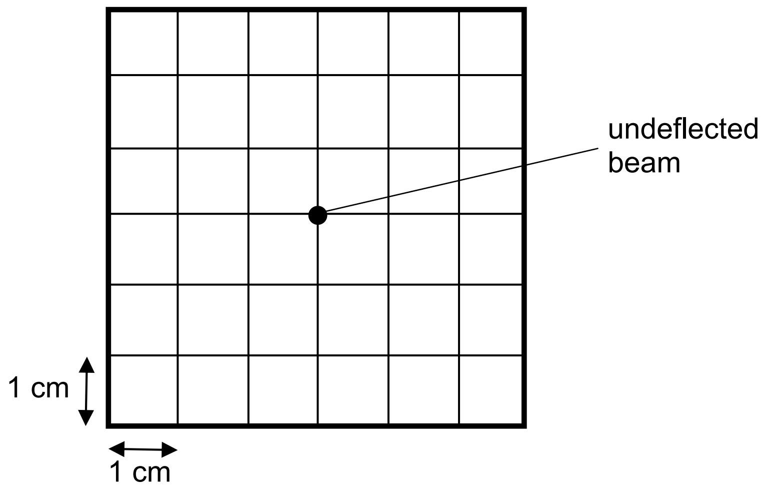

Fig. 3.2

Mark on Fig. 3.2 the position of the deflected beam of electrons. Label your answer **A**. [1]

(ii) On Fig. 3.2, draw a sketch diagram to show the trace on the screen if the p.d. across the plates varies sinusoidally with r.m.s. value 80 V.

Label your sketch **S**. [2]

4 **(a)** Define the tesla.

....

....

.... [1]

(b) Two wires X and Y, which are at right angles to the plane of the paper, carry currents I_x, and I_y out of the plane of paper and are separated by a distance r as shown in Fig. 4.1. The magnitude of I_y is **twice** the magnitude of I_x.

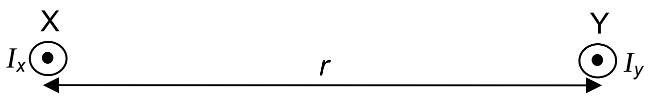

Fig. 4.1

(i) Sketch the pattern of magnetic field due to these wires on Fig. 4.2. [2]

Fig. 4.2

(ii) B, the magnetic flux density due to a long straight wire, is given by the expression

$$B=\frac{\mu_o I}{2\pi r}$$

where permeability of free space, μ_o is $4\pi \times 10^{-7}$ H m^{-1}.

In terms of I_x, I_y, r and μ_o,

1. write an expression for the magnetic flux density of wire X at wire Y,

[1]

2. hence derive an expression for the force per unit length on wire Y.

[1]

(iii) One particular overhead powerline consists of 2 parallel cables with a separation of 5.0 m. The current in the first and second cable is 100 A and 200 A respectively.

Explain why it is not possible, by looking at the cables, to detect the instant at which the current is switched on.

....

....

....

.... [2]

5 **(a)** A scanning tunnelling microscope (STM) is able to map out atomic-scale images of surfaces by using the "tunnelling" effect of electrons across an energy barrier.

(i) State what constitutes the energy barrier when using the STM.

.... [1]

(ii) Hence, describe briefly how the STM is able to map out atomic-scale images of surfaces.

[2]

(b) Distinguish between conduction band and valence band.

[2]

(c) A junction is formed between slices of p-type and of n-type semiconductor material, as shown in Fig 5.

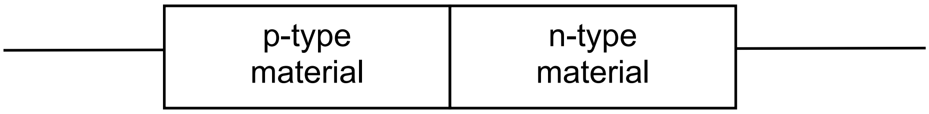

Fig. 5

(i) Describe the origin of the depletion region at the junction.

[4]

(ii) On Fig. 5, draw the symbol for a battery, connected so as to increase the width of the depletion region. [1]

6 **(a)** Explain what is meant by half-life.

[1]

(b) The thickness of a sheet of aluminium foil is to be monitored using β-radiation as illustrated in Fig. 6.

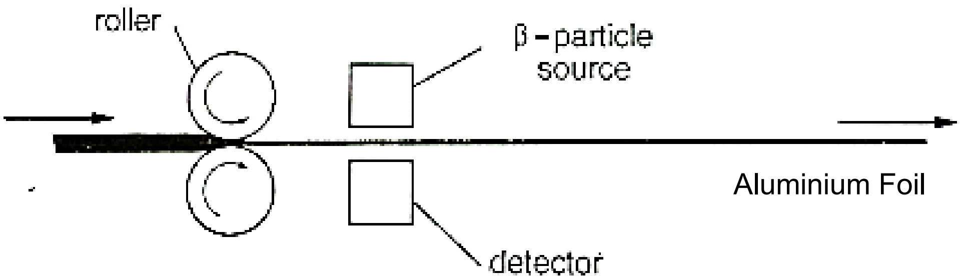

Fig. 6

The separation of the rollers is controlled by the output from the detector with the intention of maintaining a constant foil thickness.

(i) State and explain what would happen to the separation of the rollers if the output from the detector were to decrease.

[2]

(ii) A β-particle source of half-life 14 days is installed in the monitor and then used for a working day of 8.0 hours.

Calculate the ratio $\frac{\text{activity of source at end of working day}}{\text{activity of source at start of working day}}$.

ratio = ______________ [2]

(iii) Suggest one advantage and one disadvantage of using a β-source which has a short half-life.

....

....

....

....

.... [2]

(iv) Suggest why a γ-radiation source would not be satisfactory for monitoring changes in thickness of the foil.

....

....

.... [1]

7 Dangers associated with exposure to radiation have been recognised for many years. As a result of these hazards, measures have been adopted to reduce exposure to radiation to as low a level as possible. One such measure is to shield individuals from radioactive sources using radiation absorbing materials.

Experiments have been carried out to investigate the effectiveness of materials as absorbers of γ- ray photons. One possible experiment is illustrated in Fig. 7.1.

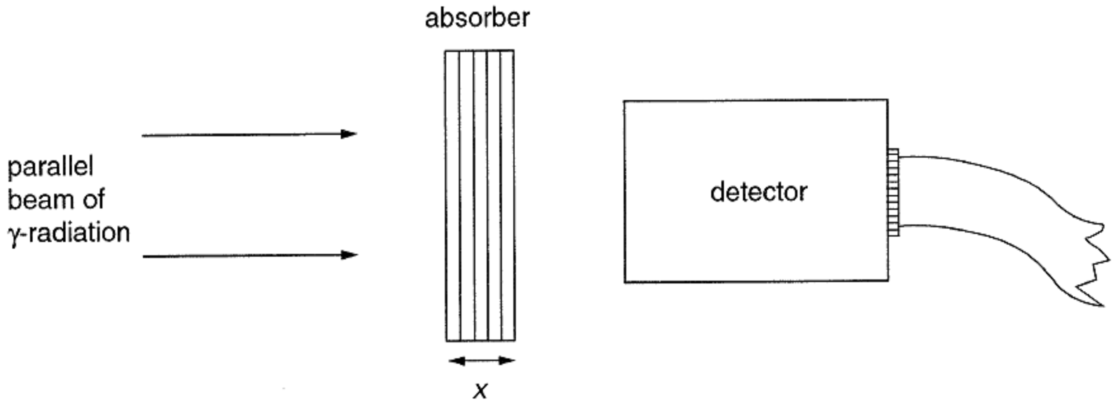

Fig. 7.1

The count-rate C_x of γ- ray photons is measured for various thicknesses x of the absorber, together with the count-rate C_0 for no absorber. Fig. 7.2 shows the variation with thickness x of the ratio C_x/C_0 for lead.

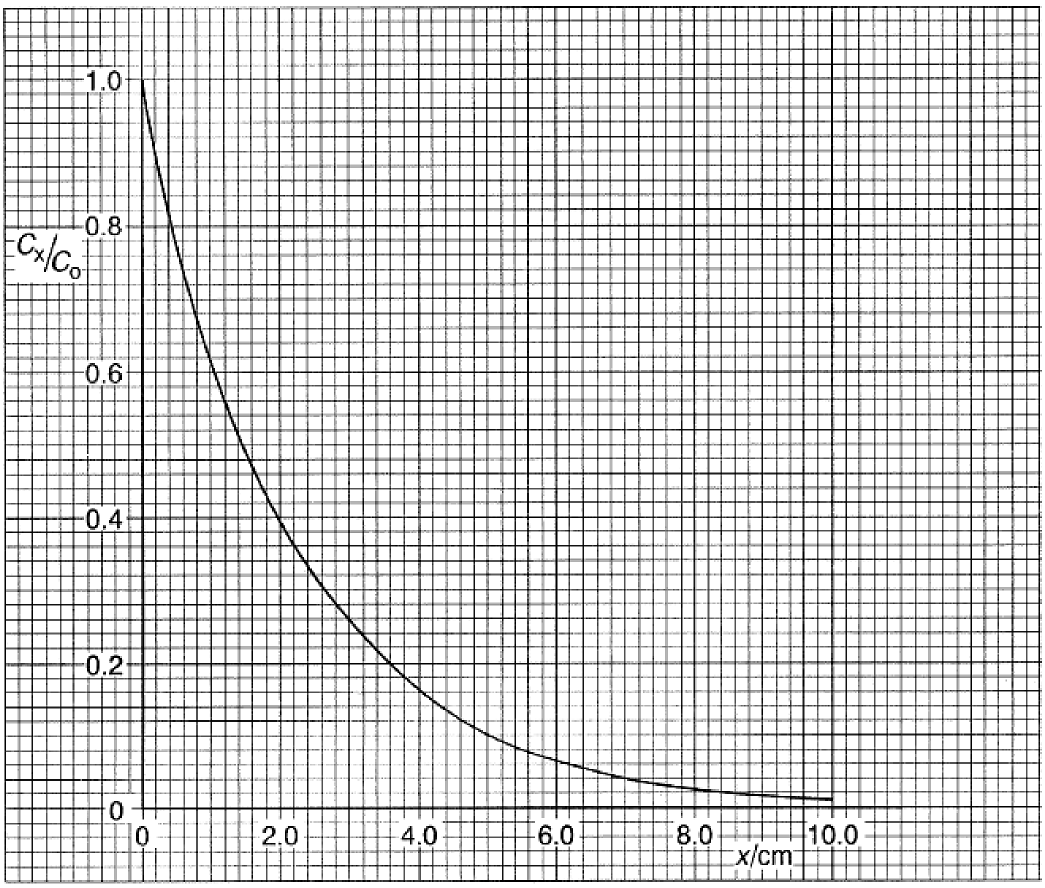

Fig. 7.2

(a) **(i)** In the experiment, suggest why it is necessary to have a parallel beam of γ-radiation.

....

.... [1]

(ii) Explain, based on Fig. 7.2, if complete shielding is theoretically possible.

....

....

.... [2]

(b) Fig. 7.2 indicates that there may be an exponential decrease of the ratio C_x/C_0 with thickness x. In order to test this suggestion, a graph of ln(C_x/C_0) against x is plotted.

This is shown in Fig. 7.3.

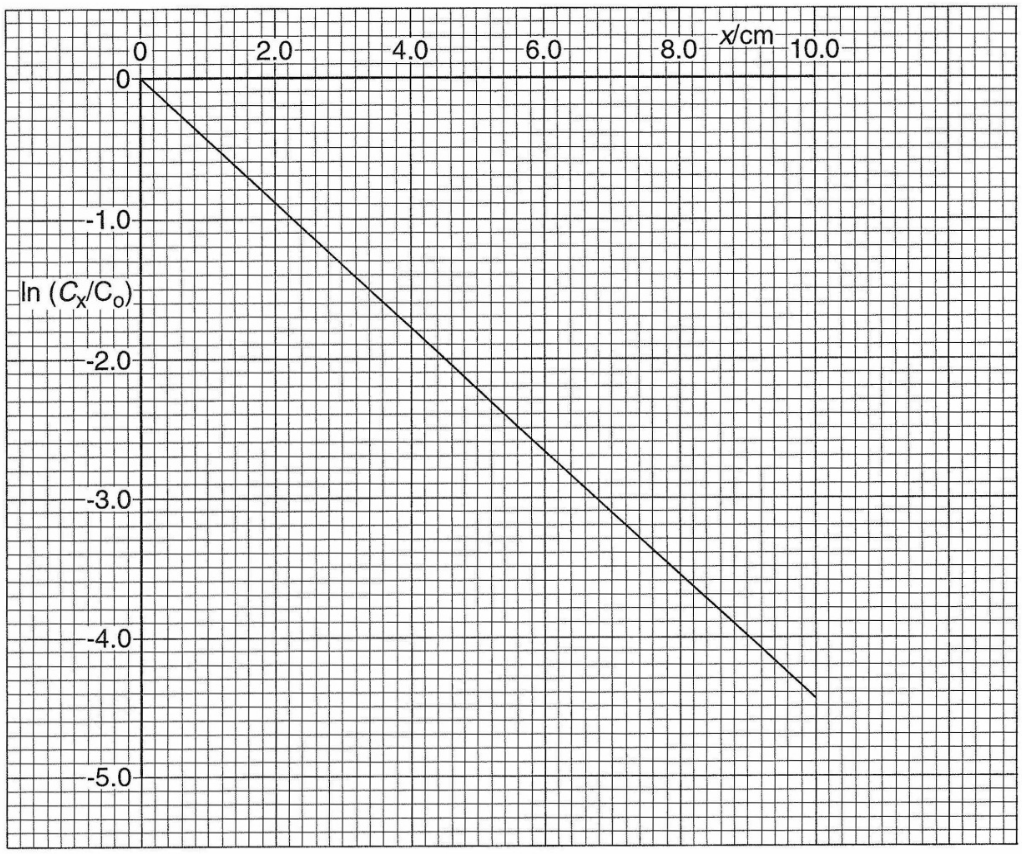

Fig. 7.3

(i) Show that Fig. 7.3 indicates a relationship of the form

$$C_x = C_0 e^{-\mu x},$$

where μ is a constant. [2]

(ii) The constant μ is known as the linear absorption coefficient.

Use Fig. 7.3 to calculate a value of μ for lead.

μ = ... cm^{-1} [1]

(c) The linear absorption coefficient μ has been found to depend on photon energy and on the absorbing material itself. For γ ray photons of one energy, μ is different for different materials.

In order to assess absorption of γ ray photons in matter such that the material of the absorber does not have to be specified, a quantity known as the mass absorption coefficient μ_m is calculated. μ_m is given by the expression

$$\mu_m = \frac{\mu}{\rho},$$

where ρ is the density of the absorbing material.

Values of μ for 2.75 MeV photons and of ρ for different materials are given in Fig. 7.4.

material	**μ / cm^{-1}**	**ρ / g cm^{-3}**	**μ_m /**
aluminium	0.095	2.70	0.035
tin	0.267	7.28	0.037
lead		11.3	

Fig. 7.4

In the table of Fig. 7.4,

(i) give a consistent unit for μ_m, [1]

(ii) use your answer to **(b)(ii)** to complete the table of values for lead. [2]

(d) Concrete is a common building material which is sometimes used for shielding. The density of concrete is 2.4×10^3 kg m^{-3}.

(i) The linear absorption coefficient μ for 2.75 MeV photons in concrete is approximately 0.09 cm^{-1}.

By reference to Fig. 7.2, calculate the approximate thickness of concrete which would provide the same level of shielding, for 2.75 MeV photons, as a thickness of 4.0 cm of lead.

thickness = ... cm [3]

(ii) Make two suggestions as to why concrete may be used, in preference to lead, where radioactive sources of high activity are to be shielded.

....

....

....

.... [2]

8 Fig. 8.1 illustrates a bow used in archery competitions.

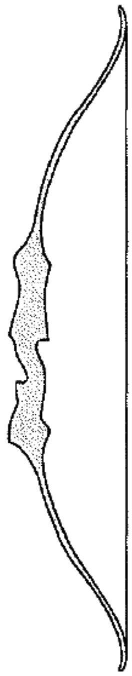

Fig. 8.1

A designer of bows is attempting to maximise the efficiency of his bow. This means that as much of the potential energy stored in the bow as possible is converted to the kinetic energy of an arrow.

Some preliminary experiments are carried out with the bow when the centre of the string is moved through a distance *x* by a force *F* as shown in Fig. 8.2.

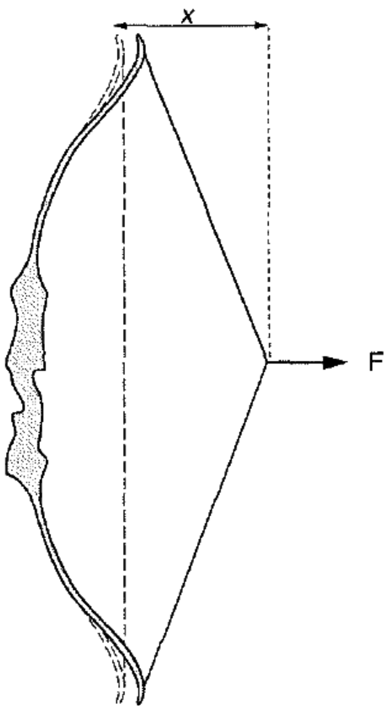

Fig. 8.2

These experiments indicate that x is not proportional to F.

The efficiency of the bow may be defined as

$$\text{efficiency } \eta = \frac{\text{kinetic energy of an arrow}}{\text{potential energy of the bow}}$$

The efficiency of a bow is thought to depend on the distance x. The relation between the efficiency and the distance x may be written in the form

$$\eta = ax^b$$

where a and b are constants.

Design an experiment to determine the value of b.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use,

(c) the procedure to be followed,

(d how to determine

  (i) the potential energy stored in the bow just before the arrow is released, and

  (ii) the kinetic energy of the arrow after the string is released,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[12]

Diagram

End of Paper