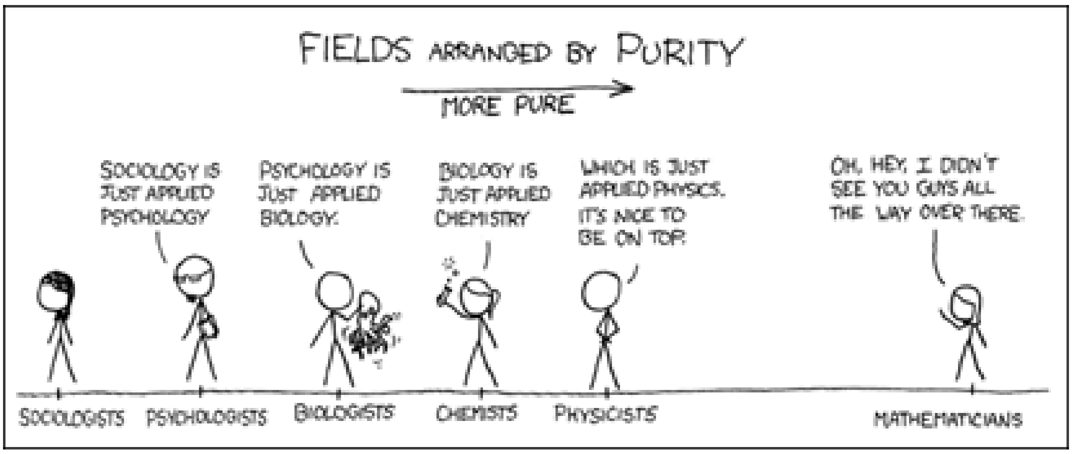
Advanced Higher Physics

Past Paper Questions

1.1 Kinematics (& Uncertainties)



2017

1. An athlete competes in a one hundred metre race on a flat track, as shown in Figure 1A.

Figure 1A

Starting from rest, the athlete's speed for the first 3·10 seconds of the race can be modelled using the relationship

$$v = 0 \cdot 4t^2 + 2t$$

where the symbols have their usual meaning.

According to this model:

(a) determine the speed of the athlete at $t = 3{\cdot}10\,\text{s}$; 2

2016

(b) determine, using calculus methods, the distance travelled by the athlete in this time. 3

A car on a long straight track accelerates from rest. The car's run begins at time $t = 0$.

1. Its velocity v at time t is given by the equation

$$v = 0 \cdot 135t^2 + 1 \cdot 26t$$

where v is measured in $\text{m}\,\text{s}^{-1}$ and t is measured in s.

Using calculus methods:

(a) determine the acceleration of the car at $t = 15{\cdot}0\,\text{s}$; 3

(b) determine the displacement of the car from its original position at this time. 3

1. The acceleration of a particle moving in a straight line is described by the expression

$$a = 1{\cdot}2t.$$

At time, $t = 0$ s the displacement of the particle is 0 m and its velocity is $1{\cdot}4\,\text{m s}^{-1}$.

(*a*) Show that the velocity of the particle at time t is given by the expression

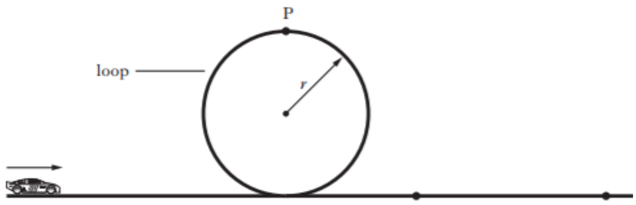
$$v = 0{\cdot}6t^2 + 1{\cdot}4.$$ **2**

(*b*) Calculate the displacement of the particle when its velocity is $3{\cdot}8\,\text{m s}^{-1}$. **3**

(5)

Revised & Traditional 2013

1. A stunt driver is attempting to "loop the loop" in a car as shown in Figure 1. Before entering the loop the car accelerates along a horizontal track.



The radius r of the circular loop is 6·2 m.
The total mass of the car and driver is 870 kg.

(*a*) Show that the car must have a minimum speed of $7{\cdot}8\,\text{m s}^{-1}$ at point P to avoid losing contact with the track. **2**

(*b*) During one attempt the car is moving at a speed of $9{\cdot}0\,\text{m s}^{-1}$ at point P.

(i) Draw a labelled diagram showing the vertical forces acting on the car at point P. **1**

(ii) Calculate the size of each force. **3**

(*c*) When the car exits the loop the driver starts braking at point X. For one particular run the displacement of the car from point X **until the car comes to rest** at point Y is given by the equation

$$s = 9{\cdot}1t - 3{\cdot}2\,t^2$$

Sketch a graph to show how the displacement of the car varies with time between points X and Y.

Numerical values are required on both axes. **3**

(9)

2. (*a*) The acceleration of a particle moving in a straight line is given by

$$a = \frac{dv}{dt}$$

where the symbols have their usual meaning.

(i) Show, by integration, that when a is constant

$$v = u + at.$$ **2**

(ii) Show that when a is constant

$$v^2 = u^2 + 2as.$$ **1**

Traditional 2012

Marks

10. Figure 10 shows a model helicopter flying in a straight horizontal path from student A to student B.

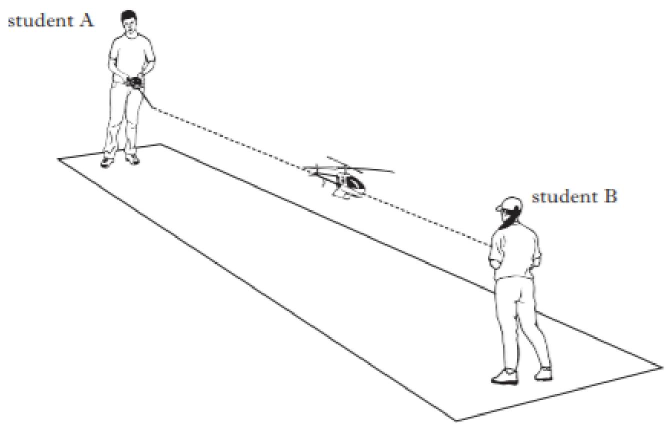


Figure 10

The helicopter has a siren that emits sound of frequency 595 Hz.

(*a*) For the first two seconds the displacement of the helicopter relative to student A is described by the equation

$$s = 4 \cdot 1 t^2.$$

(i) Calculate the velocity of the helicopter when $t = 2 \cdot 0$ s. **2**

(ii) Suggest what happens to the frequency of the sound heard by student B as the helicopter accelerates towards her.

Justify your answer. **2**

(*b*) After 2·0 s the helicopter continues towards student B with a constant velocity. Calculate the frequency of the sound heard by student B. **2**

(6)

Marks

1. Figure 1A shows a space shuttle shortly after take-off.

Figure 1A

(*a*) Immediately after take off, the vertical displacement of the shuttle for part of its journey can be described using the equation

$$s = 3{\cdot}1t^2 + 4{\cdot}1t.$$

(i) Find, by differentiation, the equation for the vertical velocity of the shuttle. **1**

(ii) At what time will the vertical velocity be $72\,\text{m}\,\text{s}^{-1}$? **2**

(iii) Calculate the vertical linear acceleration during this time. **1**

6. A student investigates the relationship between the force exerted on a wire in a magnetic field and the current in the wire.
A pair of magnets is fixed to a yoke and placed on a top pan Newton balance. A rigid copper wire is suspended between the poles of the magnets. The wire is fixed at 90° to the magnetic field, as shown in Figure 9.

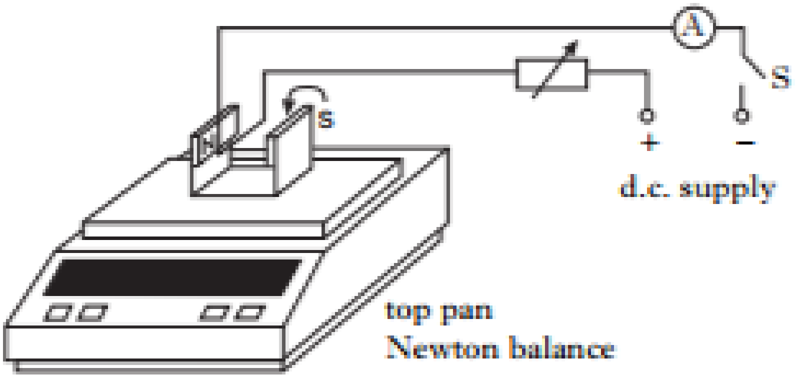


Figure 9

With switch S open the balance is set to zero.
Switch S is closed. The resistor is adjusted and the force recorded for several values of current.

The results are given in the table below.

Current/A	0·50	1·00	1·50	2·00	2·50
Force/10^{-3} N	0·64	0·85	2·56	3·07	3·87

The uncertainty in the current is ± 0·01 A.
The uncertainty in the force is ± 0·03 × 10^{-3} N.

Figure 10, on *Page eleven*, shows the corresponding graph with the best fit straight line for the results.

(*a*) (i) Show that the gradient of the line is 1·7 × 10^{-3} N A^{-1}. **1**

(ii) Calculate the absolute uncertainty in the gradient of the line. **3**

(iii) The length of wire in the magnetic field is 52 mm. Use the information obtained from the graph to calculate the magnitude of the magnetic induction.

The uncertainty in the magnetic induction is **not** required. **2**

(*b*) In the student's evaluation it is stated that the line does not pass through the origin.

(i) Suggest a possible reason for this. **1**

(ii) Suggest **one** improvement to the experiment to reduce the absolute uncertainty in the gradient of the line. **1**

(8)

6. **(continued)**

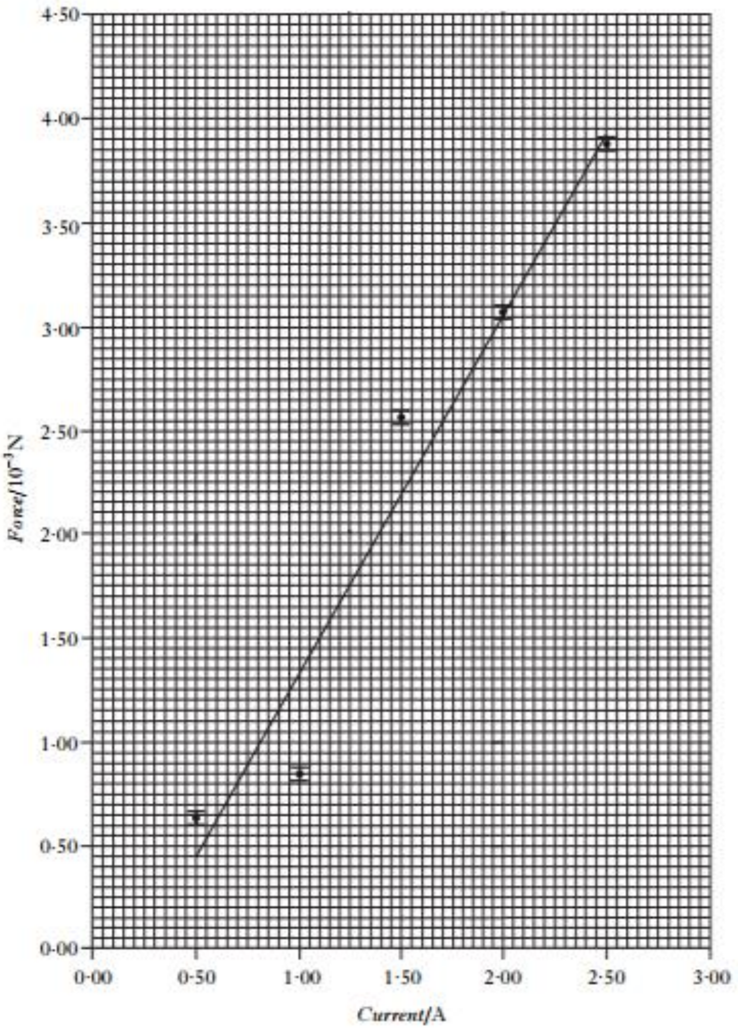


Figure 10

Traditional 2007

Marks

1. (*a*) A particle has displacement $s = 0$ at time $t = 0$ and moves with constant acceleration a.

The velocity of the object is given by the equation $v = u + at$, where the symbols have their usual meanings.

Using calculus, derive an equation for the displacement s of the object as a function of time t. **2**

(*b*) A cyclotron accelerates protons to a velocity of $2{\cdot}80 \times 10^8\,\text{m}\,\text{s}^{-1}$.

Calculate the relativistic energy of a proton at this velocity. **4**

(6)

Marks

10. In an experiment to measure the speed of sound in air, a loudspeaker, a signal generator and a reflector are set up as shown in Figure 14.

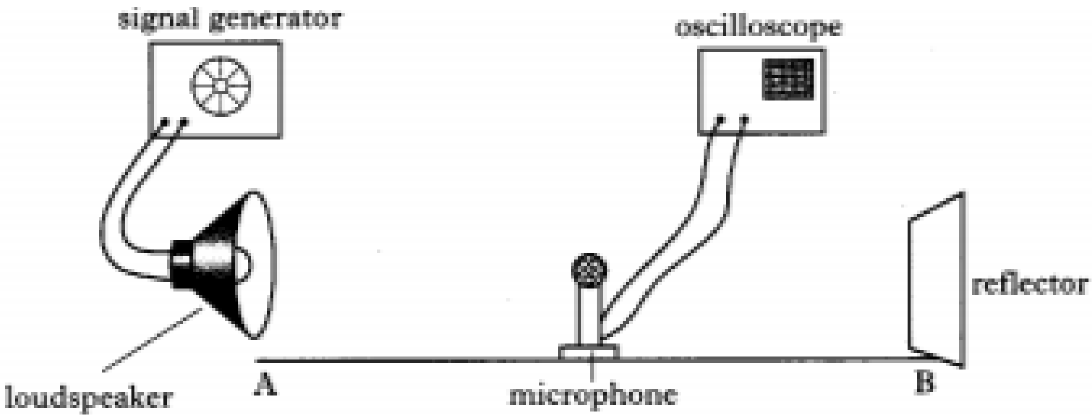


Figure 14

A stationary wave pattern is produced between the loudspeaker and the reflector. The intensity of the sound is monitored using a microphone connected to an oscilloscope. The microphone is moved steadily along line AB and the oscilloscope indicates alternate maximum and minimum values of sound intensity.

(*a*) What name is given to the points in the stationary wave pattern at which **minimum** values of sound intensity occur? **1**

(*b*) The signal generator is adjusted until the frequency of the sound produced is 2000 Hz. The distance between two successive points of minimum sound intensity is measured as 88 mm.

(i) Use this data to calculate the speed of sound in air. **3**

(ii) Suggest **one** improvement to the experiment which would result in a more accurate value for the speed of sound in air.

Justify your answer. **2**

(*c*) The microphone is placed at a position of minimum sound intensity. Without moving the microphone, the reflector is moved away from the loudspeaker until a minimum is again detected.

The intensity of sound at this minimum is found to be **greater** than the intensity of sound before the reflector was moved.

Explain this observation. **2**

(8)

Marks

1. (*a*) The average acceleration of a radio controlled car is investigated by a student.

She marks distance AB on a straight track, as shown in Figure 1 and measures this distance using a measuring tape.

Figure 1

She places the car at A and uses the radio control to accelerate the car.

The car starts from rest and accelerates in a straight line along the track to B.

Using a stopwatch, the student measures the time for the car to travel the distance AB.

She repeats this several times and obtains the following results.

Distance AB = (3·54 ± 0·01) m.

Stopwatch readings: 2·53 s; 2·29 s; 2·34 s; 2·36 s; 2·65 s; 2·53 s.

(i) Starting with the appropriate equation of motion, show that the acceleration of the car is given by

$$a = \frac{2s}{t^2}$$

where the symbols have their usual meanings.

(ii) Calculate the average value of the car's acceleration.

(iii) Calculate the random uncertainty in the time measurement.

(iv) Calculate the percentage uncertainty in the average acceleration.

(v) Express the numerical result of her investigation in the form

final value ± absolute uncertainty. 7

Marks

1. (*a*) An object moves with constant acceleration a.

At time $t = 0$ its displacement s is zero.

The velocity v of the object is given by $v = u + at$.

Derive the equation

$$s = ut + \frac{1}{2}at^2$$

where the symbols have their usual meanings. **2**

Marks

1. A car accelerates uniformly from rest from a point A and is timed over the distance AB as shown in Figure 1.

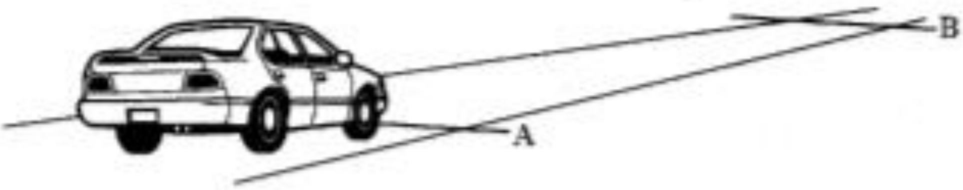


Figure 1

The results are as follows:

distance travelled, AB = (100 ± 1) m

time taken = (8·0 ± 0·4) s.

(*a*) Calculate:

(i) the acceleration of the car;

(ii) the percentage uncertainty in the acceleration. **4**

(*b*) The radius of each car wheel is 0·30 m.

Calculate the angular acceleration of a wheel as the car travels from A to B. **2**

(*c*) A small stone of mass 4·0 g is stuck in the tyre tread, as shown in Figure 2.

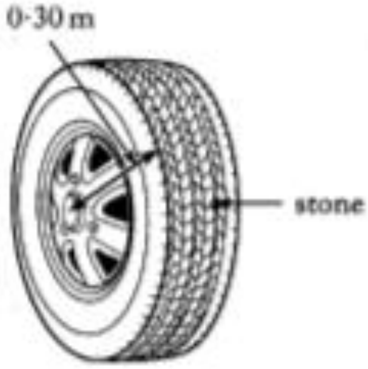


Figure 2

The stone is held in place by a radial frictional force which has a maximum value of 3·0 N.

(i) As the car's speed increases, the stone will eventually be released from the tread of the tyre. Explain why this happens.

(ii) Calculate the linear speed of the car just as the stone is released.

(iii) The stone works its way completely free of the tyre when it is at its highest point above road level. Describe the direction of the velocity of the stone just as it becomes free of the tyre tread. **5**

(11)