Higher Momentum and Impulse Questions

1. A rugby player of mass **94kg** sprints to the line to score a try at **8ms^{-1}**.

Calculate the momentum of the rugby player.

2. A football of mass **0.42kg** is thrown at a stationary student of mass **50.0kg** who is wearing roller blades as shown below.

When she catches the ball she moves to the right.

The instantaneous speed after she catches the ball is **0.10ms^{-1}**.

Calculate the speed of the ball just before it is caught.

3. A rocket of mass **5.0kg** is travelling horizontally with a speed of **200ms^{-1}** when it explodes into two parts.

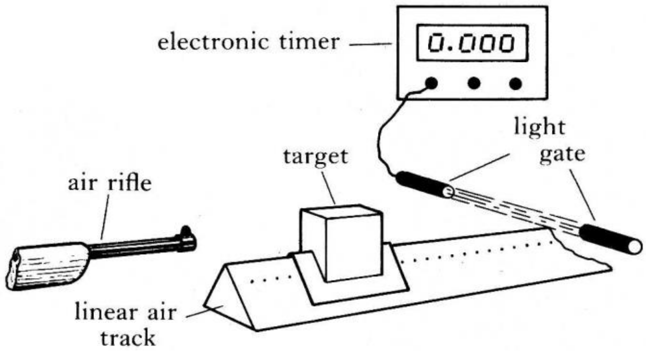
One part of mass **3.0kg** continues tin the original direction with a speed of **100ms^{-1}** and the other part continues in the same direction.

Calculate the unknown speed of the other part.

4. A shell of mass **6.0kg** travelling with an unknown speed v travelling horizontally explodes into two parts. One part of mass **4.0kg** continues in the original direction with a speed of **80ms^{-1}** and the other part continues in the same direction with a speed of **140ms^{-1}**.

Calculate the **initial unknown speed v**.

5. The experimental arrangement shown below is used **to measure the speed of an air rifle pellet**.



The speed of the pellet is calculated from the equation below.

$$\text{speed of pellet} = \frac{\text{final mass of target} \times \text{speed of target}}{\text{mass of pellet}}$$

The results from one experiment are

final mass of target = $(2{\cdot}00 \pm 0{\cdot}02)$ kg

mass of pellet = $(10{\cdot}0 \pm 0{\cdot}5)$ g

speed of target = $(0{\cdot}50 \pm 0{\cdot}01)\ \text{m s}^{-1}$

Calculate the percentage uncertainty in the speed of the pellet.

6. Fill in the table below using the words **conserved**, **not conserved** and **gained**.

Type of Collision	**Total Momentum**	**Total Energy**	**Kinetic Energy**
Elastic			
Inelastic			
Explosion			

7. A **white pool ball** of mass **200g** is hit with a velocity of **1.6ms^{-1}** and collides with a stationary striped ball of the same mass.

If the striped ball moves off with a velocity of **1.9ms^{-1}** then calculate or find:

a) **Velocity** of the **white ball** after the collision.
b) Show by calculation **which type of collision is taking place**.

8. A car of mass **1400kg** travelling at a velocity of **19ms^{-1}** collides **head on** with a car of mass **1600kg** travelling at **15ms^{-1}**. If the **cars lock together** after impact then calculate or find:

a) Calculate the **common velocity** of the cars **after the collision**.
b) **Show by calculation** what type of collision is taking place.

9. A **bullet** of mass **8g** is stationary in the barrel of a **gun** of mass **4kg**.

The trigger is pulled and a force of **2.8kN** is exerted on the bullet for **1.7ms**.

Calculate or find:

a) **Velocity of the bullet** as it leaves the barrel of the gun.
b) **Recoil velocity of the gun**.
c) Show by calculation **which type of collision** is taking place.

10.

A pupil carries out an experiment on a linear air track with two vehicles X and Y. Vehicle X is propelled towards vehicle Y which is initially at rest and the vehicles are allowed to collide.

The results obtained are shown in the tables below.

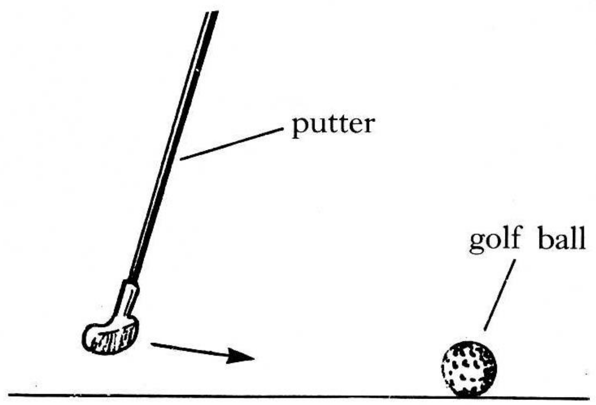
Before Collision			
Momentum of X/ kg m s^{-1}	*Momentum of Y*/ kg m s^{-1}	*Kinetic energy of X*/J	*Kinetic energy of Y*/J
0·12	0	0·036	0

After Collision			
Momentum of X/ kg m s^{-1}	*Momentum of Y*/ kg m s^{-1}	*Kinetic energy of X*/J	*Kinetic energy of Y*/J
0·06	0·06	0·009	0·018

Explain whether the collision between the vehicles is elastic or inelastic.

11.

A stationary golf ball of mass 0·05 kg is hit by a putter as shown below.



The ball moves off with an initial velocity of 2·0 m s^{-1}. The time of contact between the putter and ball is measured electronically to be 0·060 s.

(*a*) Calculate the average force exerted by the putter on the golf ball.

(*b*) Sketch a possible force–time graph for the impact of the putter with the golf ball.

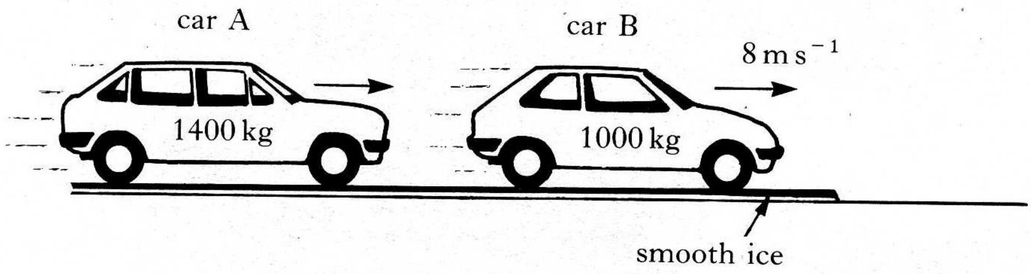
12.

(*a*) State the law of conservation of linear momentum as it applies to a collision between two objects.

(*b*) Two cars, travelling in the same direction, skid on a patch of smooth, level ice.

Car A, of mass 1400 kg, skids straight into the back of car B, of mass 1000 kg.

The two cars become entangled after the impact and continue to move in the same straight line.



Immediately before the impact, car B is moving with a speed of $8\,m\,s^{-1}$.

Immediately after the impact, both cars are moving with a speed of $15\,m\,s^{-1}$.

(i) Calculate the speed of car A just before the collision takes place.

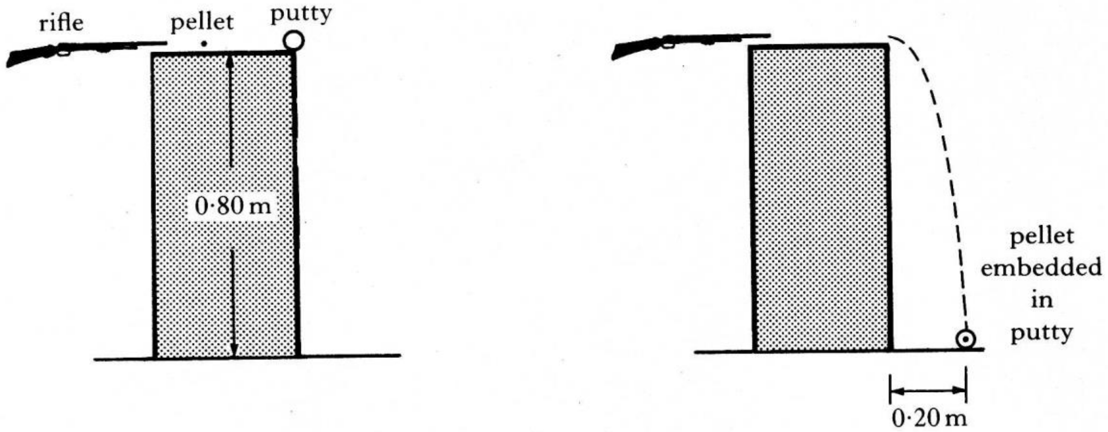
(ii) After the collision, the cars leave the patch of ice and continue skidding along the road. They come to rest in a distance of 20 metres after leaving the ice.

Calculate the average frictional force acting on the cars as they come to rest.

(iii) State what happens to the kinetic energy of the cars after they leave the ice.

13.

The diagrams below illustrate an experimental method which can be used to measure the speed of an air rifle pellet.



A lump of putty, of mass 0·10 kg, is resting on the edge of a bench of height 0·80 m. The pellet, of mass $5{\cdot}0 \times 10^{-4}$ kg, is fired at the lump of putty.

The putty, with the pellet embedded in it, lands 0·20 m from the foot of the bench as shown.

(*a*) Show that the horizontal velocity of the putty after the impact of the pellet is $0{\cdot}5\,m\,s^{-1}$.

(*b*) (i) State the principle of conservation of momentum.

(ii) Using this principle, calculate the velocity of the pellet just before it strikes the putty.

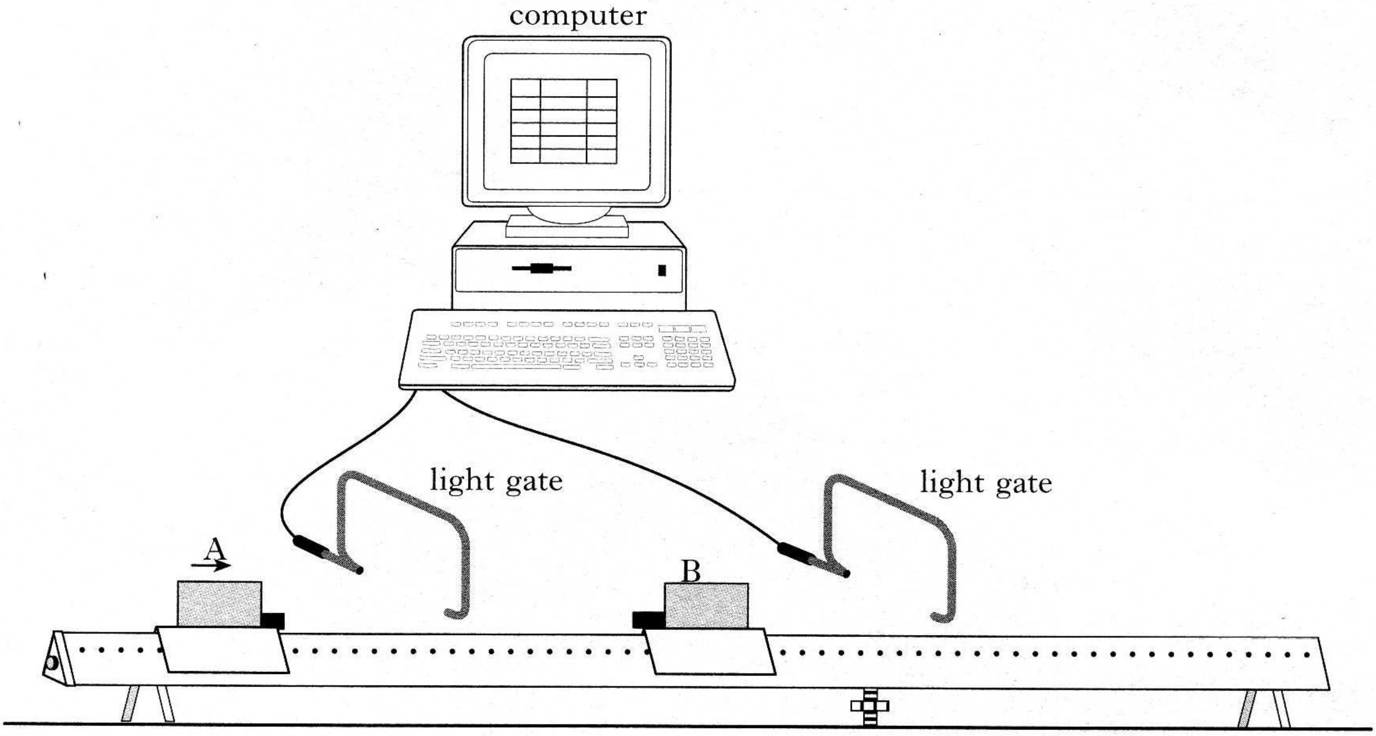
(*c*) Using only the apparatus above, suggest one way of improving the accuracy of this experiment.

14.

(*a*) State the law of conservation of linear momentum.

(*b*) The diagram shows a linear air track on which two vehicles are free to move. Vehicle A moves towards vehicle B which is initially at rest.

A computer displays the speeds of the two vehicles before and after the collision.



The table of results below shows the mass and velocity of each vehicle before and after the collision.

Vehicle	*Mass*	*Velocity before collision*	*Velocity after collision*
A	0·75 kg	0·82 $m\,s^{-1}$ to the right	0·40 $m\,s^{-1}$ to the right
B	0·50 kg	0·00 $m\,s^{-1}$	0·63 $m\,s^{-1}$ to the right

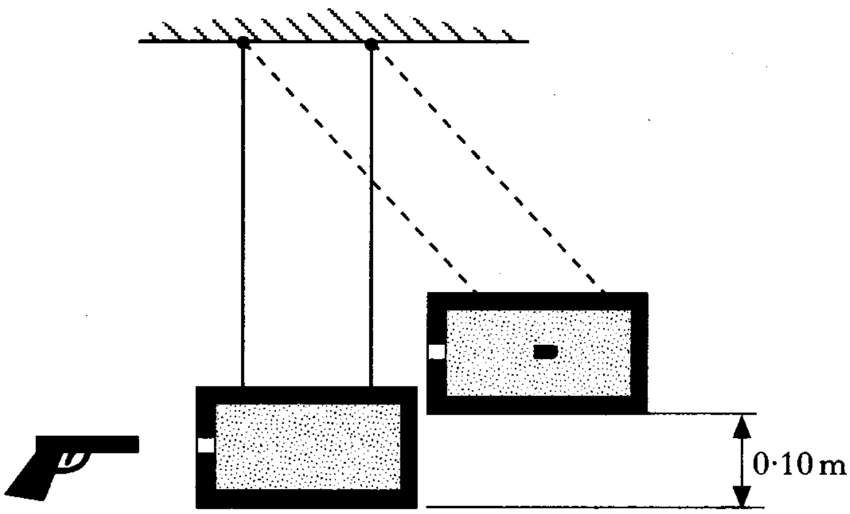
(i) Use these results to show that the change in momentum of vehicle A is equal in size but opposite in direction to the change in momentum of vehicle B.

(ii) Use the data in the table to show whether the collision is elastic or inelastic.

15.

(*a*) A bullet of mass 25 g is fired horizontally into a sand-filled box which is suspended by long strings from the ceiling. The combined mass of the bullet, box and sand is 10·kg.

After impact, the box swings upwards to reach a maximum height as shown in the diagram.

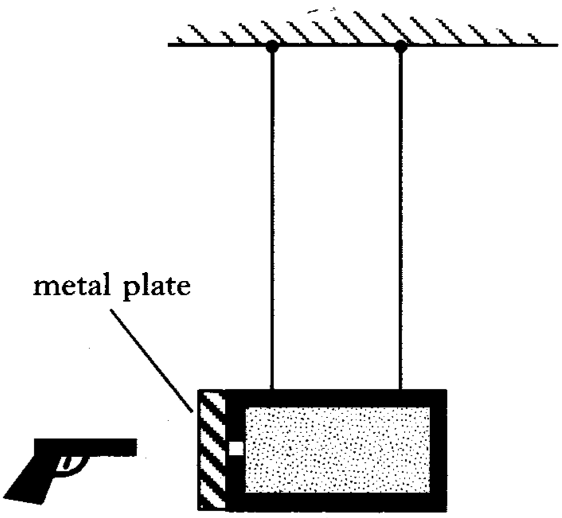


Calculate:

(i) the maximum velocity of the box after impact;

(ii) the velocity of the bullet just before impact.

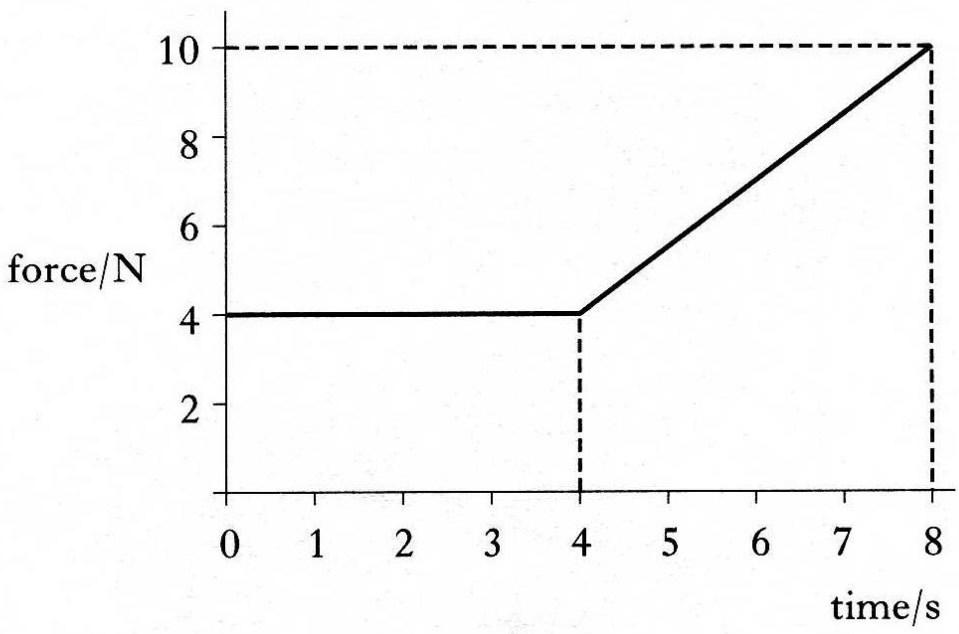
(*b*) The experiment is repeated with a metal plate fixed to one end of the box as shown.



The mass of sand is reduced so that the combined mass of the sand, box and metal plate is 10 kg.

In this experiment, the bullet bounces back from the metal plate. Explain how this would affect the maximum height reached by the box compared with the maximum height reached in part (*a*).

16. The graph below shows the force which acts on a 7kg object over a time interval of 8 seconds.

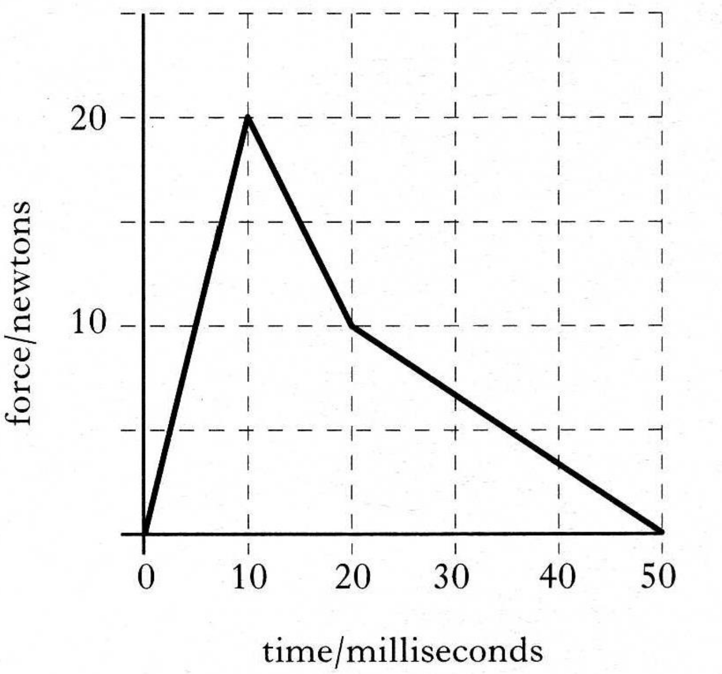


Calculate or find:

a) **Impulse** on the object.
b) **Change in momentum** of the object.
c) The **final velocity** of the object if it is **initially** travelling at **6ms^{-1}**.

17. The force acting on an object is measured and the results are stored on a computer.

The **force-time graph** obtained from the computer is shown below.



Calculate the **average force acting** on the object **during the 50ms**.

18. A ball is thrown horizontally at a wall with a velocity of **12ms^{-1}** and rebounds with a velocity of **-9ms^{-1}**.

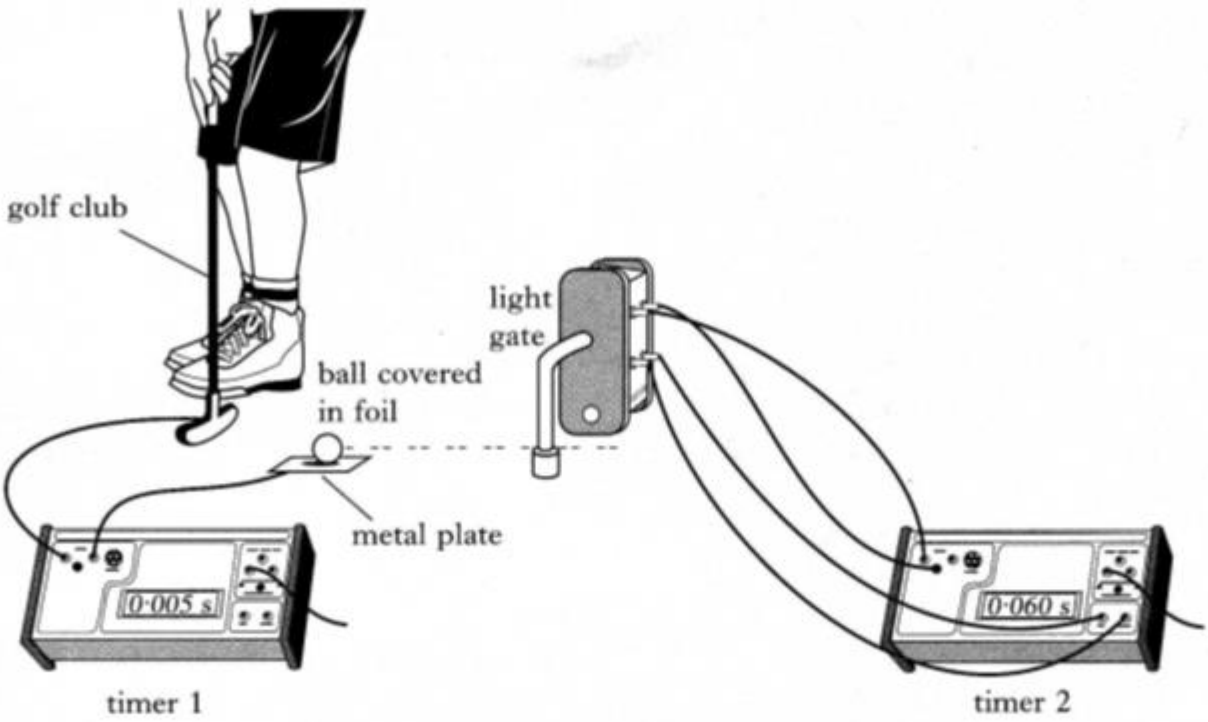
The time of contact with the ball and the wall is 35ms and the change in momentum is **-7kgms^{-1}**.

Calculate or find:

a) **Mass of the ball**.
b) **Average force exerted** on the ball.

19.

The apparatus in the diagram is being used to investigate the average force exerted by a golf club on a ball.



The club hits the stationary ball. Timer 1 records the time of contact between the club and the ball. Timer 2 records the time taken for the ball to pass through the light gate beam.

The mass of the ball is 45·00 ± 0·01 g.

The time of the contact between club and ball is 0·005 ± 0·001 s.

The time for the ball to pass through the light gate beam is 0·060 ± 0·001 s.

The diameter of the ball is 24 ± 1 mm.

(*a*) (i) Calculate the speed of the ball as it passes through the light gate.

(ii) Calculate the average force exerted on the ball by the golf club.

(b) **Show by calculation** which measurement contributes the **largest percentage uncertainty** in the final value of the average force of the ball.

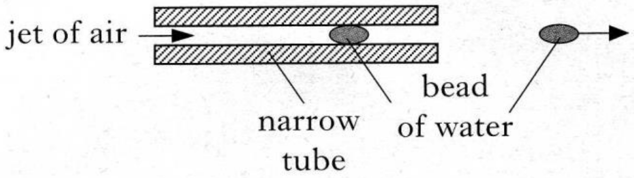
(c) Express your numerical answer to (a) (ii) in the form

Average Force ± Absolute Uncertainty.

20.

Beads of liquid moving at high speed are used to move threads in modern weaving machines.

(*a*) In one design of machine, beads of water are accelerated by jets of air as shown in the diagram.



Each bead has a mass of $2{\cdot}5 \times 10^{-5}$ kg.

When designing the machine, it was estimated that each bead of water would start from rest and experience a constant unbalanced force of 0·5 N for a time of 3·0 ms.

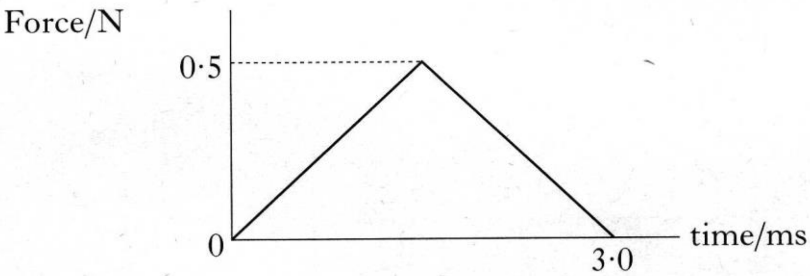
(i) Calculate:

(A) the impulse on a bead of water;

(B) the speed of the bead as it emerges from the tube.

(ii) In practice the force on a bead varies.

The following graph shows how the actual unbalanced force exerted on each bead of water varies with time.



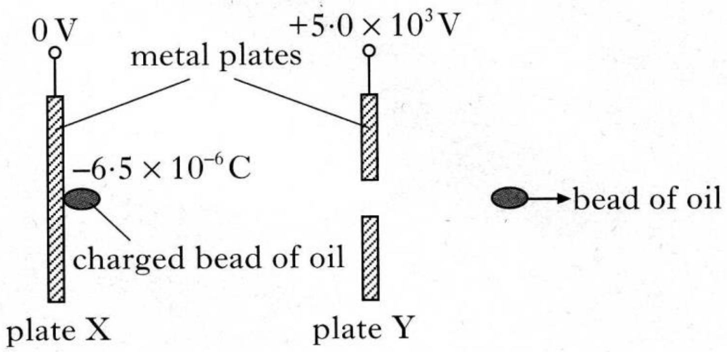
Use information from this graph to show that the bead leaves the tube with a speed equal to half of the value calculated in part (i)(B).

(*b*) Another design of machine uses beads of oil and two metal plates X and Y.

The potential difference between these plates is $5{\cdot}0 \times 10^{3}$ V.

Each bead of oil has a mass of $4{\cdot}0 \times 10^{-5}$ kg and is given a negative charge of $6{\cdot}5 \times 10^{-6}$ C.

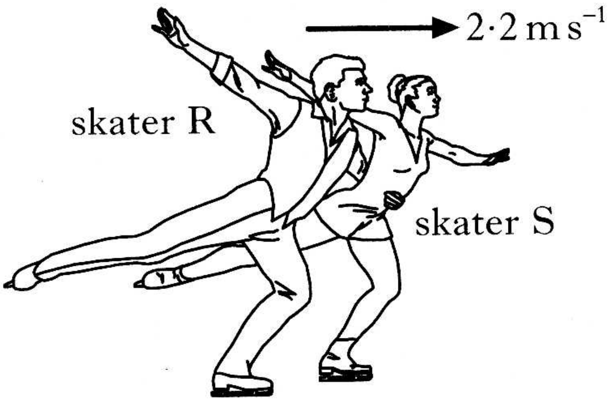
The bead accelerates from rest at plate X and passes through a hole in plate Y.



Neglecting air friction, calculate the speed of the bead at plate Y.

21.

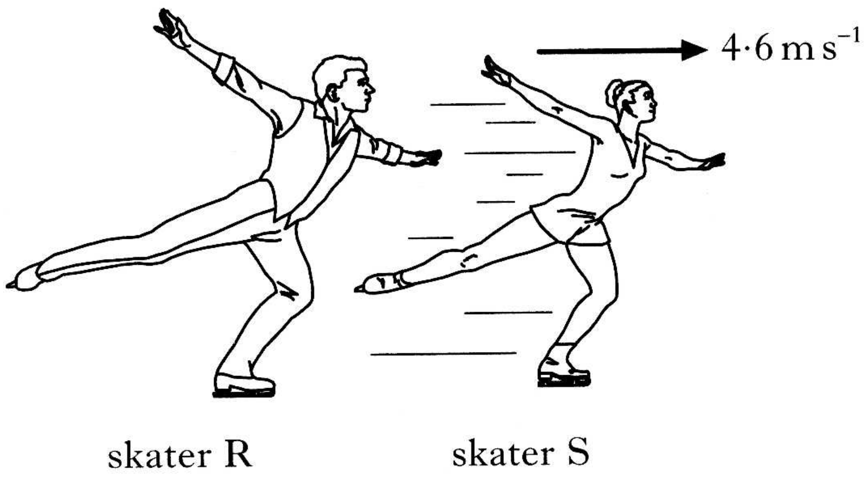
Two ice skaters are initially skating together, each with a velocity of $2 \cdot 2\,\mathrm{m\,s^{-1}}$ to the right as shown.



The mass of skater R is 54 kg. The mass of skater S is 38 kg.

Skater R now pushes skater S with an average force of 130 N for a short time. This force is in the same direction as their original velocity.

As a result, the velocity of skater S increases to $4 \cdot 6\,\mathrm{m\,s^{-1}}$ to the right.



(*a*) Calculate the magnitude of the change in momentum of skater S.

(*b*) How long does skater R exert the force on skater S?

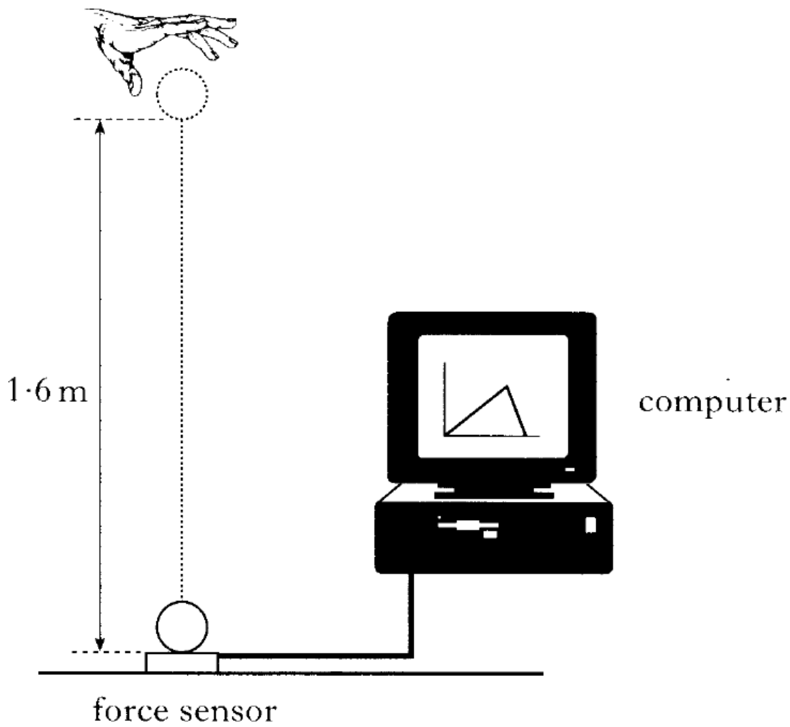
(*c*) Calculate the velocity of skater R immediately after pushing skater S.

(*d*) Is this interaction between the skaters elastic?

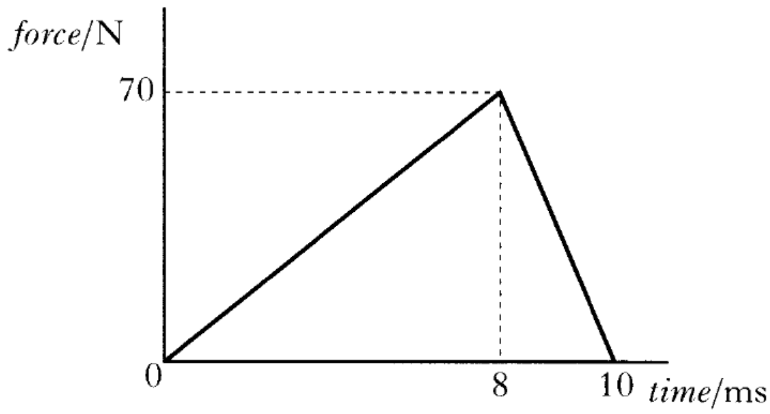
You must justify your answer by calculation.

22.

A force sensor is used to investigate the impact of a ball as it bounces on a flat horizontal surface. The ball has a mass of 0·050 kg and is dropped vertically, from rest, through a height of 1·6 m as shown.



(*a*) The graph shows how the force on the ball varies with time during the impact.



(i) Show by calculation that the magnitude of the impulse on the ball is 0·35 N s.

(ii) What is the magnitude and direction of the change in momentum of the ball?

(iii) The ball is travelling at 5·6 m s^{-1} just before it hits the force sensor. Calculate the speed of the ball just as it leaves the force sensor.

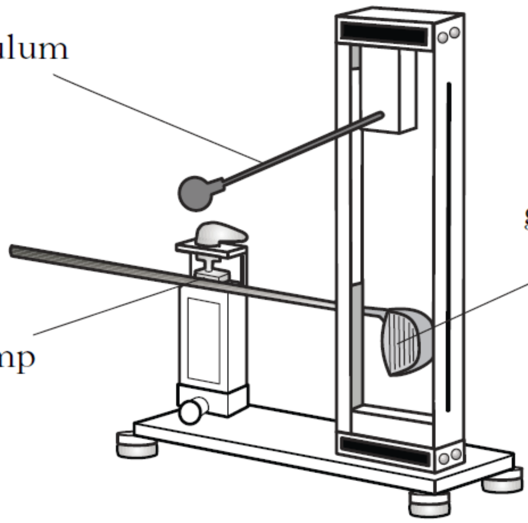
(*b*) Another ball of identical size and mass, but made of a harder material, is dropped from rest and from the same height onto the same force sensor. Sketch the force-time graph shown above and, on the same axes, sketch another graph to show how the force on the harder ball varies with time.

Numerical values are not required but you must label the graphs clearly.

23.

Golf clubs are tested to ensure they meet certain standards.

(*a*) In one test, a securely held clubhead is hit by a small steel pendulum. The time of contact between the clubhead and the pendulum is recorded.



The experiment is repeated several times.

The results are shown.

248 μs	259 μs	251 μs	263 μs	254 μs

(i) Calculate:

(A) the mean contact time between the clubhead and the pendulum;

(B) the approximate absolute random uncertainty in this value.

(ii) In this test, the standard required is that the maximum value of the mean contact time must not be greater than 257 μs.

Does the club meet this standard?

You must justify your answer.

(*b*) In another test, a machine uses a club to hit a stationary golf ball.

The mass of the ball is $4{\cdot}5 \times 10^{-2}$ kg. The ball leaves the club with a speed of $50{\cdot}0\,\mathrm{m\,s^{-1}}$. The time of contact between the club and ball is 450 μs.

(i) Calculate the average force exerted on the ball by the club.

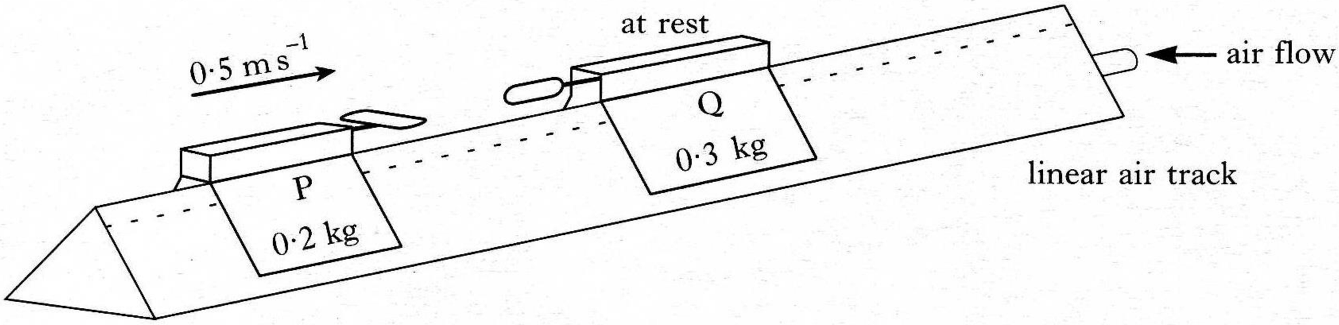
(ii) The test is repeated using a different club and an identical ball. The machine applies the same average force on the ball but with a longer contact time.

What effect, if any, does this have on the speed of the ball as it leaves the club?

Justify your answer.

24.

The diagram below shows two vehicles P and Q on a linear air track.



Vehicle P, of mass 0·2 kg, is projected with a velocity of 0·5 m s^{-1} to the right along the linear air track.

It collides with vehicle Q, of mass 0·3 kg, which is initially at rest.

After the collision, the vehicles move in opposite directions. Vehicle Q moves off with a velocity of 0·4 m s^{-1} to the right.

(*a*) Show that vehicle P rebounds with a speed of 0·1 m s^{-1} after the collision.

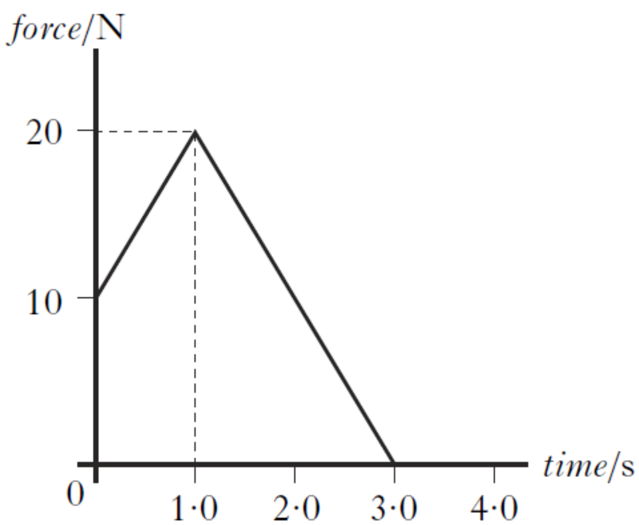
(*b*) Calculate the change in momentum of vehicle P as a result of the collision.

(*c*) During the collision, a timing device records the time of contact between the two vehicles as 0·06 s.

(i) Calculate the average force acting on vehicle P during the collision.

(ii) Sketch a graph showing how the force on vehicle P could vary with time while the two vehicles are in contact.

25. The graph below shows the **force acting** on a mass of **5.0kg**.



Calculate the change in the objects momentum.