Compiled by Leong Yee Pak

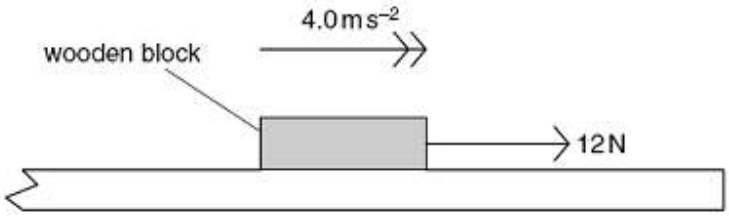
Dynamics

4.1 Newton's laws of motion
4.2 Linear momentum and its conservation

4.1 Momentum and Newton's laws of motion

****1 June 02 P1 Q10**

A wooden block of mass 0.60 kg is on a rough horizontal surface. A force of 12 N is applied to the block and it accelerates at 4.0 m s^{-2}.



What is the magnitude of the frictional force acting on the block?

A 2.4 N

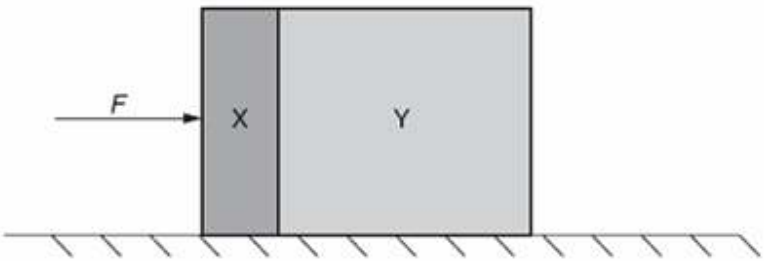
B 9.6 N

C 14 N

D 16 N

****2 June 03 P1 Q10**

Two blocks X and Y, of masses *m* and 3*m* respectively, are accelerated along a smooth horizontal surface by a force *F* applied to block X as shown.

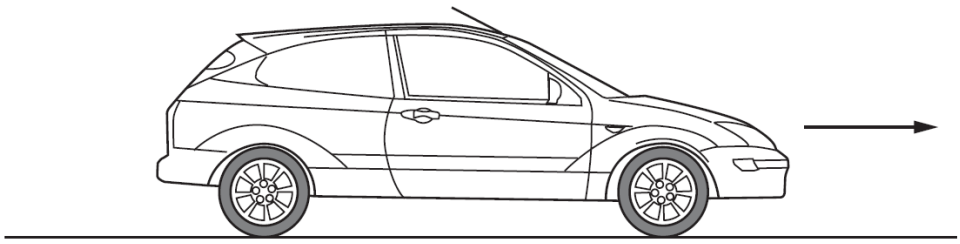


What is the magnitude of the force exerted by block X on block Y during this acceleration?

A $\frac{F}{4}$ **B** $\frac{F}{3}$ **C** $\frac{F}{2}$ **D** $\frac{3F}{4}$

*****3 June 03 P1 Q11**

11 A car with front-wheel drive accelerates in the direction shown.



Which diagram best shows the direction of the total force exerted by the road on the front wheels?

A B C D

****4 Nov 03 P1 Q10**

A mass accelerates uniformly when the resultant force acting on it

A is zero.

B is constant but not zero.

C increases uniformly with respect to time.

D is proportional to the displacement from a fixed point.

****5 Nov 03 P1 Q11**

A molecule of mass *m* travelling horizontally with velocity *u* hits a vertical wall at right angles to the wall. It then rebounds horizontally with the same speed.

What is its change in momentum?

A zero **B** mu **C** $-mu$ **D** $-2mu$

**6 June 04 P1 Q10

A ball falls vertically and bounces on the ground.

The following statements are about the forces acting while the ball is in contact with the ground.

Which statement is correct?

A The force that the ball exerts on the ground is always equal to the weight of the ball.

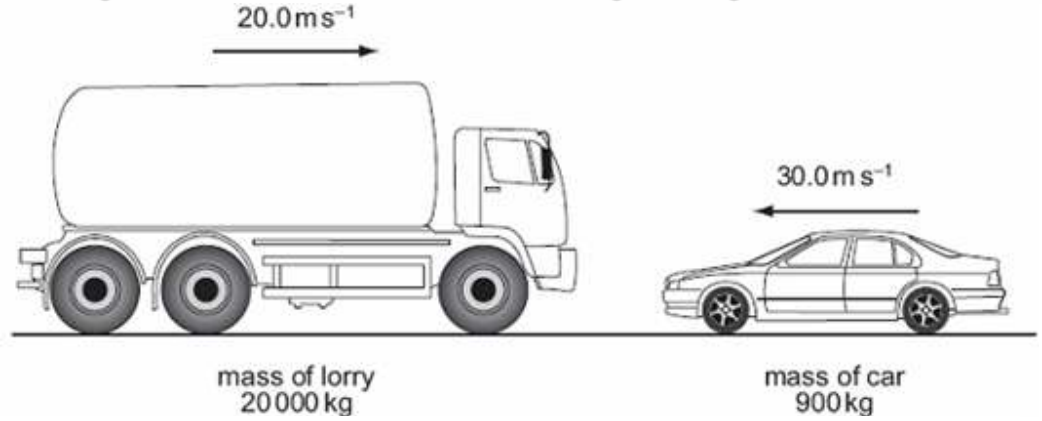
B The force that the ball exerts on the ground is always equal in magnitude and opposite in direction to the force the ground exerts on the ball.

C The force that the ball exerts on the ground is always less than the weight of the ball.

D The weight of the ball is always equal in magnitude and opposite in direction to the force that the ground exerts on the ball.

**7 June 04 P1 Q11

The diagram shows a situation just before a head-on collision. A lorry of mass 20000 kg is travelling at 20.0 m s^{-1} towards a car of mass 900 kg travelling at 30.0 m s^{-1} towards the lorry.



What is the magnitude of the total momentum?

A 373 kN s **B** 427 kN s **C** 3600 kN s **D** 4410 kN s

**8 Nov 04 P1 Q10

A constant mass undergoes uniform acceleration.

Which of the following is a correct statement about the resultant force acting on the mass?

A It increases uniformly with respect to time.

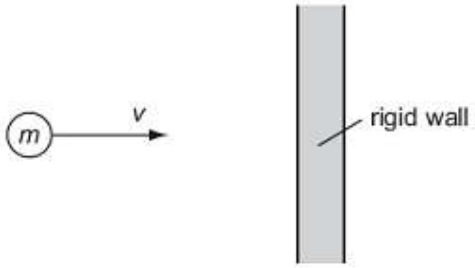
B It is constant but not zero.

C It is proportional to the displacement from a fixed point.

D It is proportional to the velocity.

**9 Nov 04 P1 Q11

A particle of mass m strikes a vertical rigid wall perpendicularly from the left with velocity v.



If the collision is perfectly elastic, the total change in momentum of the particle that occurs as a result of the collision is

A $2mv$ to the right.

B $2mv$ to the left.

C mv to the right.

D mv to the left.

*10 June 05 P1 Q10

Which is **not** one of Newton's laws of motion?

A The total momentum of a system of interacting bodies remains constant, providing no external force acts.

B The rate of change of momentum of a body is directly proportional to the external force acting on the body and takes place in the direction of the force.

C If body A exerts a force on body B, then body B exerts an equal and oppositely-directed force on body A.

D A body continues in a state of rest or of uniform motion in a straight line unless acted upon by some external force.

*11 June 05 P1 Q12

12 What is the centre of gravity of an object?

A the geometrical centre of the object

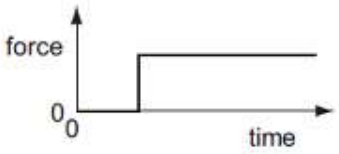
B the point about which the total torque is zero

C the point at which the weight of the object may be considered to act

D the point through which gravity acts

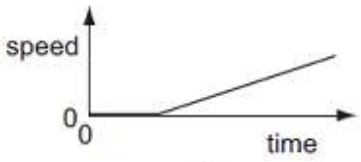
**12 Nov 05 P1 Q8

A car driver sharply presses down the accelerator when the traffic lights go green. The resultant horizontal force acting on the car varies with time as shown.

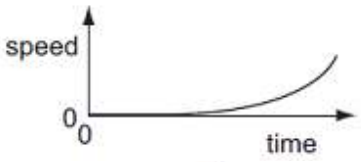


Which graph shows the variation with time of the speed of the car?

A

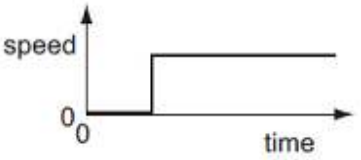


B



C

D



**13 Nov 05 P1 Q10

10 The gravitational field strength on the surface of planet P is one tenth of that on the surface of planet Q.

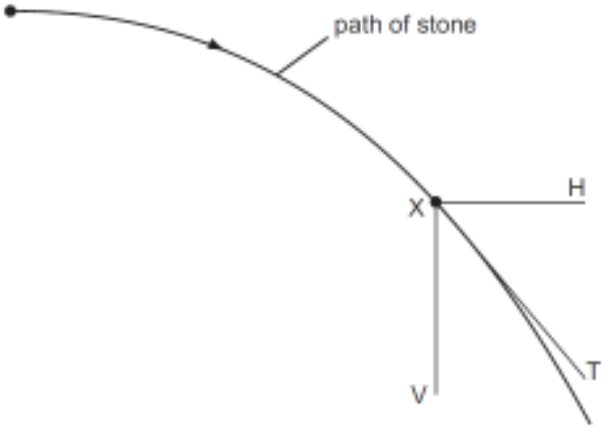
On the surface of P, a body has its mass measured to be 1.0 kg and its weight measured to be 1.0 N.

What results are obtained for measurements of the mass and weight of the same body on the surface of planet Q?

	mass on Q	weight on Q
A	1.0 kg	0.1 N
B	1.0 kg	10 N
C	10 kg	10 N
D	10 kg	100 N

**14 Nov 05 P1 Q11

11 A stone is projected horizontally in a vacuum and moves along a path as shown. X is a point on this path. XV and XH are vertical and horizontal lines respectively through X. XT is the tangent to the path at X.



Along which direction or directions do forces act on the stone at X?

A XV **B** XH **C** XV and XH **D** XT

***15 40 June 06 P1 Q10**

A cyclist is riding at a steady speed on a level road.

According to Newton's third law of motion, what is equal and opposite to the backward push of the back wheel on the road?

A the force exerted by the cyclist on the pedals

B the forward push of the road on the back wheel

C the tension in the cycle chain

D the total air resistance and friction force

***16 Nov 06 P1 Q10**

A force *F* is applied to a freely moving object. At one instant of time, the object has velocity *v* and acceleration *a*.

Which quantities **must** be in the same direction?

A *a* and *v* only

B *a* and *F* only

C *v* and *F* only

D *v*, *F* and *a*

***17 June 07 P1 Q9**

9 What is meant by the weight of an object?

A the gravitational field acting on the object

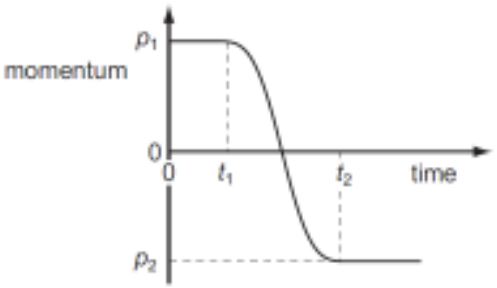
B the gravitational force acting on the object

C the mass of the object multiplied by gravity

D the object's mass multiplied by its acceleration

*****18 June 07 P Q10**

10 The graph shows the variation with time of the momentum of a ball as it is kicked in a straight line.



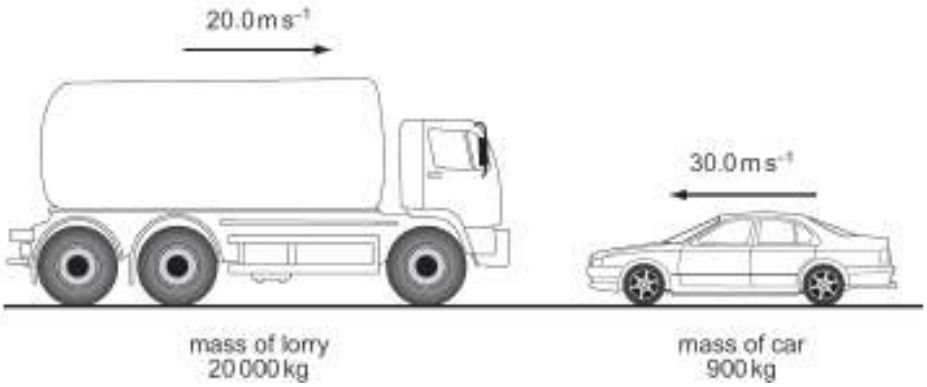
Initially, the momentum is p_1 at time t_1. At time t_2 the momentum is p_2.

What is the magnitude of the average force acting on the ball between times t_1 and t_2?

A $\frac{p_1 - p_2}{t_2}$ **B** $\frac{p_1 - p_2}{t_2 - t_1}$ **C** $\frac{p_1 + p_2}{t_2}$ **D** $\frac{p_1 + p_2}{t_2 - t_1}$

****19 June 07 P1 Q11**

11 A lorry of mass 20 000 kg is travelling at 20.0 m s^{-1}. A car of mass 900 kg is travelling at 30.0 m s^{-1} towards the lorry.

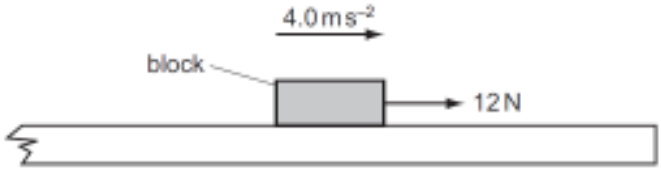


What is the magnitude of the total momentum?

A 209 kN s **B** 373 kN s **C** 427 kN s **D** 1045 kN s

**20 Nov 07 P1 Q10

10 A block of mass 0.60 kg is on a rough horizontal surface. A force of 12 N is applied to the block and it accelerates at 4.0 m s^{-2}.

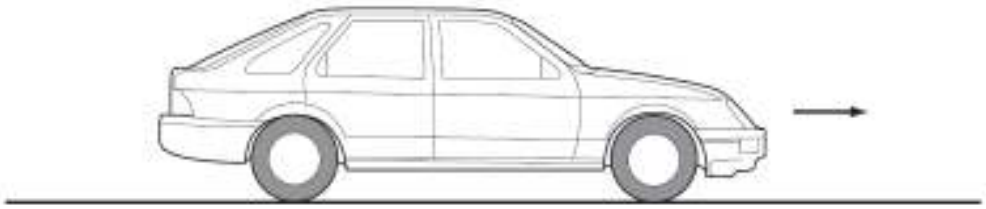


What is the magnitude of the frictional force acting on the block?

A 2.4N **B** 5.3N **C** 6.7N **D** 9.6N

***21 Nov 07 P1 Q11

11 A car with front-wheel drive accelerates in the direction shown.

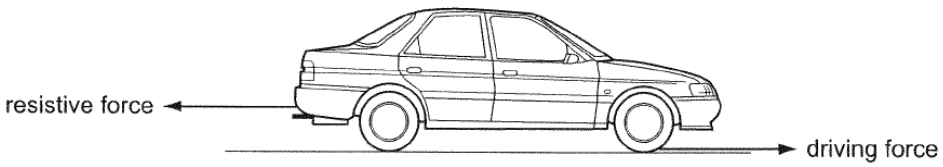


Which diagram best shows the direction of the total force exerted by the road on the front wheels?

A **B** **C** **D**

**22 June 08 P1 Q11

11 A car of mass 750 kg has a horizontal driving force of 2.0 kN acting on it. It has a forward horizontal acceleration of 2.0 m s^{-2}.



What is the resistive force acting horizontally?

A 0.5 kN **B** 1.5 kN **C** 2.0 kN **D** 3.5 kN

****23 Nov 08 P1 Q9**

9 A ball falls vertically and bounces on the ground.

The following statements are about the forces acting while the ball is in contact with the ground.

Which statement is correct?

A The force that the ball exerts on the ground is always equal to the weight of the ball.

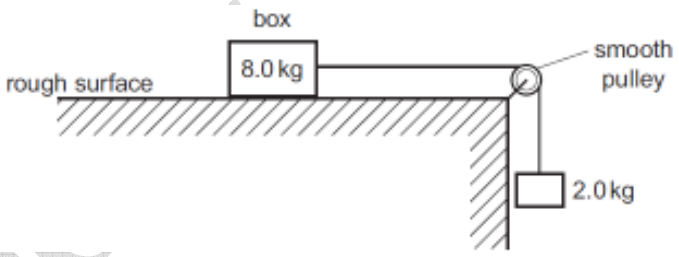
B The force that the ball exerts on the ground is always equal in magnitude and opposite in direction to the force the ground exerts on the ball.

C The force that the ball exerts on the ground is always less than the weight of the ball.

D The weight of the ball is always equal in magnitude and opposite in direction to the force that the ground exerts on the ball.

*****24 Nov 08 P1 Q11**

11 A box of mass 8.0 kg rests on a horizontal, rough surface. A string attached to the box passes over a smooth pulley and supports a 2.0 kg mass at its other end.



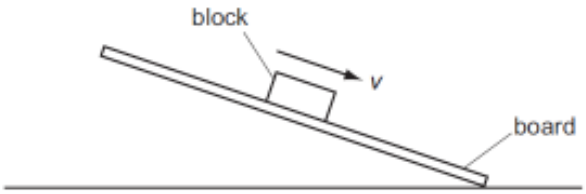
When the box is released, a friction force of 6.0 N acts on it.

What is the acceleration of the box?

A $1.4\,m\,s^{-2}$ **B** $1.7\,m\,s^{-2}$ **C** $2.0\,m\,s^{-2}$ **D** $2.5\,m\,s^{-2}$

***25 Nov 08 P1 Q12**

12 A wooden block rests on a rough board. The end of the board is then raised until the block slides down the plane of the board at constant velocity *v*.

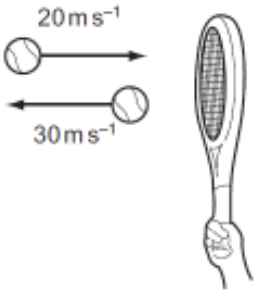


Which row describes the forces acting on the block when sliding with constant velocity?

	frictional force on block	resultant force on block
A	down the plane	down the plane
B	down the plane	zero
C	up the plane	down the plane
D	up the plane	zero

****26 June 09 P1 Q9**

9 A tennis ball of mass 100 g is struck by a tennis racket. The velocity of the ball is changed as shown.



What is the magnitude of the change in momentum of the ball?

A 1 kg m s^{-1} **B** 5 kg m s^{-1} **C** 1000 kg m s^{-1} **D** 5000 kg m s^{-1}

Section B

1 Nov 03 P2 Q2

2 (a) Distinguish between the mass of a body and its weight.

mass .....

.....

weight .....

..... [3]

(b) State two situations where a body of constant mass may experience a change in its apparent weight.

1. .....

.....

2. .....

..... [2]

2 Nov 05 P2Q4

4 A trolley of mass 930 g is held on a horizontal surface by means of two springs, as shown in Fig. 4.1.

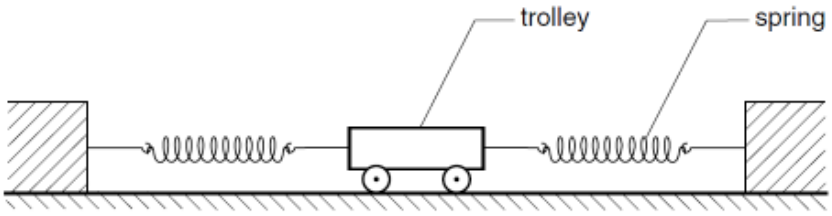


Fig. 4.1

The variation with time *t* of the speed *v* of the trolley for the first 0.60 s of its motion is shown in Fig. 4.2.

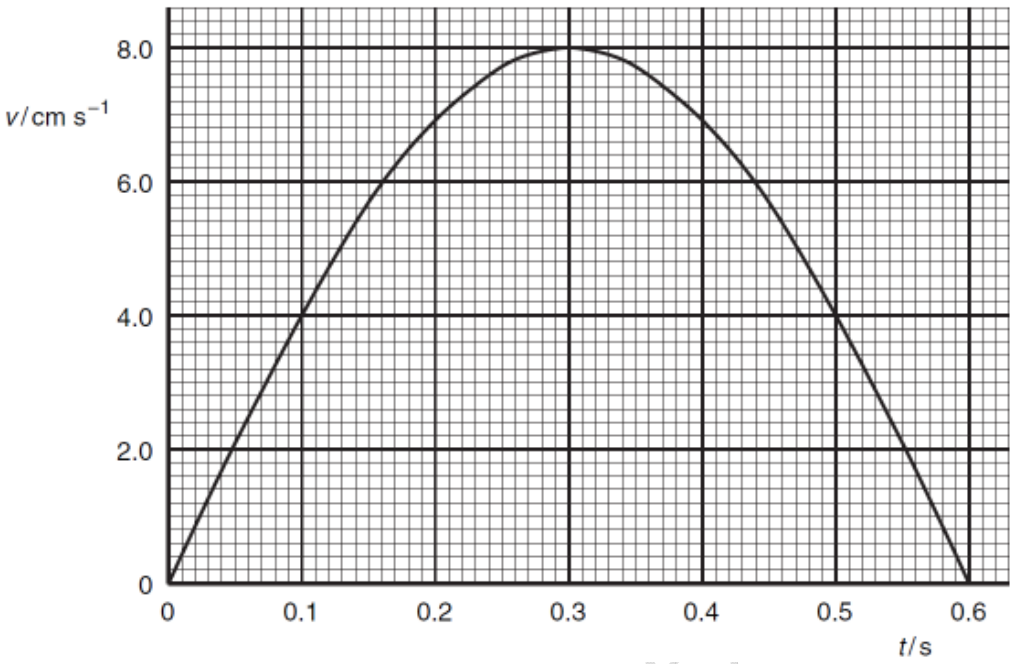


Fig. 4.2

(a) Use Fig. 4.2 to determine

(i) the initial acceleration of the trolley,

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

(ii) the distance moved during the first 0.60 s of its motion.

distance = ... m [3]

(b) **(i)** Use your answer to **(a)(i)** to determine the resultant force acting on the trolley at time $t = 0$.

force = ... N [2]

(ii) Describe qualitatively the variation with time of the resultant force acting on the trolley during the first 0.60 s of its motion.

.....

.....

.....

..... [3]

3 June 08 P2 Q3

3 A shopping trolley and its contents have a total mass of 42 kg. The trolley is being pushed along a horizontal surface at a speed of 1.2 m s^{-1}. When the trolley is released, it travels a distance of 1.9 m before coming to rest.

(a) Assuming that the total force opposing the motion of the trolley is constant,

(i) calculate the deceleration of the trolley,

deceleration = ... m s^{-2} [2]

(ii) show that the total force opposing the motion of the trolley is 16 N.

[1]

(b) Using the answer in **(a)(ii)**, calculate the power required to overcome the total force opposing the motion of the trolley at a speed of 1.2 m s^{-1}.

power = ... W [2]

(c) The trolley now moves down a straight slope that is inclined at an angle of 2.8° to the horizontal, as shown in Fig. 3.1.

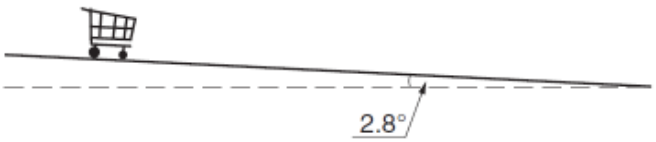


Fig. 3.1

The constant force that opposes the motion of the trolley is 16 N.

Calculate, for the trolley moving down the slope,

(i) the component down the slope of the trolley's weight,

component of weight = ... N [2]

(ii) the time for the trolley to travel from rest a distance of 3.5 m along the length of the slope.

time = ... s [4]

(d) Use your answer to **(c)(ii)** to explain why, for safety reasons, the slope is not made any steeper.

.....

.....[1]

4.2 Conservation of Momentum

Section A

**1 June 02 P1 Q9

Two similar spheres, each of mass m and travelling with speed v, are moving towards each other.

The spheres have a head-on elastic collision.

Which statement is correct?

A The spheres stick together on impact.

B The total kinetic energy after impact is mv^2.

C The total kinetic energy before impact is zero.

D The total momentum before impact is $2mv$.

***2 June 02 Q11

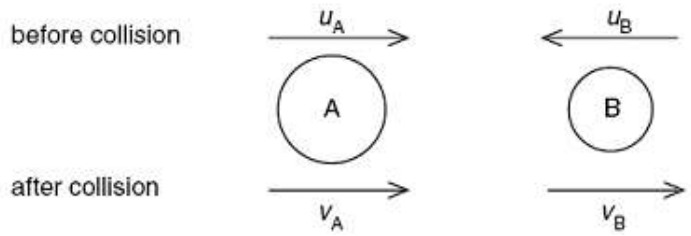
A body, initially at rest, explodes into two masses M_1 and M_2 that move apart with speeds v_1 and v_2 respectively.

What is the ratio $\frac{v_1}{v_2}$?

A $\frac{M_1}{M_2}$ **B** $\frac{M_2}{M_1}$ **C** $\left(\frac{M_1}{M_2}\right)^{\frac{1}{2}}$ **D** $\left(\frac{M_2}{M_1}\right)^{\frac{1}{2}}$

**3 Nov 02 P1 Q11

Two spheres A and B approach each other along the same straight line with speeds u_A and u_B. The spheres collide and move off with speeds v_A and v_B, both in the same direction as the initial direction of sphere A, as shown below.



Which equation applies to an elastic collision?

A $u_A + u_B = v_B - v_A$

B $u_A - u_B = v_B - v_A$

C $u_A - u_B = v_B + v_A$

D $u_A + u_B = v_B + v_A$

**4 Nov 02 P1 Q12

Two equal masses travel towards each other on a frictionless air track at speeds of 60 cm s^{-1} and 30 cm s^{-1}. They stick together on impact.

What is the speed of the masses after impact?

A 15 cm s^{-1} B 20 cm s^{-1} C 30 cm s^{-1} D 45 cm s^{-1}

**5 June 03 P1 Q12

12 A ball of mass 2 kg travelling at 8 m s^{-1} strikes a ball of mass 4 kg travelling at 2 m s^{-1}. Both balls are moving along the same straight line as shown.

After collision, both balls move at the same velocity v.

What is the magnitude of the velocity v?

A $4\,m\,s^{-1}$ **B** $5\,m\,s^{-1}$ **C** $6\,m\,s^{-1}$ **D** $8\,m\,s^{-1}$

***6 Nov 03 P1 Q9**

Which of the following is a statement of the principle of conservation of momentum?

A Momentum is the product of mass and velocity.

B In an elastic collision, momentum is constant.

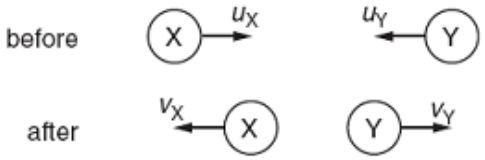
C The momentum of an isolated system is constant.

D The force acting on a body is proportional to its rate of change of momentum.

****7 Nov 03 P1 Q12**

Two balls X and Y approach each other along the same straight line and collide elastically.

Their speeds are u_X and u_Y respectively. After the collision they move apart with speeds v_X and v_Y respectively. Their directions are shown on the diagram.



Which of the following equations is correct?

A $u_X + u_Y = v_X + v_Y$

B $u_X + u_Y = v_X - v_Y$

C $u_X - u_Y = v_X + v_Y$

D $u_X - u_Y = v_X - v_Y$

****8 June 05 P1 Q11**

11 Two equal masses travel towards each other on a frictionless air track at speeds of $60\,cm\,s^{-1}$ and $40\,cm\,s^{-1}$. They stick together on impact.

What is the speed of the masses after impact?

A $10\,cm\,s^{-1}$ **B** $20\,cm\,s^{-1}$ **C** $40\,cm\,s^{-1}$ **D** $50\,cm\,s^{-1}$

**9 Nov 05 P1 Q9

Which is a statement of the principle of conservation of momentum?

A A force is equal to the rate of change of momentum of the body upon which it acts.

B In a perfectly elastic collision, the relative momentum of the bodies before impact is equal to their relative momentum after impact.

C The momentum of a body is the product of the mass of the body and its velocity.

D The total momentum of a system of interacting bodies remains constant, providing no external force acts.

**10 June 06 P1 Q11

In perfectly elastic collisions between two atoms, it is always true to say that

A the initial speed of one atom will be the same as the final speed of the other atom.

B the relative speed of approach between the two atoms equals their relative speed of separation.

C the total momentum must be conserved, but a small amount of the total kinetic energy may be lost in the collision.

D whatever their initial states of motion, neither atom can be stationary after the collision.

**11 June 06 P1 Q12

Two railway trucks of masses m and $3m$ move towards each other in opposite directions with speeds $2v$ and v respectively. These trucks collide and stick together.

What is the speed of the trucks after the collision?

A $\frac{v}{4}$ **B** $\frac{v}{2}$ **C** v **D** $\frac{5v}{4}$

**12 Nov 06 P1 Q11

The diagram shows two identical spheres X and Y.

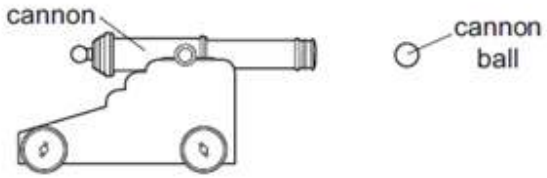
Initially X moves with speed v directly towards Y. Y is stationary. The spheres collide elastically.

What happens?

	X	Y
A	moves with speed $\frac{1}{2}v$ to the right	moves with speed $\frac{1}{2}v$ to the right
B	moves with speed v to the left	remains stationary
C	moves with speed $\frac{1}{2}v$ to the left	moves with speed $\frac{1}{2}v$ to the right
D	stops	moves with speed v to the right

****13 Nov Q6 P1 Q12**

The diagram shows a cannon ball fired from a cannon.



The mass of the cannon is 1000 kg and the mass of the cannon ball is 10 kg.

The recoil velocity of the cannon is 5 m s^{-1} horizontally.

What is the horizontal velocity of the cannon ball?

A 200 m s^{-1} **B** 500 m s^{-1} **C** 2000 m s^{-1} **D** 5000 m s^{-1}

****14 June 07 P1 Q12**

12 The diagram shows the masses and velocities of two trolleys about to collide.

After the impact they move off together.

What is the total kinetic energy of the trolleys after the collision?

A 1.3 J **B** 12 J **C** 18 J **D** 19 J

***15 June 08 P1 Q9**

Which is a statement of the principle of conservation of momentum?

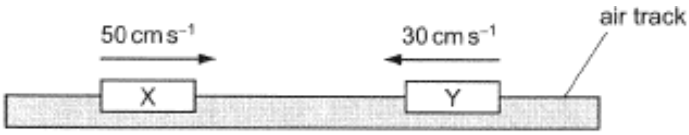
A Momentum is the product of mass and velocity

B Momentum is conserved only in Eleatic collisions.

C Momentum is conserved by all bodies in a collision.
D Momentum is conserved providing no external forces act.

****16 June 08 P1 Q10**

10 Two equal masses X and Y are moving towards each other on a frictionless air track as shown. The masses make an elastic collision.

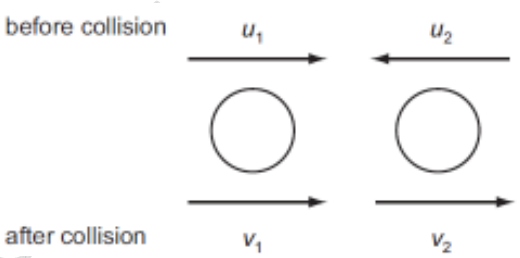


Which row gives possible velocities for the two masses after the collision?

	velocity of X	velocity of Y
A	zero	20 cm s^{-1} to the right
B	10 cm s^{-1} to the right	10 cm s^{-1} to the right
C	20 cm s^{-1} to the left	zero
D	30 cm s^{-1} to the left	50 cm s^{-1} to the right

****17 Nov 08 P1 Q10**

10 Two spheres approach each other along the same straight line. Their speeds are u_1 and u_2 before collision, and v_1 and v_2 after collision, in the directions shown below.



Which equation is correct if the collision is perfectly elastic?

A $u_1 - u_2 = v_2 + v_1$

B $u_1 - u_2 = v_2 - v_1$

C $u_1 + u_2 = v_2 + v_1$

D $u_1 + u_2 = v_2 - v_1$

*****18 June 09 P1 Q7**

7 Which statement about Newton's laws of motion is correct?

A The first law follows from the second law.

B The third law follows from the second law.

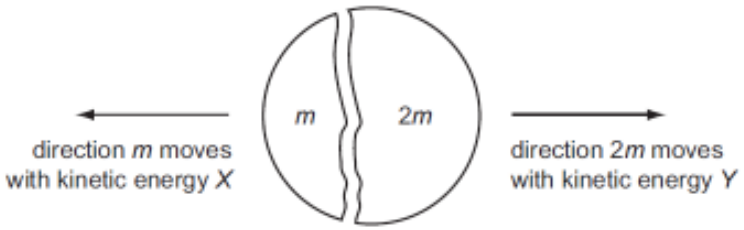
C Conservation of energy is a consequence of the third law.

D Conservation of linear momentum is a consequence of the first law.

*****19 June 09 P1 Q10**

10 A stationary body explodes into two components of masses m and $2m$.

The components gain kinetic energies X and Y respectively.



What is the value of the ratio $\frac{X}{Y}$?

A $\frac{1}{4}$ **B** $\frac{1}{2}$ **C** $\frac{2}{1}$ **D** $\frac{4}{1}$

Section B

1 June 02 P2 Q4

4 A steel ball of mass 73 g is held 1.6 m above a horizontal steel plate, as illustrated in Fig. 4.1.

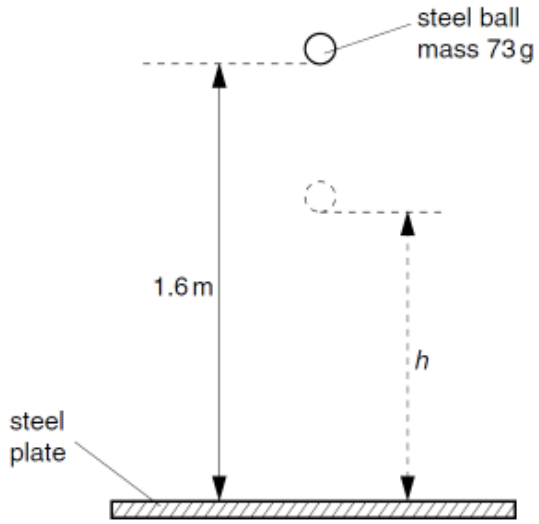


Fig. 4.1

The ball is dropped from rest and it bounces on the plate, reaching a height *h*.

(a) Calculate the speed of the ball as it reaches the plate.

speed = ... $m\,s^{-1}$ [2]

(b) As the ball loses contact with the plate after bouncing, the kinetic energy of the ball is 90% of that just before bouncing. Calculate

(i) the height *h* to which the ball bounces,

h = ... m

(ii) the speed of the ball as it leaves the plate after bouncing.

speed = ... $m\,s^{-1}$
[4]

(c) Using your answers to **(a)** and **(b)**, determine the change in momentum of the ball during the bounce.

change = ... N s [3]

(d) With reference to the law of conservation of momentum, comment on your answer to **(c)**.

.....

.....

.....[3]

2 June 04 P2 Q4

A ball has mass *m*. It is dropped onto a horizontal plate as shown in Fig. 4.1.

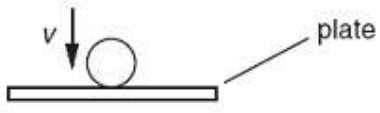


Fig. 4.1

Just as the ball makes contact with the plate, it has velocity *v*, momentum *p* and kinetic energy E_k.

(a) **(i)** Write down an expression for momentum p in terms of m and v.

.....

(ii) Hence show that the kinetic energy is given by the expression

$$E_k = \frac{p^2}{2m}.$$

[3]

(b) Just before impact with the plate, the ball of mass 35 g has speed 4.5 m s^{-1}. It bounces from the plate so that its speed immediately after losing contact with the plate is 3.5 m s^{-1}. The ball is in contact with the plate for 0.14 s.

Calculate, for the time that the ball is in contact with the plate,

(i) the average force, in addition to the weight of the ball, that the plate exerts on the ball,

magnitude of force = ... N

direction of force = ...

[4]

(ii) the loss in kinetic energy of the ball.

loss = ... J [2]

(c) State and explain whether linear momentum is conserved during the bounce.

.....

.....

.....

..... [3]

3 June 05 P2 Q3

A bullet of mass 2.0 g is fired horizontally into a block of wood of mass 600 g. The block is suspended from strings so that it is free to move in a vertical plane.
The bullet buries itself in the block. The block and bullet rise together through a vertical distance of 8.6 cm, as shown in Fig. 3.1.

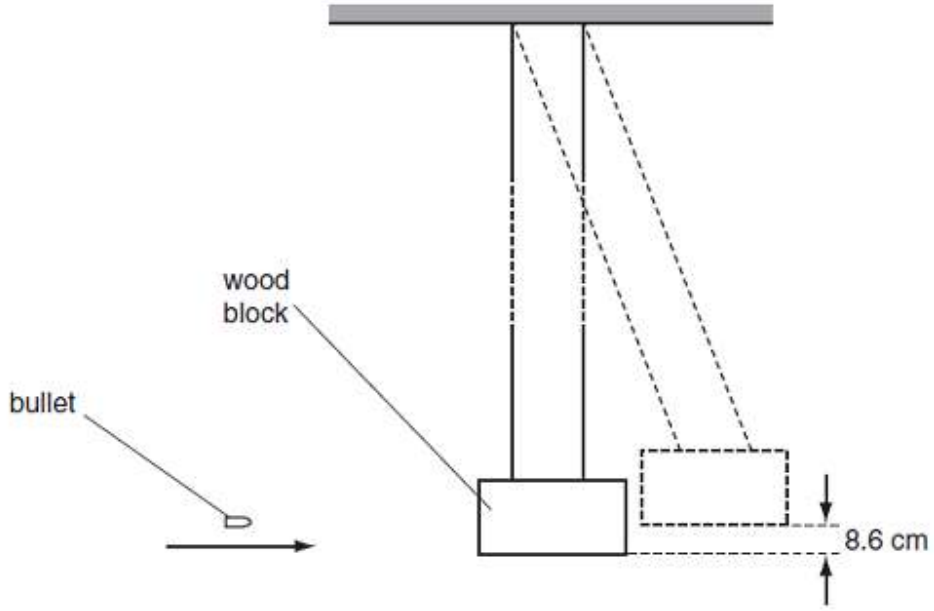


Fig. 3.1

(a) (i) Calculate the change in gravitational potential energy of the block and bullet.

change = ... J [2]

(ii) Show that the initial speed of the block and the bullet, after they began to move off together, was $1.3\,m\,s^{-1}$.

[1]

(b) Using the information in **(a)(ii)** and the principle of conservation of momentum, determine the speed of the bullet before the impact with the block.

speed = ... $m\,s^{-1}$ [2]

(c) **(i)** Calculate the kinetic energy of the bullet just before impact.

kinetic energy = ... J [2]

(ii) State and explain what can be deduced from your answers to **(c)(i)** and **(a)(i)** about the type of collision between the bullet and the block.

.....

.....

.....[2]

4 Nov 06 P2 Q3

Francium-208 is radioactive and emits α-particles with a kinetic energy of 1.07×10^{-12} J to form nuclei of astatine, as illustrated in Fig. 3.1.

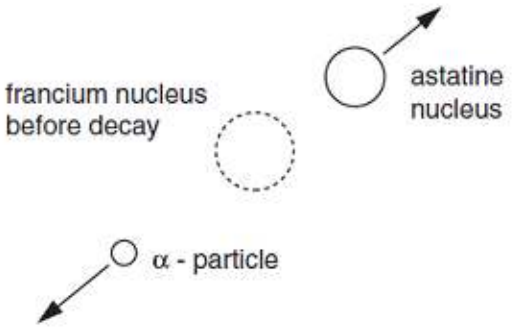


Fig. 3.1

(a) State the nature of an α-particle.

.....

..... [1]

(b) Show that the initial speed of an α-particle after the decay of a francium nucleus is approximately $1.8\times10^{7}\,m\,s^{-1}$.

[2]

(c) (i) State the principle of conservation of linear momentum.

.....

.....

..... [2]

(ii) The Francium-208 nucleus is stationary before the decay. Estimate the speed of the astatine nucleus immediately after the decay.

speed = ... $m\,s^{-1}$ [3]

(d) Close examination of the decay of the francium nucleus indicates that the astatine nucleus and the α-particle are not ejected exactly in opposite directions.

Suggest an explanation for this observation.

.....

.....

..... [2]

5 June 09 P2 Q2

2 A ball B of mass 1.2 kg travelling at constant velocity collides head-on with a stationary ball S of mass 3.6 kg, as shown in Fig. 2.1.

Fig. 2.1

Frictional forces are negligible.

The variation with time t of the velocity v of ball B before, during and after colliding with ball S is shown in Fig. 2.2.

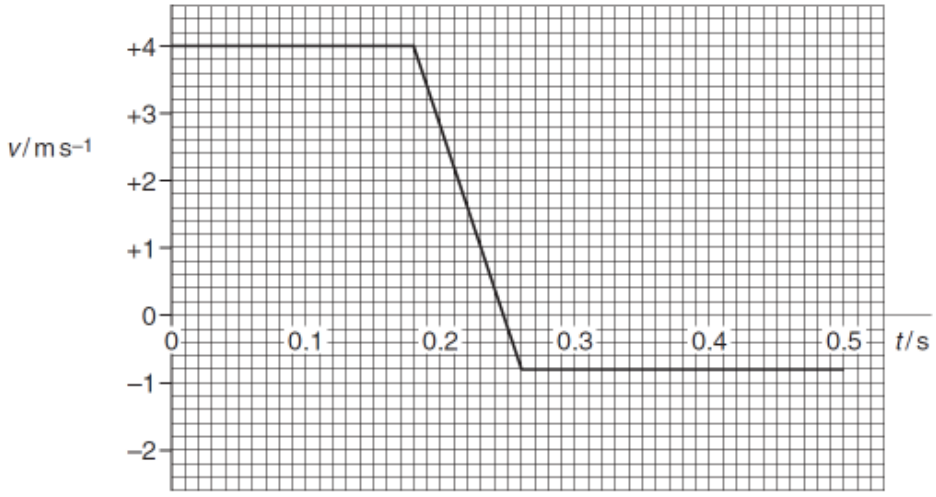


Fig. 2.2

(a) State the significance of positive and negative values for *v* in Fig. 2.2.

.....

..... [1]

(b) Use Fig. 2.2 to determine, for ball B during the collision with ball S,

(i) the change in momentum of ball B,

change in momentum = ... Ns [3]

(ii) the magnitude of the force acting on ball B.

force = ... N [3]

(c) Calculate the speed of ball S after the collision.

speed = ... $m\,s^{-1}$ [2]

(d) Using your answer in **(c)** and information from Fig. 2.2, deduce quantitatively whether the collision is elastic or inelastic.

.....

..... [2]