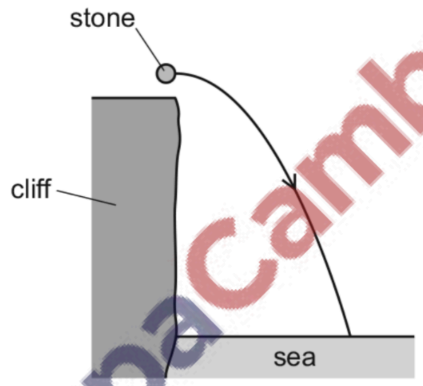
Paper 1

1.

A stone is thrown horizontally from the top of a cliff and falls into the sea below. Air resistance is negligible. The path of the stone is shown.



In which direction does the resultant force on the stone act during its fall?

A horizontally to the right

B parallel to its velocity

C perpendicular to its velocity

D vertically downwards

Ans: D

Direction of resultant force = direction of acceleration = vertically downwards (acceleration due to gravity)

2.

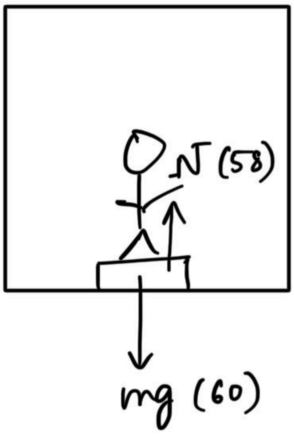
A person of mass 60 kg stands on accurate bathroom scales, placed on the floor of an elevator (lift) which operates in a tall building.

At a certain instant the bathroom scales read 58 kg.

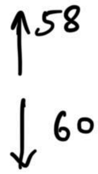
Which row could give the person's direction of movement and type of motion?

	direction	motion
A	downwards	constant speed
B	downwards	slowing down
C	upwards	constant speed
D	upwards	slowing down

Ans: D



the scale shows the contact force (normal reaction force)



F_{net} is downwards ∴ person accelerates downward

options A & C ruled out since there is F_{net} ∴ not constant v.

Slowing down ⇒ deceleration ⇒ v & a are in opp directions.

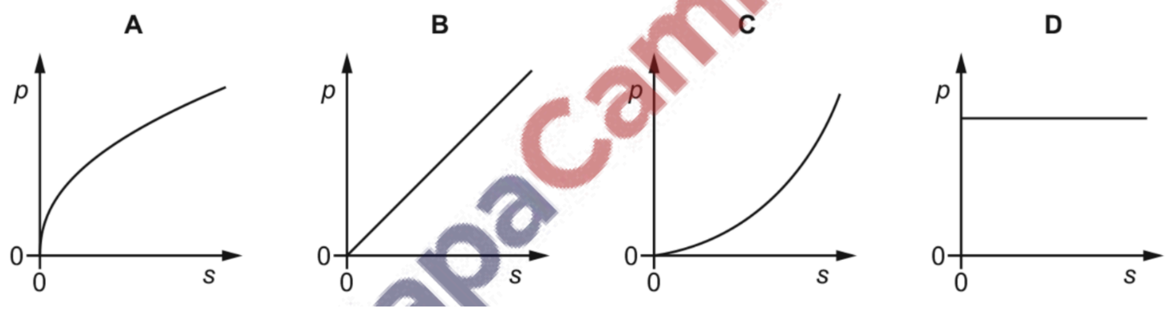
∴ if a acts down, v should act up

↳ option D!

3.

A car accelerates from rest in a straight line with constant acceleration.

Which graph best represents the variation of the momentum p of the car with the distance s travelled by the car?

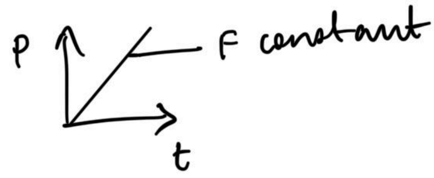


Ans: A

1) $F = \frac{\Delta p}{\Delta t}$

$F = ma$

since a constant



∴ graph B would be for p-t not p-s

2) car starts from rest so should start from origin

∴ rule out D.

3) relate p and s.

$$p = mv = m\sqrt{u^2 + 2as} = m\sqrt{2as}$$

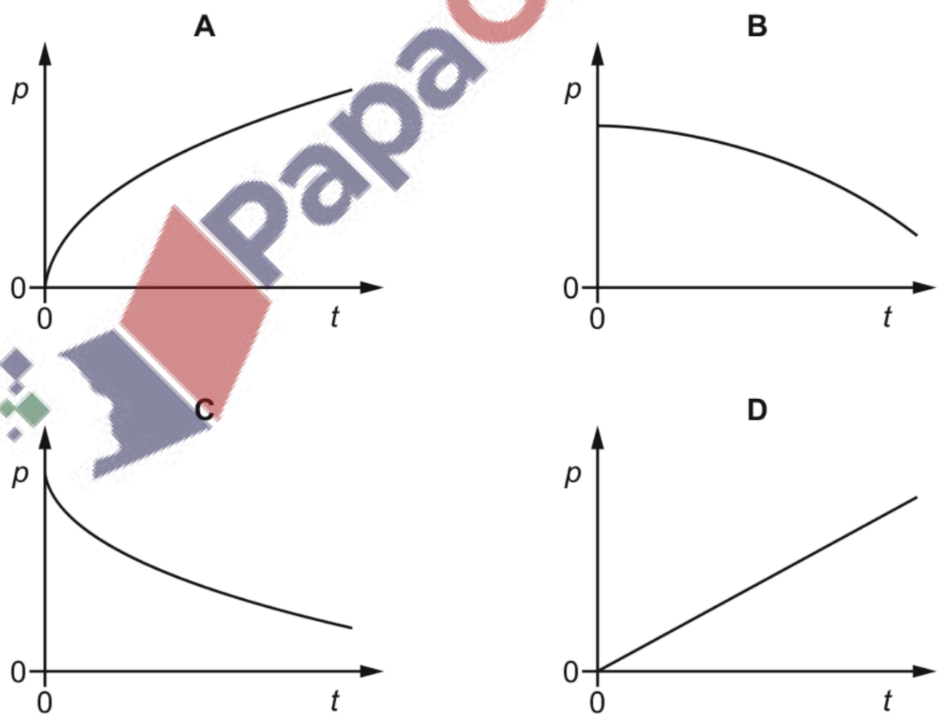
$$\therefore p \propto \sqrt{s}$$

square root graphs will look like the graph in A.

4.

The resultant force acting on an object is slowly increased.

Which graph could show the variation with time *t* of the momentum *p* of the object?



Ans: B

$$F = \frac{\Delta p}{\Delta t}$$

$\therefore$ F = gradient of p-t graph

so look for a graph where gradient is increasing.

A) gradient decreases

B) graph gets steeper & gradient increases

C) gradient decreases

D) constant gradient

5.

A ball of mass m travels vertically downwards and then hits a horizontal floor at speed u.

It rebounds vertically upwards with speed v.

The collision lasts a time Δt.

What is the average resultant force exerted on the ball during the collision?

A $\dfrac{mv - mu}{\Delta t}$ downwards

B $\dfrac{mv - mu}{\Delta t}$ upwards

C $\dfrac{mv + mu}{\Delta t}$ downwards

D $\dfrac{mv + mu}{\Delta t}$ upwards

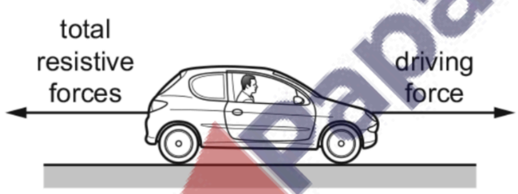
Ans: D

6.

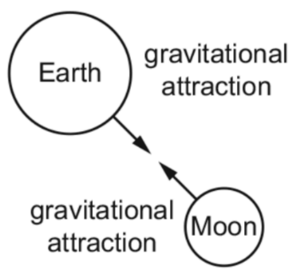
Each diagram illustrates a pair of forces of equal magnitude.

Which diagram gives an example of a pair of forces that is described by Newton's third law of motion?

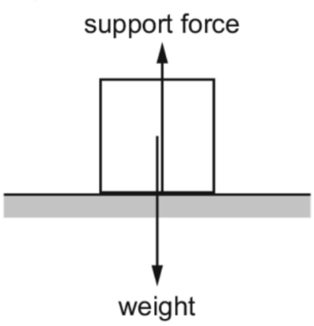
A



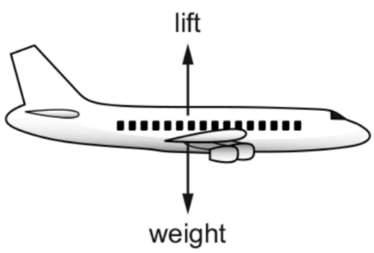
B



C



D



Ans: B

7.

A car has mass *m*. A person needs to push the car with force *F* in order to give the car acceleration *a*. The person needs to push the car with force 2*F* in order to give the car acceleration 3*a*.

Which expression gives the constant resistive force opposing the motion of the car?

A *ma* **B** 2*ma* **C** 3*ma* **D** 4*ma*

Ans: A

$F - x = ma \Rightarrow F = ma + x$

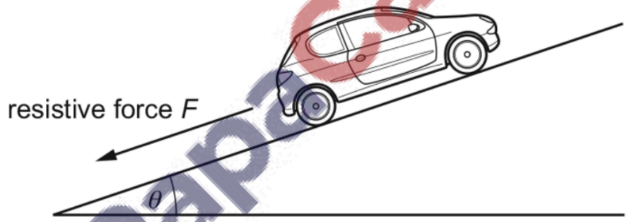
$2F - x = 3ma$

$\Rightarrow 2ma + 2x - x = 3ma$

$\Rightarrow x = 3ma - 2ma = ma$

8.

A car of mass *m* travels at constant speed up a slope at an angle θ to the horizontal, as shown in the diagram. Air resistance and friction provide a resistive force *F*. The acceleration of free fall is *g*.



What is the force needed to propel the car at this constant speed?

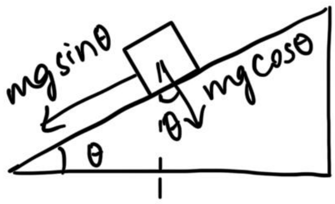
A $mg \cos \theta$

B $mg \sin \theta$

C $mg \cos \theta + F$

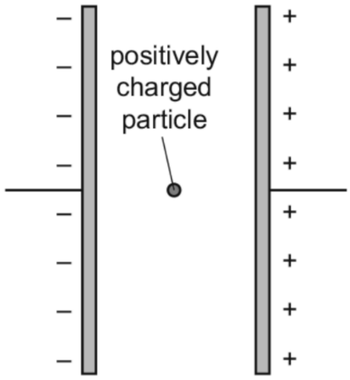
D $mg \sin \theta + F$

Ans: D



9.

A uniform electric field is created by two parallel vertical plates. A positively charged particle is in the vacuum between the plates, as shown.



Which statement is correct?

A The electric field makes the particle move towards the negative plate with a constant speed.

B The electric field makes the particle move towards the negative plate with a constant acceleration.

C The electric field produces a uniform rate of decrease in the particle's acceleration.

D The electric field produces a uniform rate of increase in the particle's acceleration.

Ans: B
constant acceleration because electrostatic force is constant due to uniform electric field.

10.

Steel pellets, each with a mass of 0.60 g, fall vertically onto a horizontal plate at a rate of 100 pellets per minute. They strike the plate with a velocity of $5.0\,\text{m}\,\text{s}^{-1}$ and rebound with a velocity of $4.0\,\text{m}\,\text{s}^{-1}$.

What is the average force exerted on the plate by the pellets?

A 0.0010 N **B** 0.0054 N **C** 0.0090 N **D** 0.54 N

Ans: C
(change in momentum of each x 100) / 60

11.

The momentum of a car of mass m increases from p_1 to p_2.

What is the increase in the kinetic energy of the car?

A $\dfrac{(p_2^2 - p_1^2)}{2m}$ **B** $\dfrac{(p_2 - p_1)^2}{2m}$ **C** $\dfrac{p_2 - p_1}{2m}$ **D** $\dfrac{p_1 - p_2}{2m}$

Ans: A

$$\frac{1}{2}mv^2 = \frac{1}{2}pv$$

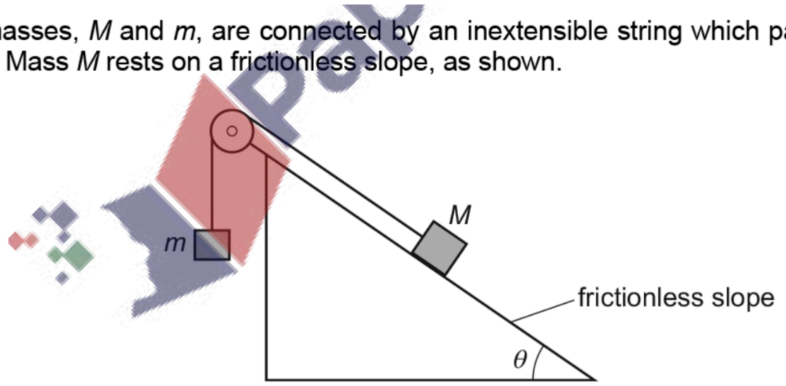
$$v = \frac{p}{m}$$

$$\therefore \frac{1}{2}p_2 \cdot \frac{p_2}{m} - \frac{1}{2}p_1 \cdot \frac{p_1}{m}$$

$$= \frac{p_2^2 - p_1^2}{2m}$$

12.

Two masses, *M* and *m*, are connected by an inextensible string which passes over a frictionless pulley. Mass *M* rests on a frictionless slope, as shown.



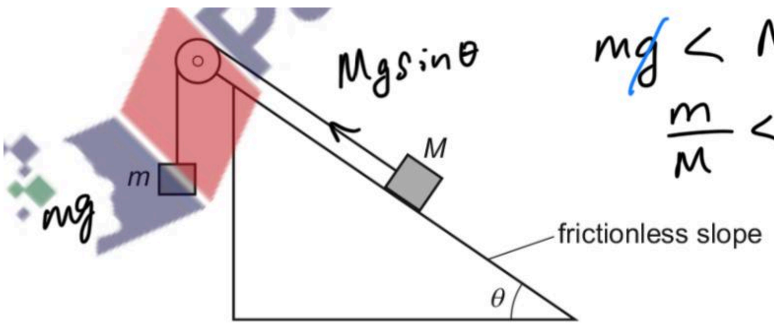
The slope is at an angle θ to the horizontal.

The two masses are initially held stationary and then released. Mass *M* moves down the slope.

Which expression **must** be correct?

A $\sin\theta < \frac{m}{M}$ **B** $\cos\theta < \frac{m}{M}$ **C** $\sin\theta > \frac{m}{M}$ **D** $\cos\theta > \frac{m}{M}$

Ans: C



$$mg < Mg\sin\theta$$

$$\frac{m}{M} < \sin\theta$$

13.

Water is pumped through a hose-pipe at a rate of 90 kg per minute. Water emerges horizontally from the hose-pipe with a speed of $20\,m\,s^{-1}$.

What is the minimum force required from a person holding the hose-pipe to prevent it moving backwards?

A 30 N **B** 270 N **C** 1800 N **D** 108 000 N

Ans: A

(90 x 20) / 60 = 30N

14.

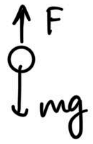
A ball of mass *m* is thrown vertically into the air. When the ball has speed *v*, the air resistance acting on the ball is *F*.

What is the magnitude of the acceleration of the ball when its speed is *v* as it rises and as it falls?

	acceleration when ball is rising	acceleration when ball is falling
A	$g - \frac{F}{m}$	$g - \frac{F}{m}$
B	$g - \frac{F}{m}$	$g + \frac{F}{m}$
C	$g + \frac{F}{m}$	$g - \frac{F}{m}$
D	$g + \frac{F}{m}$	$g + \frac{F}{m}$

Ans: C

Fall

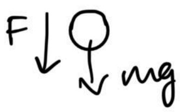


$F_{resultant}$ = downward

$ma = mg - F$

$a = g - \frac{F}{m}$

Rising



$F_{resultant}$: downward

$ma = F + mg$

$a = \frac{F}{m} + g$

air resistance opposes motion
∴ when rising, air resistance acts downward. while falling it acts upward.

15.

Two isolated spheres have masses 2.0 kg and 4.0 kg. The spheres collide and then move apart.

During the collision, the 2.0 kg mass has an average acceleration of $8.0\,m\,s^{-2}$.

What is the average acceleration of the 4.0 kg mass?

A $2.0\,m\,s^{-2}$ **B** $4.0\,m\,s^{-2}$ **C** $8.0\,m\,s^{-2}$ **D** $16\,m\,s^{-2}$

Ans: B

Use F = ma

F = 2 x 8 = 16

a = 16 / 4 = 4

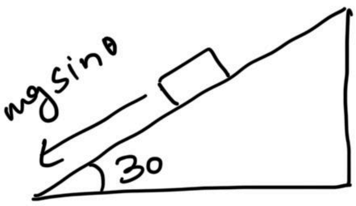
16.

A mass is placed on a frictionless slope inclined at 30° to the horizontal. The mass is then released.

What is its acceleration down the slope?

A $4.9\,m\,s^{-2}$ **B** $5.7\,m\,s^{-2}$ **C** $8.5\,m\,s^{-2}$ **D** $9.8\,m\,s^{-2}$

Ans: A



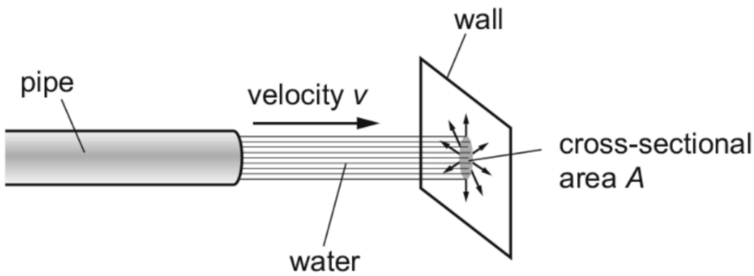
$$F_{net} = mg\sin\theta$$

$$a = \frac{F_{net}}{m} = \frac{\cancel{m}g\sin 30}{\cancel{m}}$$

$$= 4.905$$

17.

Water flows out of a pipe and hits a wall.



When the jet of water hits the wall, it has horizontal velocity v and cross-sectional area A.

The density of the water is ρ. The water does not rebound from the wall.

What is the force exerted on the wall by the water?

A $\frac{\rho v}{A}$ **B** $\frac{\rho v^2}{A}$ **C** $\rho A v$ **D** $\rho A v^2$

Ans: D

$$F = \frac{\Delta p}{\Delta t} \qquad \Delta p = mv$$

$$m = \rho \times vol = \rho \times vA$$

$$\Delta p = \rho vA \times v \quad (v = \frac{l}{t} \therefore t \text{ is alr the denominator})$$

$$\therefore F = \rho A v^2$$

18.

The mass of a rocket-propelled truck is approximately equal to the mass of the fuel in its tank. The fuel is ignited and the truck is propelled along horizontal tracks by a constant force. The effect of air resistance is negligible.

During a test run the fuel is consumed at a constant rate.

Which statement describes the acceleration of the truck during the test run?

A The acceleration of the truck decreases as the fuel is consumed.

B The acceleration of the truck increases as the fuel is consumed.

C The acceleration of the truck remains constant.

D The acceleration of the truck is zero and the truck moves at a constant velocity.

Ans: B

F = ma

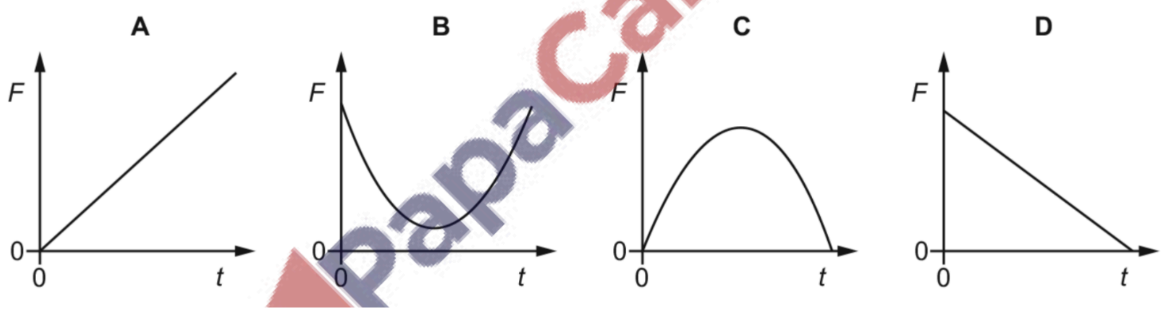
a = F/m

m is constantly decreasing, so a increases

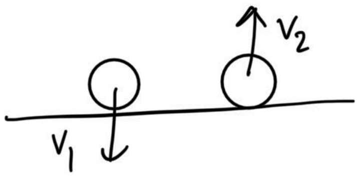
19.

A rubber ball is dropped onto a table and bounces back up. The table exerts a force *F* on the ball.

Which graph best shows the variation with time *t* of the force *F* for the short time that the ball is in contact with the table?



Ans: C



ball gets deformed slightly when in contact with table, as it is pushed down. This deformation is due to F exerted by table upwards.
This deformation has a peak: increases as it touches table to maximum, and then decreases as the ball leaves.

∴ graph C.

20.

A golf ball of mass m is dropped onto a hard surface from a height h_1 and rebounds to a height h_2.

The momentum of the golf ball just as it reaches the surface is different from its momentum just as it leaves the surface.

What is the total change in the momentum of the golf ball between these two instants? (Ignore air resistance.)

A $m\sqrt{2gh_1} - m\sqrt{2gh_2}$

B $m\sqrt{2gh_1} + m\sqrt{2gh_2}$

C $m\sqrt{2g(h_1 - h_2)}$

D $m\sqrt{2g(h_1 + h_2)}$

Ans: B

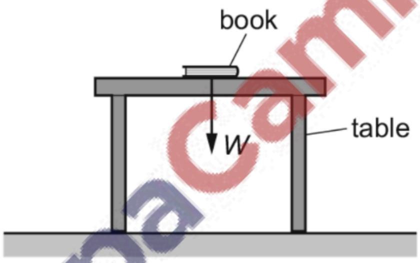
KE = PE

Use this to find v in each case = sqrt(2gh1) and sqrt(2gh2)

Change in momentum = mv1 + mv2 = m x sqrt(2gh1) + m x sqrt(2gh2)

21.

A book of weight *W* is at rest on a table. A student attempts to state Newton's third law of motion by saying that 'action equals reaction'.



If the weight of the book is the 'action' force, what is the 'reaction' force?

A the force *W* acting downwards on the Earth from the table

B the force *W* acting upwards on the book from the table

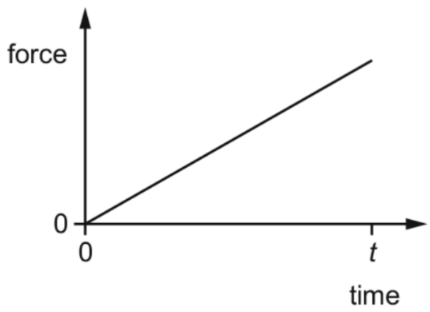
C the force *W* acting upwards on the Earth from the book

D the force *W* acting upwards on the table from the floor

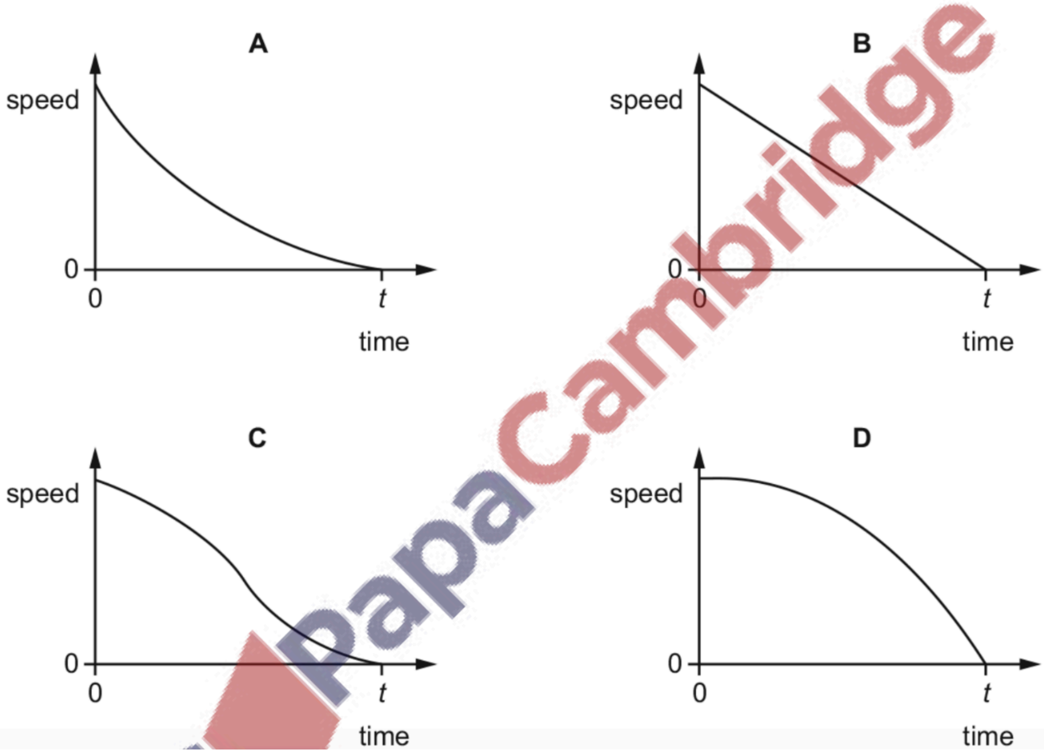
Ans: C

22.

A driver stops his car in time t by gradually increasing the total braking force on the car. The graph shows the resultant force on the car.



Which graph shows how the speed of the car will vary during this time?



Ans: D

F = ma

So if force increases, acceleration increases

Acceleration = gradient of speed–time graph

Thus, gradient of this graph must increase = D

23.

An ice-hockey puck of mass 150 g moves with an initial speed of $2.0\,\mathrm{m\,s^{-1}}$ along the surface of an ice rink.

The puck slides a distance of 30 m in a straight line before stopping.

What is the average frictional force acting on the puck?

A 0.010 N **B** 0.020 N **C** 0.067 N **D** 0.44 N

Ans: A

$$v^2 = u^2 + 2as$$

$$\Rightarrow 0 = 4 + 2a \times 30 \Rightarrow a = -\frac{1}{15}$$

$$F = ma = \frac{150}{1000} \times \frac{1}{15} = 0.01$$

24.

A constant force pushes a block along a horizontal frictionless surface. The block moves from rest through a fixed distance.

What is the relationship between the final speed *v* of the block and its mass *m*?

A $\sqrt{v} \propto \frac{1}{m}$ **B** $v \propto \sqrt{m}$ **C** $v \propto \frac{1}{\sqrt{m}}$ **D** $\sqrt{v} \propto m$

Ans: C

$$v^2 = u^2 + 2as \; ; \quad a = \frac{F}{m} \; ; \quad u = 0$$

$$v^2 = 2\left(\frac{F}{m}\right)s$$

$$v = \sqrt{\frac{2Fs}{m}} \quad \therefore \quad v \propto \sqrt{\frac{1}{m}}$$

25.

A car is moving at constant speed in a straight line with the engine providing a driving force equal to the resistive force *F*.

When the engine is switched off, the car is brought to rest in a distance of 100 m by the resistive force.

It may be assumed that *F* is constant during the deceleration.

The process is then repeated for the same car with the same initial speed but with a constant resistive force of 0.800 *F*.

How far will the car travel while decelerating?

A 120 m **B** 125 m **C** 156 m **D** 250 m

Ans: B

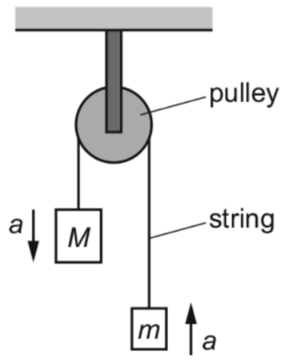
$a = \frac{F}{m}$; $v^2 = u^2 + 2as$; $v^2 = 0$ & u is same for both

$\therefore 2\left(\frac{F}{m}\right) \times 100 = 2\left(\frac{0.8F}{m}\right) \times s \Rightarrow s = \frac{200}{2 \times 0.8} = 125$

NOTE: principle of conservation of momentum = the momentum of an isolated system is constant.

26.

Two blocks of masses M and m are joined by a thin string which passes over a frictionless pulley, as shown.

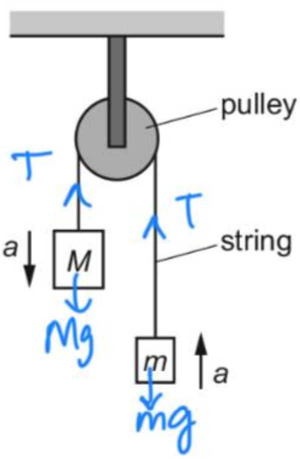


The acceleration of free fall is g.

What is the acceleration a of the two blocks?

A $\frac{(M+m)}{(M-m)}g$ **B** $\frac{(M-m)}{(M+m)}g$ **C** $\frac{M}{m}g$ **D** $\frac{m}{M}g$

Ans: B



Tension is the same on both sides

For M, a is downward, so Fnet is downward. For m, a is upward so Fnet is up.

Fnet for M:

$Mg - T = Ma$

(downward)

Fnet for m:

$T - mg = ma$

(upward)

↓

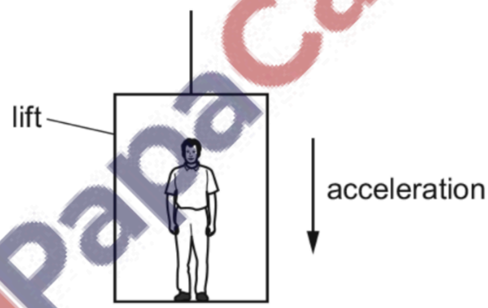
$T = mg + ma$

$Mg - mg - ma = Ma$

$g(M - m) = a(m + M)$ $\therefore a = \frac{(M-m)g}{(M+m)}$

27.

A man stands in a lift that is accelerating vertically downwards, as shown.



Which statement describes the force exerted by the man on the floor?

A It is equal to the weight of the man.

B It is greater than the force exerted by the floor on the man.

C It is less than the force exerted by the floor on the man.

D It is less than the weight of the man.

Ans: D

- Not A, because this is only true if there was no acceleration
- Not B or C, because force exerted by man on floor = force exerted by floor on man
- Fnet = downward, which means normal reaction force (by floor on man) is less than weight of the man.
- Since force of floor on man = force of man on floor, this is also less than weight.

28.

Which statement **defines** force?

A When a force acts on a body that is free to move, the force is the product of the mass of the body and its acceleration.

B When a force acts on a body that is free to move, the force is the rate of change of momentum of the body.

C When a force acts on a body that is free to move, the force is the work done by the force divided by the distance moved by the body.

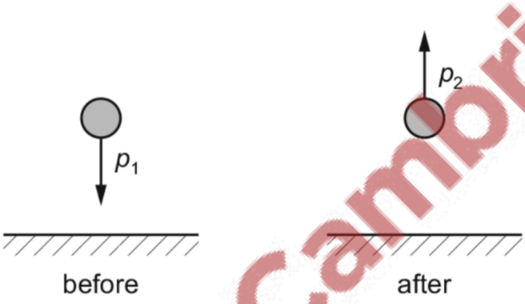
D When a force acts on a lever and causes a moment, the force is the moment divided by the perpendicular distance of the force from the pivot.

Ans: B

NOTE: definition of force = rate of change of momentum!!

29.

A ball falls vertically onto horizontal ground and rebounds, as shown.



The ball has momentum p_1 downwards just before hitting the ground. After rebounding, the ball leaves the ground with momentum p_2 upwards. The ball is in contact with the ground for 0.020 s. During this time interval, an average resultant force of 25 N acts on the ball.

What is a possible combination of values for p_1 and p_2?

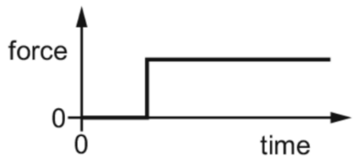
	p_1 / kg m s^{-1}	p_2 / kg m s^{-1}
A	0.15	0.65
B	0.20	0.30
C	0.30	0.20
D	0.65	0.15

Ans: C

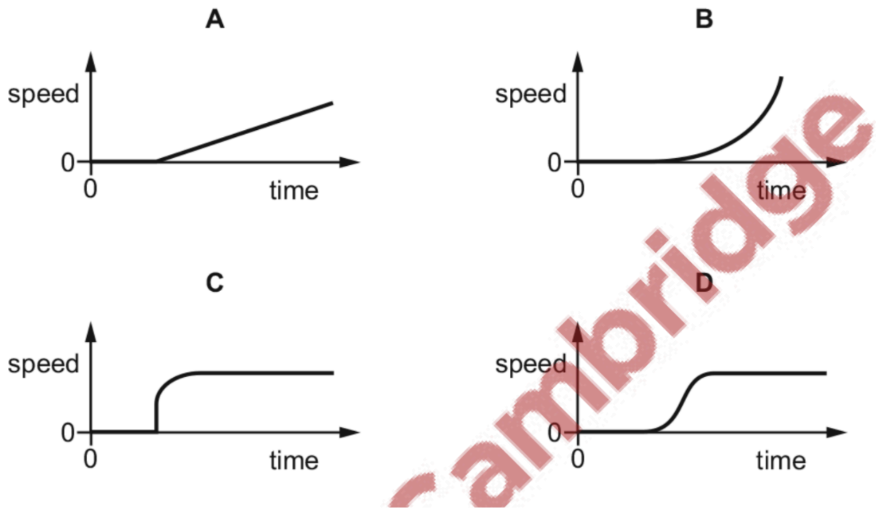
- Change in momentum = 0.5 (p1 + p2 = 0.5)
- Magnitude of p1 should be higher than magnitude of p2

30.

A car is stationary at traffic lights. When the traffic lights change to green, the driver presses down sharply on the accelerator. 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?



Ans: A

F = ma

For first part, F = 0, so acceleration = 0

For second part, F = constant, so acceleration is constant

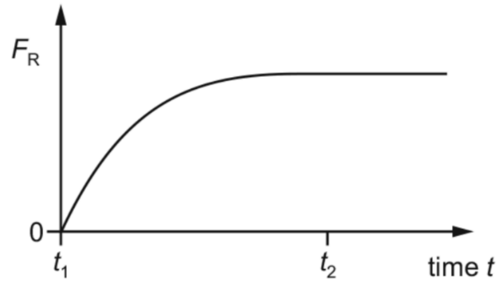
Thus graph A shows no acceleration in the beginning, followed by constant acceleration.

NOTE: the acceleration is constant, not 0!! So it cannot be graphs C or D.

31.

A light ball is falling vertically through air.

The variation with time t of the resistive force F_R acting on the ball is shown.



At which times are the speed of the ball zero, the speed at a maximum and the acceleration zero?

	zero speed	maximum speed	zero acceleration
A	t_1	t_2	t_1
B	t_1	t_2	t_2
C	t_2	t_1	t_1
D	t_2	t_1	t_2

Ans: B

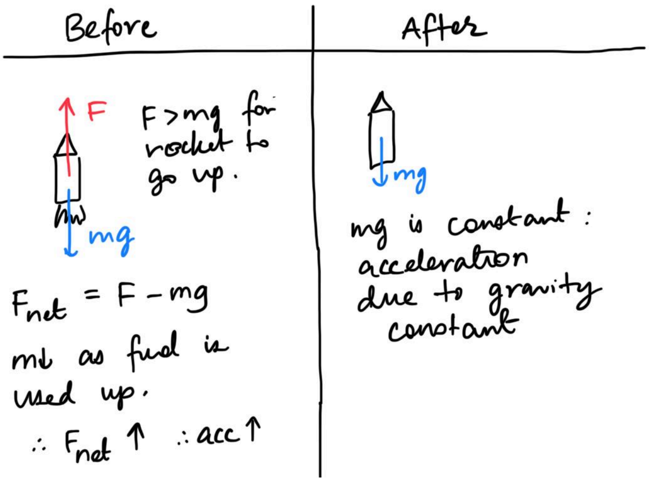
32.

A firework rocket is fired vertically upwards. The fuel burns and produces a constant upwards force on the rocket. After 5 seconds there is no fuel left. Air resistance is negligible.

What is the acceleration before and after 5 seconds?

	before 5 seconds	after 5 seconds
A	constant	constant
B	constant	zero
C	increasing	constant
D	increasing	zero

Ans: C



33.

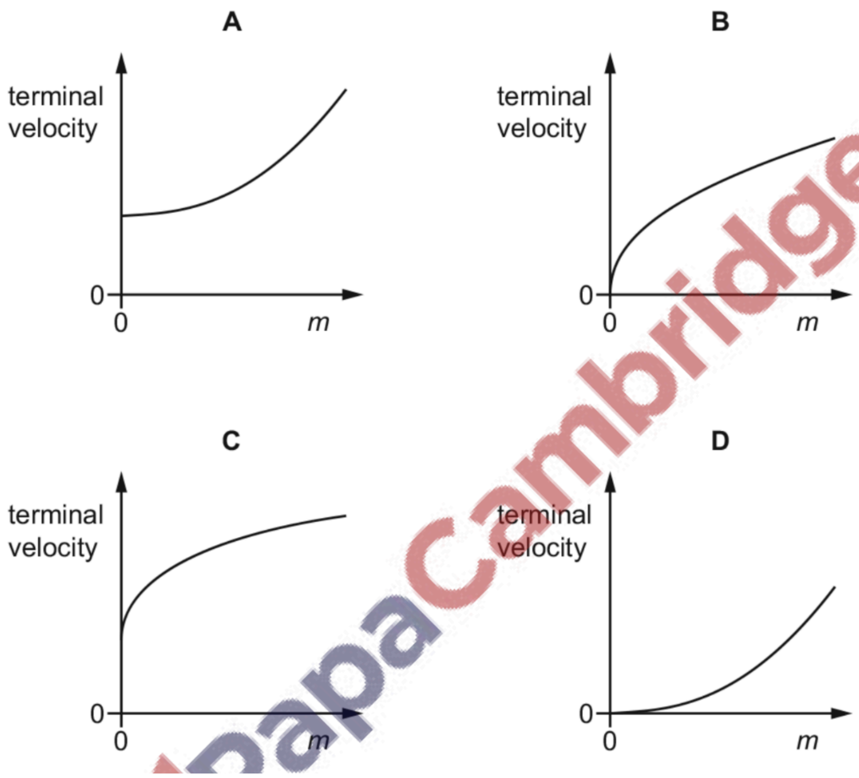
The resultant force F on a raindrop of mass m falling vertically with velocity v is given by the equation

$$F = mg - kv^2$$

where k is a constant and g is the acceleration of free fall.

The falling raindrop eventually reaches a constant (terminal) velocity.

Which graph shows the variation of the terminal velocity of the raindrop with mass m?



Ans: B

$$kv^2 = mg - F \Rightarrow v = \sqrt{\frac{mg-F}{k}}$$

at terminal v, $F = 0$

$$\therefore v = \sqrt{\frac{mg}{k}} \qquad v \propto \sqrt{m}$$

Note the shape of the sqrt graph!

34.

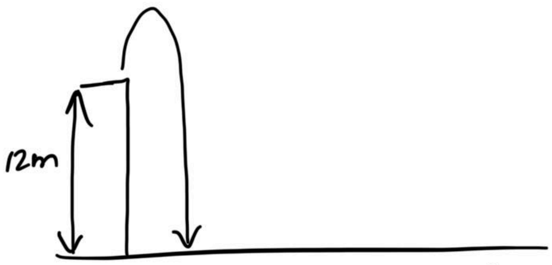
A stone is thrown vertically upwards from a point that is 12 m above the sea. It then falls into the sea below after 3.4 s.

Air resistance is negligible.

At which speed was the stone released when it was thrown?

A $3.5\,\text{m s}^{-1}$ **B** $6.6\,\text{m s}^{-1}$ **C** $13\,\text{m s}^{-1}$ **D** $20\,\text{m s}^{-1}$

Ans: C



If the ball was just dropped from 12m,

h: h↓, u↓, g↓ } all are downward

$$\therefore h = ut + \frac{1}{2}gt^2$$

But since ball moves up and then comes down,

u↑ h↓ g↓

if u is taken as +ve, h and g will be -ve.

$$\therefore -h = ut - \frac{1}{2}gt^2$$

$$-12 = 3.4u - \frac{1}{2}(9.81)(3.4)^2$$

$$\therefore u = 13\text{ m/s}$$

35.

In the absence of air resistance, a ball thrown horizontally from a tower with velocity *v*, will land after time *T* seconds.

If, however, air resistance is taken into account, which statement is correct?

A The ball lands with a horizontal velocity less than *v* after more than *T* seconds.

B The ball lands with a horizontal velocity less than *v* after *T* seconds.

C The ball lands with a horizontal velocity *v* after more than *T* seconds.

D The ball lands with a horizontal velocity *v* after *T* seconds.

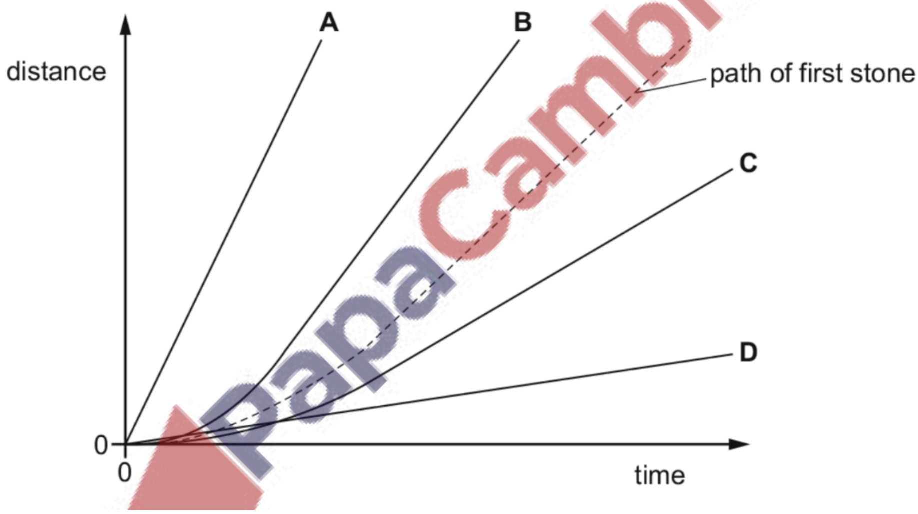
Ans: A

36.

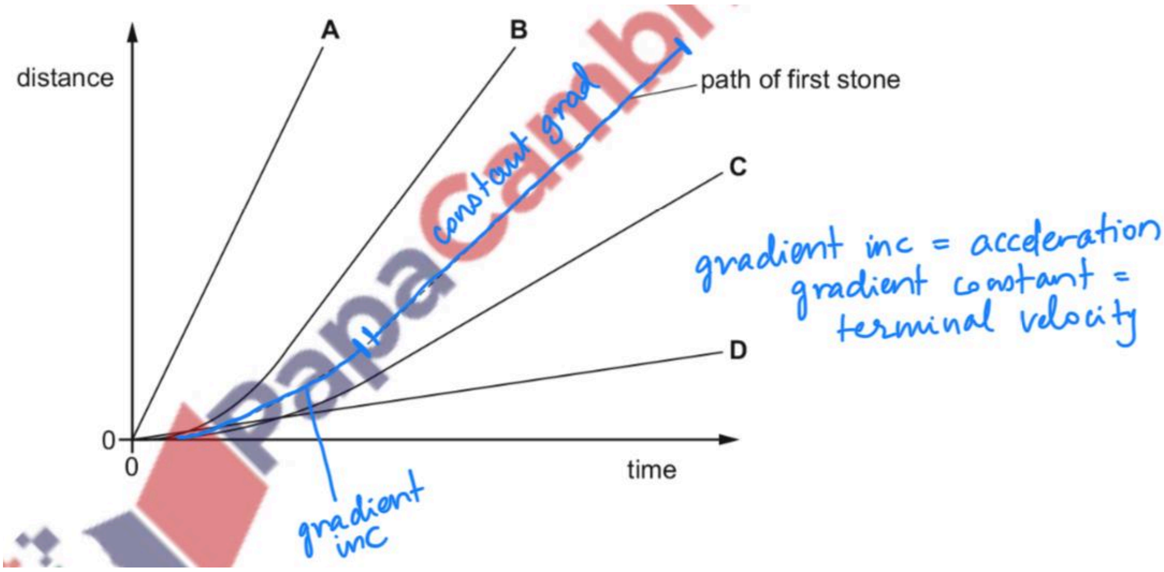
A stone is dropped from a tall building. Air resistance is significant. The variation of distance fallen with time is shown by the dashed line.

A second stone with the same dimensions but a smaller mass is dropped from the same building.

Which line represents the motion of the second stone?



Ans: C



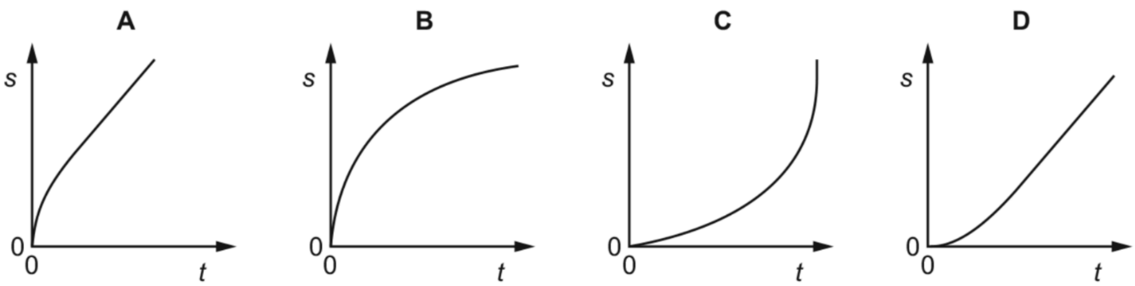
- Smaller mass = smaller weight
- Thus terminal velocity is smaller
- Cannot be D, since this is a straight line which suggests that stone is moving at constant speed throughout

Lighter objects	**Heavier objects**
Lower terminal velocity	Higher terminal velocity
Terminal velocity reached faster	Takes longer to reach terminal velocity

37.

A tennis ball is released from rest at time $t = 0$ and falls through air for a long time.

Which graph of its displacement s against time t best represents the motion of the ball?



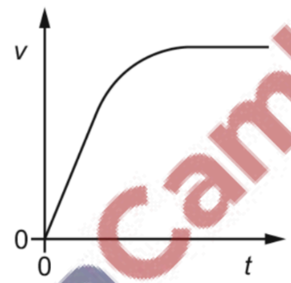
Ans: D

- Ball accelerates initially
- Acceleration decreases
- Eventually acceleration is 0 and travels at terminal velocity

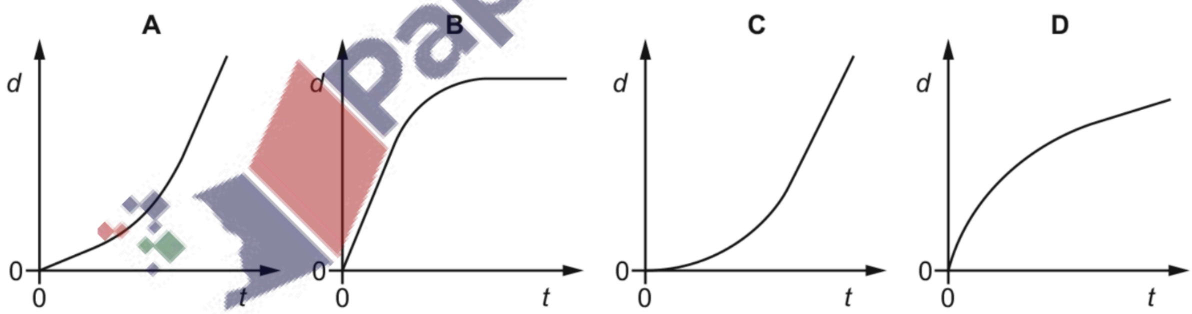
- Velocity = gradient of s–t graph, so eventually gradient becomes constant. This rules out B and C
- Initially, velocity is increasing due to acceleration, so gradient must also increase. This is shown in D (in A, gradient decreases and becomes constant, which means velocity is decreasing and then becoming constant)

38.

A sky-diver falls vertically from a helicopter and reaches constant (terminal) velocity. The graph shows the variation with time t of the speed v of the sky-diver.



Which graph shows the variation with time t of the distance d fallen by the sky-diver?



Ans: C

In A, 2 sections of graph show constant velocity, which is not true. Constant velocity is only at terminal velocity.

39.

The acceleration of free fall 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 a mass of 1.0 kg and a weight of 1.0 N.

What are the mass and the weight of the same body on the surface of planet Q?

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

Ans: B

40.

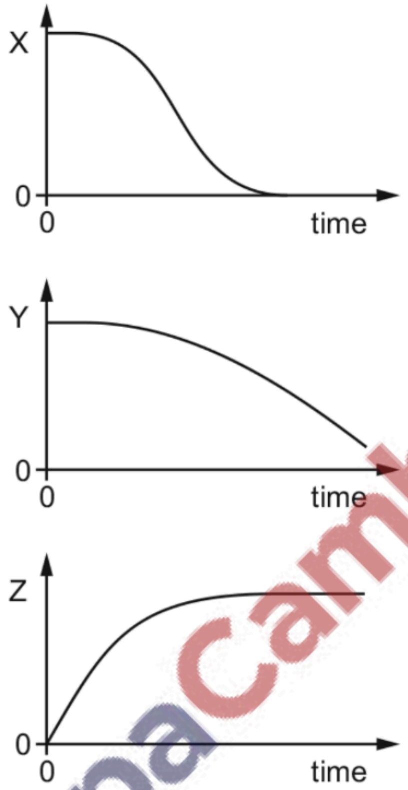
An object is dropped at time $t = 0$ from a high building. Air resistance is significant.

Three graphs are plotted against time.

the height of the object above the ground

the speed of the object

the magnitude of the resultant force on the object

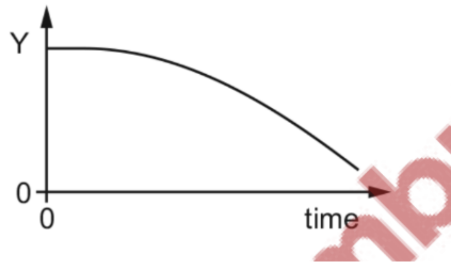


What are the quantities X, Y and Z?

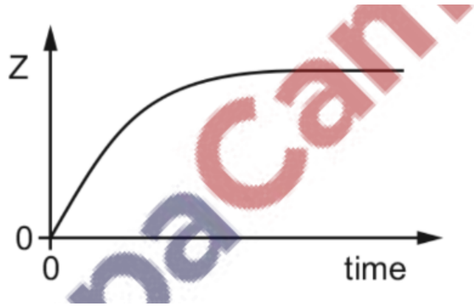
	height of the object above the ground	speed of the object	magnitude of the resultant force on the object
A	X	Y	Z
B	X	Z	Y
C	Y	Z	X
D	Z	Y	X

Ans: C

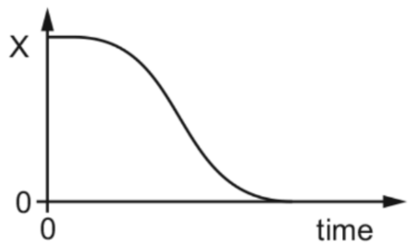
REMEMBER these graphs for freefall:



Height of object above ground vs time
(opposite to distance travelled by object vs time, because height from ground is decreasing as it falls).



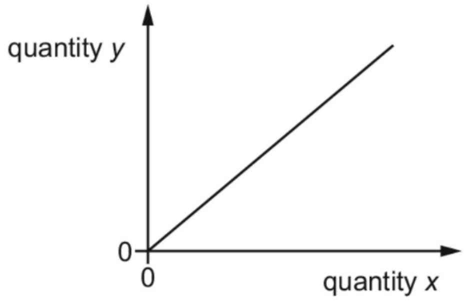
Speed of object vs time
Speed increases, and then becomes constant



Resultant force on object vs time
Resultant force is 0 at terminal velocity.

41.

The graph shows the variation of a quantity *y* with a quantity *x* for a body that is falling in air at constant (terminal) velocity in a uniform gravitational field.



Which quantities could *x* and *y* represent?

	x	*y*
A	air resistance	acceleration
B	loss of height	gain in kinetic energy
C	loss of potential energy	work done against air resistance
D	time	velocity

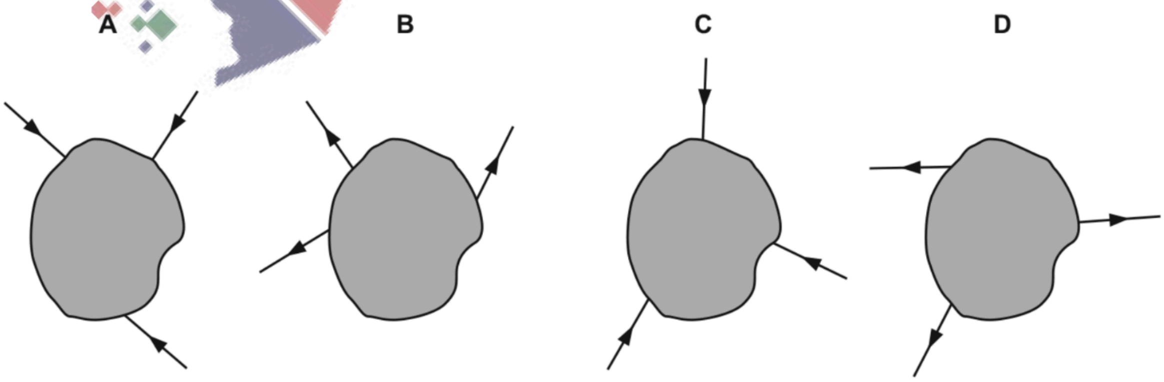
Ans: C

- Velocity = constant; acceleration = 0
- A is not possible, because acceleration is always 0; it cannot be increasing.
- B is not possible, because velocity is constant; gain in KE implies that v is increasing.
- For C: According to law of conservation of energy, loss of PE = W done against air resistance
- D is not possible, because velocity is constant; velocity cannot be increasing.

42.

Three coplanar forces act on an object in the directions shown.

In which diagram could the object be in equilibrium?

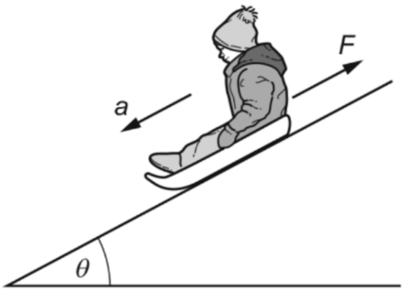


Ans: C

The lines, when extended, will meet at a point for C.

43.

A child on a sledge slides down a hill with acceleration a. The hill makes an angle θ with the horizontal.



The total mass of the child and the sledge is m. The acceleration of free fall is g.

What is the friction force F?

A $m(g\cos\theta - a)$

B $m(g\cos\theta + a)$

C $m(g\sin\theta - a)$

D $m(g\sin\theta + a)$

Ans: C

resultant force = downwards = ma
component of weight along slope = $mg\sin\theta$

Resultant force = component of weight − friction

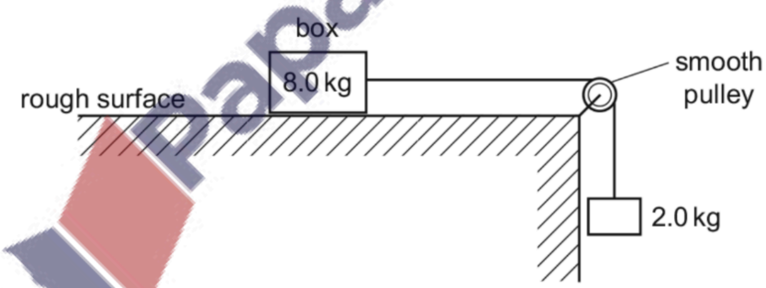
$ma = mg\sin\theta - F$

$\therefore F = mg\sin\theta - ma$

$= m(g\sin\theta - a)$

44.

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 frictional force of 6.0 N acts on it.

What is the acceleration of the box?

A $1.4\,\text{m s}^{-2}$ **B** $1.7\,\text{m s}^{-2}$ **C** $2.0\,\text{m s}^{-2}$ **D** $2.6\,\text{m s}^{-2}$

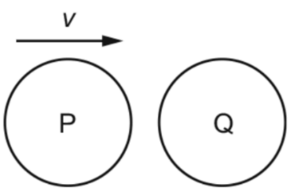
Ans: A

resultant $F = 2 \times 9.81 - 6 = 13.62\,N$

$F = ma \Rightarrow a = \dfrac{13.62}{8+2} = 1.4$

45.

The diagram shows a particle P, travelling at speed v, about to collide with a stationary particle Q of the same mass. The collision is perfectly elastic.



Which statement describes the motion of P and of Q immediately after the collision?

A P and Q both travel in the same direction with speed $\frac{1}{2}v$.

B P comes to rest and Q acquires speed v.

C P rebounds with speed $\frac{1}{2}v$ and Q acquires speed $\frac{1}{2}v$.

D P rebounds with speed v and Q remains stationary.

Ans: B

NOTE:
For perfectly elastic collision,

- Total momentum is conserved; initial momentum = final momentum

- Kinetic energy is conserved
- Relative speed of approach = relative speed of separation

For question 45:

$$\rightarrow mv_{Pi} + mv_{Qi} = mv_{Pf} + mv_{Qf}$$
$$mv = mv_P + mv_Q$$
$$v = v_P + v_Q$$

$$\rightarrow v - 0 = v_Q - v_P$$
$$v = v_Q - v_P$$
$$\cancel{v_Q} - v_P = v_P + \cancel{v_Q}$$
$$\therefore v_P = 0$$
$$v_Q = v$$

$\therefore$ P comes to rest and Q acquires speed v.

46.

A stationary toy gun fires a bullet.

Which statement about the bullet and the gun, immediately after firing, is **not** correct?

A The force exerted on the bullet by the gun has the same magnitude as the force exerted on the gun by the bullet.

B The force exerted on the bullet by the gun is in the opposite direction to the force exerted on the gun by the bullet.

C The gun and the bullet have the same magnitude of momentum.

D The kinetic energy of the gun must equal the kinetic energy of the bullet.

Ans: D

47.

A mass m_1 travelling with speed u_1 collides with a mass m_2 travelling with speed u_2 in the same direction. After the collision, mass m_1 has speed v_1 and mass m_2 has speed v_2 in the same direction. The collision is perfectly elastic.

before the collision　　　　after the collision

Which equation is **not** correct?

A $m_1u_1^2 - m_1v_1^2 = m_2v_2^2 - m_2u_2^2$

B $v_2 + u_2 = v_1 + u_1$

C $m_1(u_1 - v_1) = m_2(v_2 - u_2)$

D $m_1(u_1 - v_1)^2 = m_2(u_2 - v_2)^2$

Ans: D

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$
$$u_1 - u_2 = v_2 - v_1$$

48.

A ball of mass m, moving at a velocity v, collides with a stationary ball of mass $2m$.

The two balls stick together.

Which fraction of the initial kinetic energy is lost on impact?

A $\frac{1}{9}$　　**B** $\frac{1}{3}$　　**C** $\frac{2}{3}$　　**D** $\frac{8}{9}$

Ans: C

$$mv = 3mv_f$$
$$v_f = \frac{mv}{3m} = \frac{1}{3}v$$

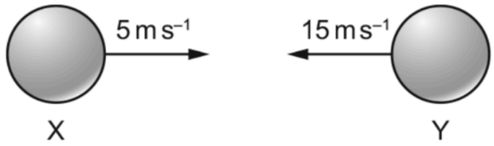
$$KE_i = \frac{1}{2}mv^2$$
$$KE_f = \frac{1}{2} \times \cancel{3}m \times \frac{1}{\cancel{9}\,3}v^2 = \frac{1}{6}mv^2$$
$$KE\ lost = \frac{1}{2} - \frac{1}{6} = \frac{1}{3}$$

However, you need <u>fraction</u> of initial KE lost :

$$\frac{1}{3} \div \frac{1}{2} = \frac{2}{3}$$

49.

Two balls X and Y are moving towards each other with speeds of $5\,m\,s^{-1}$ and $15\,m\,s^{-1}$ respectively.



They make a perfectly elastic head-on collision and ball Y moves to the right with a speed of $7\,m\,s^{-1}$.

What is the speed and direction of ball X after the collision?

A $3\,m\,s^{-1}$ to the left

B $13\,m\,s^{-1}$ to the left

C $3\,m\,s^{-1}$ to the right

D $13\,m\,s^{-1}$ to the right

Ans: B

- Since elastic, ball X moves towards left
- Relative velocity of approach = 5 + 15 = 20
- Relative velocity of separation = 20
- Velocity of X = 20 - 7 = 13

50.

A helium atom of mass *m* collides normally with a wall. The atom arrives at the wall with speed *v* and then rebounds along its original path. Assume that the collision is perfectly elastic.

What is the change in the momentum of the atom during its collision?

A zero **B** 0.5*mv* **C** *mv* **D** 2*mv*

Ans: D

Final momentum = initial momentum = mv

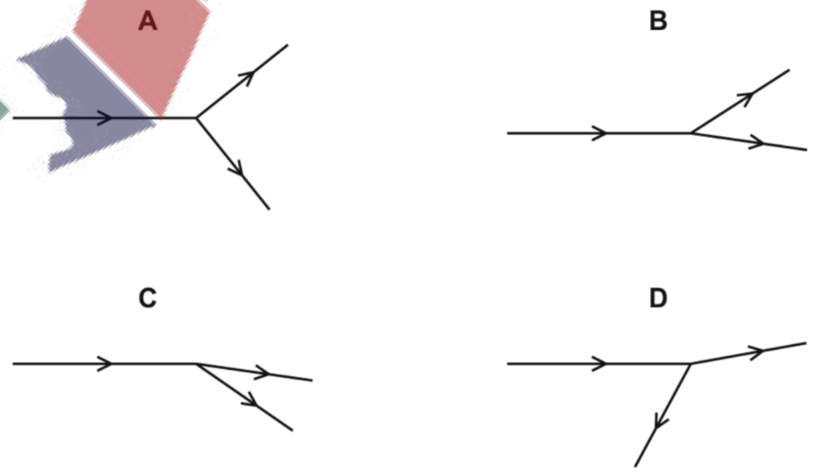
Change in momentum = final + initial (due to direction change) = 2mv

51.

A nucleus collides with a stationary nucleus in a vacuum. The diagrams show the paths of the nuclei before and after the collision.

No other particles are involved in the collision.

Which diagram is **not** possible?

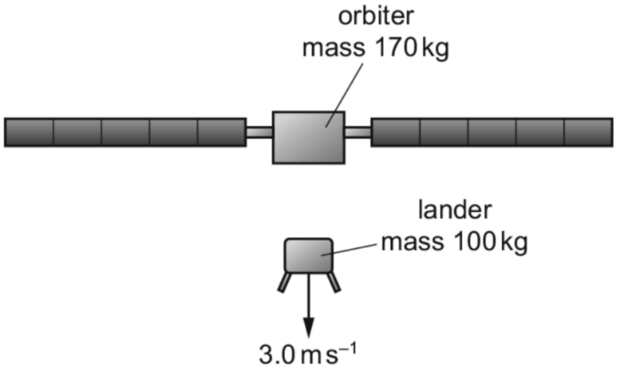


Ans: C

- Total momentum in x axis should be constant AND total momentum in y axis should be constant.
- In A, B and D there is momentum in upward direction and downward direction, which cancel out.
- In C, it is only in downward direction, which does not cancel out.

52.

The space probe Rosetta was designed to investigate a comet. The probe consisted of an orbiter and a lander. The orbiter had a mass of 170 kg and the lander had a mass of 100 kg. When the two parts separated, the lander was pushed towards the surface of the comet so that its change in velocity towards the comet was $3.0\,m\,s^{-1}$.



Assume that the orbiter and lander were an isolated system.

The orbiter moved away from the comet during the separation.

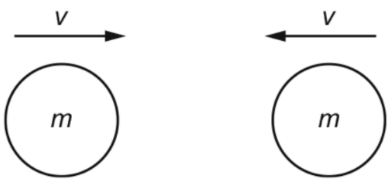
What was the change in the speed of the orbiter?

A $1.8\,m\,s^{-1}$ **B** $2.3\,m\,s^{-1}$ **C** $3.0\,m\,s^{-1}$ **D** $5.1\,m\,s^{-1}$

Ans: A

53.

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 $2mv$.

Ans: B

- The initial and final momentum in this case is 0: mv – mv = 0

54.

An elastic collision occurs between two bodies X and Y. The mass of body X is m and the mass of body Y is $4m$. Body X travels at speed v before the collision and speed $\frac{3v}{5}$ in the opposite direction after the collision. Body Y is stationary before the collision.

What is the kinetic energy of body Y after the collision?

A $\frac{8}{10}mv^2$ **B** $\frac{34}{50}mv^2$ **C** $\frac{16}{50}mv^2$ **D** $\frac{1}{5}mv^2$

Ans: C

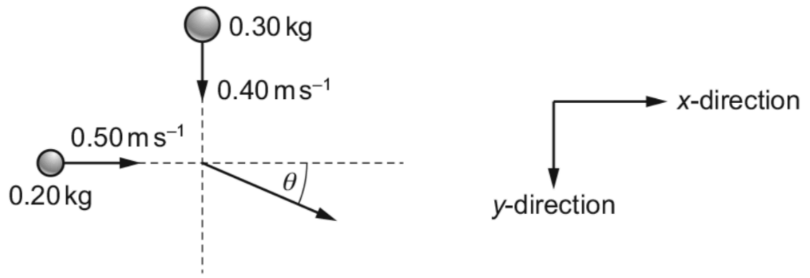
$$v - 0 = \frac{3v}{5} + x \Rightarrow x = v - \frac{3v}{5} = \frac{2v}{5}$$

$$KE = \frac{1}{2}(4m)\left(\frac{2v}{5}\right)^2 = \frac{8}{25}mv^2 = \frac{16}{50}mv^2$$

55.

A ball of mass 0.20 kg, travelling in the x-direction at a speed of $0.50\,m\,s^{-1}$, collides with a ball of mass 0.30 kg travelling in the y-direction at a speed of $0.40\,m\,s^{-1}$.

The two balls stick together after the collision, travelling at an angle θ to the x-direction.



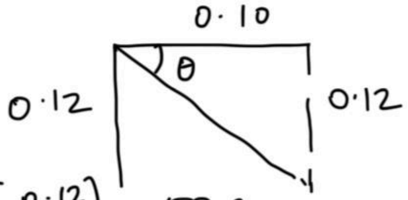
What is the value of θ?

A 39° **B** 40° **C** 50° **D** 51°

Ans: C

$P_x = 0.2 \times 0.5 = 0.10$

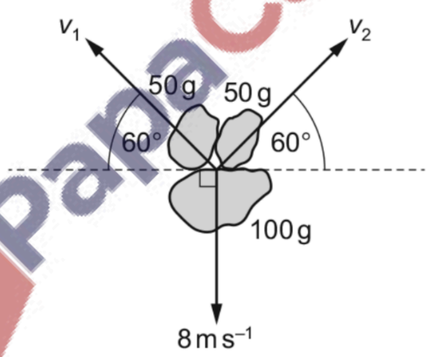
$P_y = 0.3 \times 0.4 = 0.12$



$\tan^{-1}\left(\frac{0.12}{0.1}\right) = 50.2$

56.

A stationary firework explodes into three pieces. The masses and the velocities of the three pieces immediately after the explosion are shown.



What are speed v_1 and speed v_2?

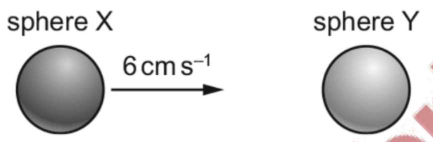
	v_1 / m s^{-1}	v_2 / m s^{-1}
A	4.0	4.0
B	9.2	9.2
C	14	14
D	16	16

Ans: B

NOTE: in inelastic collision, kinetic energy is not conserved, but total energy is conserved!

57.

Two solid spheres form an isolated system. Sphere X moves with speed $6\,cm\,s^{-1}$ in a straight line directly towards a stationary sphere Y, as shown.



The spheres have a perfectly elastic collision. After the collision, sphere X moves with speed $2\,cm\,s^{-1}$ in the same direction as before the collision.

What is the speed of sphere Y?

A $2\,cm\,s^{-1}$ **B** $4\,cm\,s^{-1}$ **C** $6\,cm\,s^{-1}$ **D** $8\,cm\,s^{-1}$

Ans: D

6 - 0 = x - 2

x = 8

58.

A slow vehicle and a fast vehicle travel towards each other in a straight line and then collide.

Which outcome is **never** possible, regardless of the masses of the vehicles?

A Both vehicles stop.

B Only one vehicle stops.

C The fast vehicle's speed increases.

D The slow vehicle's speed increases.

Ans: C

59.

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** $\frac{5v}{4}$

Ans: A

$3mv - 2mv = 4mx$

$mv = 4mx$

$\Rightarrow x = \frac{mv}{4m} = \frac{v}{4}$

They are moving in <u>opposite</u> directions, so total momentum = difference of the 2!

60.

A ball of mass m travelling at velocity u collides with a stationary ball of mass M. After collision the two balls travel at velocities v and V respectively, in the directions shown.

A student writes three equations relating to the collision.

Which row in the table indicates the correct and incorrect equations?

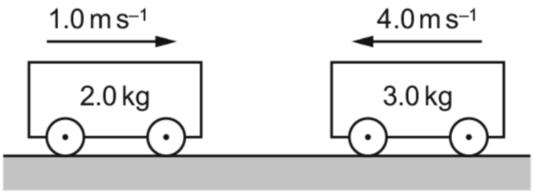
	$mu = MV + mv$	$mv \sin 30° = MV \sin 40°$	$mu = mv \cos 30° + MV \cos 40°$
A	correct	correct	correct
B	incorrect	correct	incorrect
C	correct	incorrect	incorrect
D	incorrect	correct	correct

Ans: D

- Initially there is no momentum in y direction, so y components of final momenta should cancel out.
- Initially there is only momentum in x direction, so final momentum = sum of x components of momenta.

61.

Two frictionless trolleys are moving towards each other along the same horizontal straight line. Their masses and velocities are shown.



The trolleys collide and stick together.

What is the velocity of the trolleys after the collision?

A $2.0\,\mathrm{m\,s^{-1}}$ to the left

B $2.0\,\mathrm{m\,s^{-1}}$ to the right

C $2.8\,\mathrm{m\,s^{-1}}$ to the left

D $2.8\,\mathrm{m\,s^{-1}}$ to the right

Ans: A

62.

A molecule of mass *m* travelling at speed *v* hits a wall in a direction perpendicular to the wall. The collision is elastic.

What are the changes in the momentum and in the kinetic energy of the molecule caused by the collision?

	change in momentum	change in kinetic energy
A	0	0
B	0	mv^2
C	$2mv$	0
D	mv^2	0

Ans: C

63.

Trolley X, moving along a horizontal frictionless track, collides with a stationary trolley Y. The two trolleys become attached and move off together.

Which statement about this interaction is correct?

A Some of the kinetic energy of trolley X is changed to momentum in the collision.

B Some of the momentum of trolley X is changed to kinetic energy in the collision.

C Trolley X loses some of its momentum as heat in the collision.

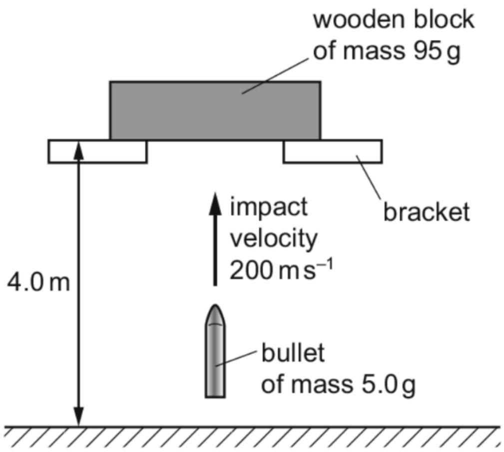
D Trolley X shares its momentum with trolley Y but some of its kinetic energy is lost.

Ans: D

NOTE: in an inelastic collision, KE is not conserved. The KE is always lost. It never increases!

64.

A wooden block is freely supported on brackets at a height of 4.0 m above the ground, as shown.



A bullet of mass 5.0 g is shot vertically upwards into the wooden block of mass 95 g. It embeds itself in the block. The impact causes the block to rise above its supporting brackets.

The bullet hits the block with a velocity of 200 m s^{-1}. How far above the ground will the block be at the maximum height of its path?

A 5.1 m **B** 5.6 m **C** 9.1 m **D** 9.6 m

Ans: C

p of bullet $= 200 \times \frac{5}{1000} = 1 \, kgm/s$

v of block + bullet upwards $= \dfrac{1}{\frac{95+5}{1000}} = 10 \, m/s$

$v^2 = u^2 + 2as$ $\quad v = 0$, $u = 10$

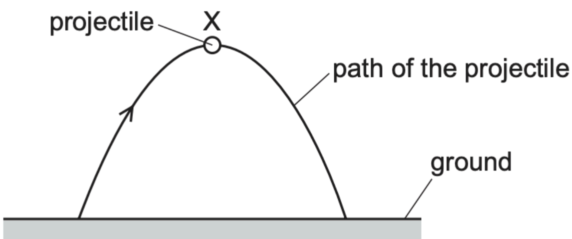
$\Rightarrow 0 = 10^2 + 2(-9.81)(s)$

$\Rightarrow s = \dfrac{-10^2}{2 \times -9.81} = 5.1$

h above ground $= 5.1 + 4 = 9.1$

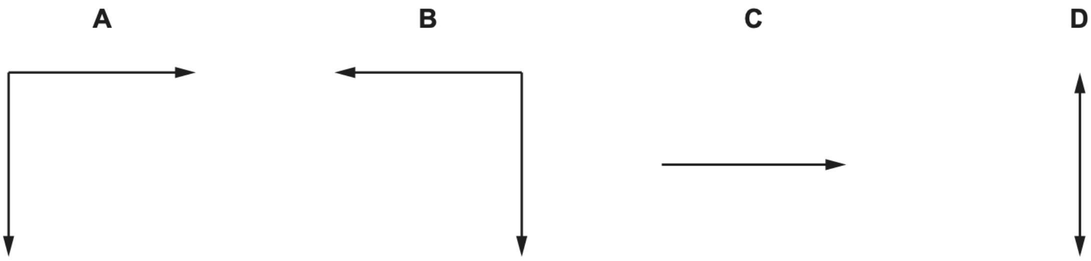
65.

A projectile is launched at an angle above horizontal ground and travels through the air.



The projectile reaches its maximum height at position X. Assume that no upthrust acts on the projectile.

Which diagram shows the **directions** of the force or forces acting on the projectile at position X?



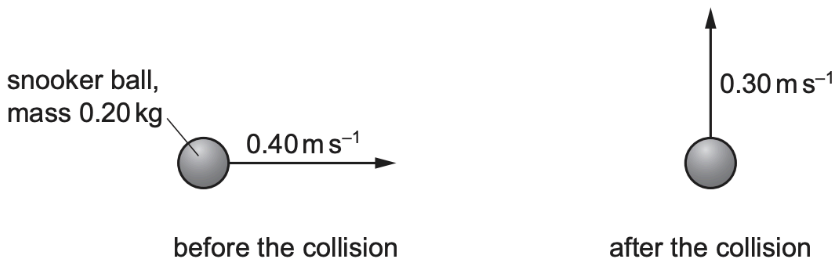
Ans: B

- Weight acts downward.
- Travels through air: thus there is air resistance.

- It travels towards the right through the air, so air resistance will oppose its motion, acting towards the left.

66.

A snooker ball of mass 0.20 kg has a collision so that its direction of movement changes by an angle of 90°, as shown.



The ball has a speed of $0.40\,\text{m s}^{-1}$ before the collision and a speed of $0.30\,\text{m s}^{-1}$ after the collision.

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

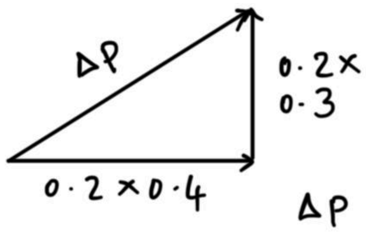
A $0.020\,\text{kg m s}^{-1}$

B $0.10\,\text{kg m s}^{-1}$

C $0.14\,\text{kg m s}^{-1}$

D $0.50\,\text{kg m s}^{-1}$

Ans: B



$$\Delta P = \sqrt{(0.2\times0.4)^2 + (0.2\times0.3)^2}$$
$$= 0.1$$

67.

A ship of mass 8.4×10^7 kg is approaching a harbour with speed $16.4\,\text{m s}^{-1}$. By using reverse thrust it can maintain a constant total stopping force of 920 000 N.

How long will it take to stop?

A 15 seconds

B 150 seconds

C 25 minutes

D 250 minutes

Ans: C

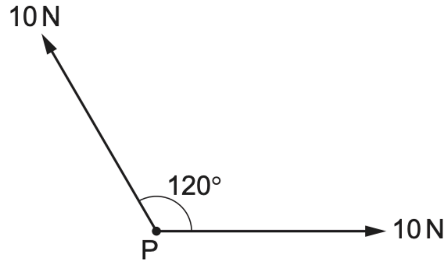
$$F = ma$$

$$920000 = 8.4 \times 10^7 \times \left(\frac{0 - 16.4}{t}\right)$$

$$t = \left(\frac{8.4 \times 10^7 \times -16.4}{920000}\right) \div 60 = 25$$

68.

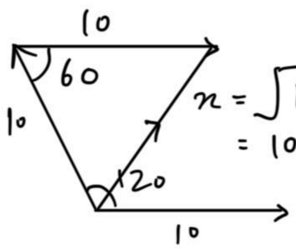
Two forces, each of 10 N, act at a point P, as shown. The angle between the directions of the forces is 120°.



What is the magnitude of the resultant force?

A 5 N **B** 10 N **C** 17 N **D** 20 N

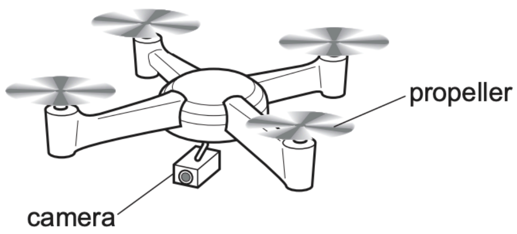
Ans: B



$$x = \sqrt{10^2 + 10^2 - 2 \times 10 \times 10 \times \cos 60}$$
$$= 10N$$

69.

A camera drone of mass 1.20 kg hovers at a fixed point above the ground. The drone has four propellers.



In a time of 1.00 s, each propeller pushes a mass of 0.400 kg of air vertically downwards.

Assume that the air above the propellers is stationary.

What is the speed of the air leaving each propeller?

A 0.750 $m s^{-1}$ **B** 3.00 $m s^{-1}$ **C** 7.36 $m s^{-1}$ **D** 29.4 $m s^{-1}$

Ans: C

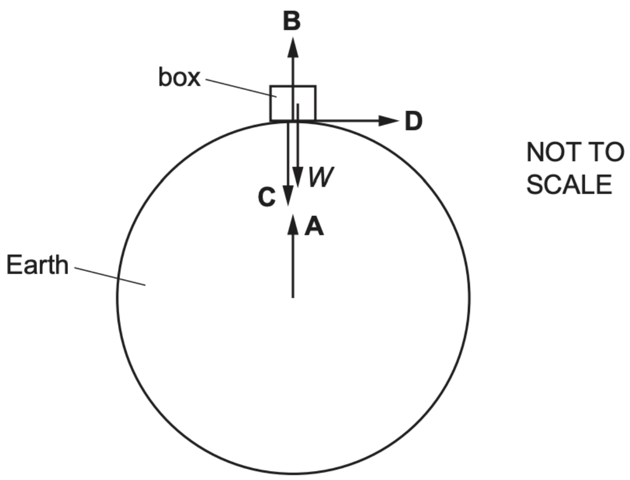
- Weight = 1.2 x 9.81 = 11.772
- Since it is at a fixed point, upward force = downward force
- Downward force on each propeller = 11.772 / 4 = 2.943
- F = $\Delta p/\Delta t$
- Upward force acting on each propeller = $\Delta mv/\Delta t$ = 2.943
- v = (2.943 x 1) / 0.4 = 7.36 m/s

70.

A box rests on the Earth, as shown.

Newton's third law describes how forces of the same type act in pairs. One of the forces of a pair is the weight *W* of the box.

Which arrow represents the other force of this pair?



Ans: A

- W = gravitational force = exerted by earth downwards on box
- Pair force = box pulling upwards on earth
- NOTE: normal reaction force acts on the box, not by the box!!

71.

An initially stationary firework explodes and splits into two fragments that move horizontally in opposite directions.

The total kinetic energy transferred to the fragments by the explosion is *E*.

One fragment has mass *m* and the other one has mass 2*m*.

What is the speed of the fragment of mass *m* immediately after the explosion?

A $\sqrt{\frac{E}{m}}$ **B** $\sqrt{\frac{2E}{m}}$ **C** $\sqrt{\frac{2E}{3m}}$ **D** $\sqrt{\frac{4E}{3m}}$

Ans: D

m | 2m
2v | v } since total momentum = 0

$\frac{1}{2}m(2v)^2 + \frac{1}{2}(2m)v^2 = E = 2mv^2 + mv^2 = 3mv^2$

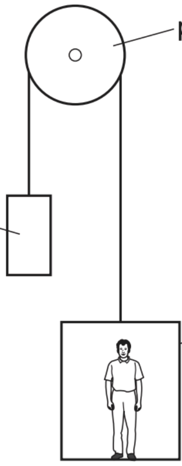
$v = \sqrt{\frac{E}{3m}}$

mass m = 2v

$\therefore 2v = 2\sqrt{\frac{E}{3m}} = \sqrt{\frac{4E}{3m}}$

72.

A lift (elevator) consists of a passenger car supported by a cable that runs over a light, frictionless pulley to a counterbalance. The counterbalance falls as the passenger car rises.



Some masses are shown in the table.

	mass / kg
passenger car	520
counterbalance	640
passenger	80

What is the magnitude of the acceleration of the car when carrying just one passenger and when the pulley is free to rotate?

A $0.032\,m\,s^{-2}$ **B** $0.32\,m\,s^{-2}$ **C** $0.61\,m\,s^{-2}$ **D** $0.65\,m\,s^{-2}$

Ans: B

- Resultant F = (640 x 9.81) – 9.81(520 + 80) = 392.4
- Acceleration = 392.4/(520+80+640) = 0.316

73.

A ball collides with a wall. Before the collision, the ball moves with velocity $8\,m\,s^{-1}$ to the right. After the collision, it moves with velocity $3\,m\,s^{-1}$ to the left.

What is the change in velocity of the ball during the collision?

A $5\,m\,s^{-1}$ to the left

B $5\,m\,s^{-1}$ to the right

C $11\,m\,s^{-1}$ to the left

D $11\,m\,s^{-1}$ to the right

Ans: C

- Initial = +8; final = -3
- Change = -3-8 = -11

- -ve sign represents left, thus 11 to left