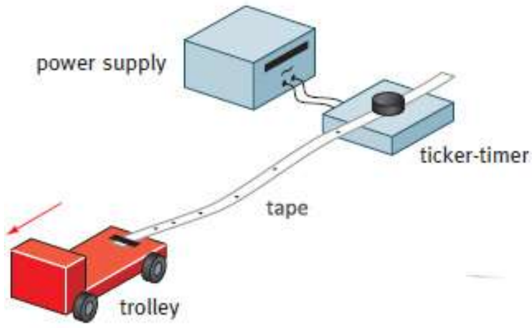
Unit 3: Motion & Forces Tutorial Questions

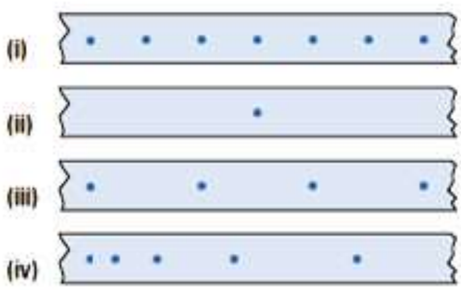
Solutions to Questions 8 and 18 provided.

Definitions of Displacement, Speed, Velocity, Acceleration

1 (a) Can a body have zero velocity and still be accelerating?
(b) Can a body move with a constant speed and still be accelerating?
(c) Can the direction of the velocity of a body change when its acceleration is constant?
(d) Can a body's speed be increasing as its acceleration decreases?

2 A trolley is attached to a ticker tape and a timer. As the trolley moves, the **timer** makes a series of dots on the **tape** at regular time intervals, usually 1/50 s (i.e. 0.02 s). Figs. (i) to (iv) shows four ticker-tapes.





Describe the motion of the trolley which produced them.

3 A stone is dropped off a cliff. When the stone has fallen 4.0 m, a second stone is dropped. Neglecting air resistance as the two stones continue to fall, which of the following statements is/are true?

A The velocity of the first stone increases faster than the velocity of the second.
B The velocities of both stones increases at the same rate.
C The separation of the two stones remains constant throughout the fall.
D The separation of the two stones increases as they continue to fall.

Graphical Representations of Motion

4 This question is about the motion of a Formula 1 racing car.

The graph below shows the velocity of a racing car in the first 4 seconds of a race as it accelerates and slows down to go around the first bend.

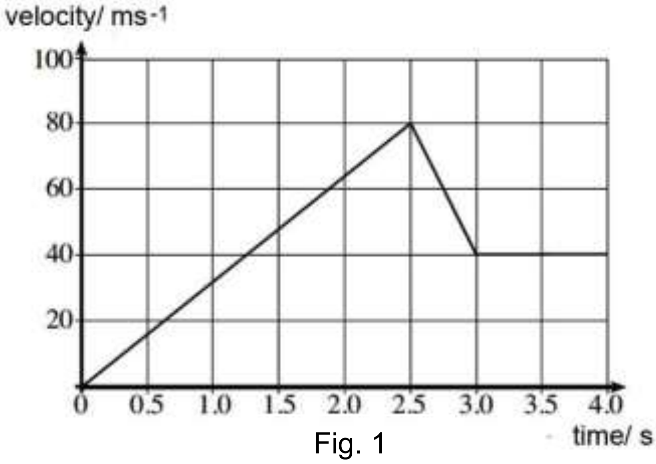
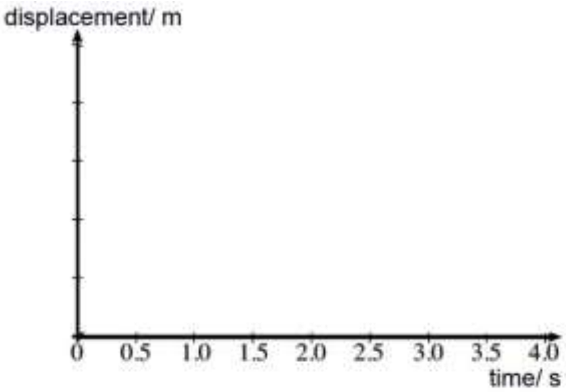


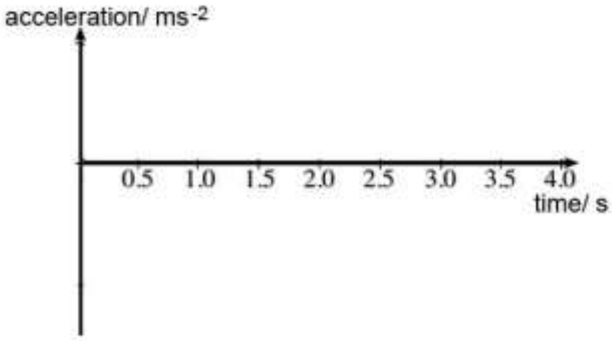
Fig. 1

(a) Using information from Fig. 1, determine
 [i] the acceleration from t = 0 to t = 2.5 s,
 [ii] the acceleration from t = 2.5 to t = 3.0 s,
 [iii] the displacement from t = 0 to t = 2.5 s,
 [iv] the displacement from t = 2.5 to t = 3.0 s,
 [v] the displacement from t = 3.0 to t = 4.0 s

(b) Calculate the average velocity of the car during the first 4 seconds.

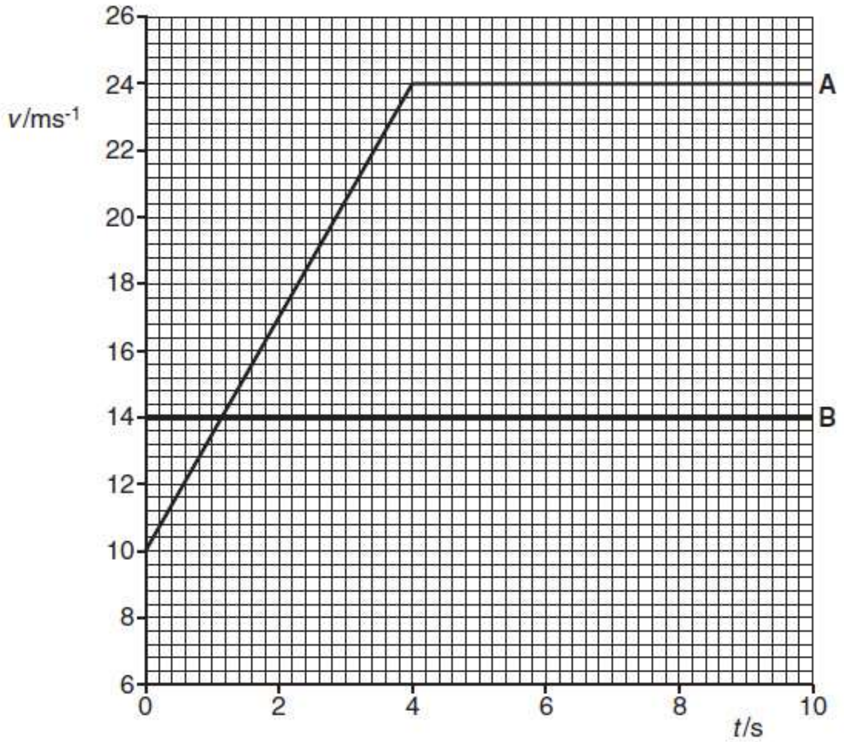
(c) Sketch the corresponding acceleration-time graph and displacement-time graph in the figures below.





[32 m s^{-2}, -80 m s^{-2}, 100 m, 30 m, 40 m, 42.5 ms^{-1}]

5 Figure shows graphs of velocity v against time t for two cars A and B travelling along a straight level road in the same direction.



At time t = 0, both cars are side-by-side.

(a) Describe the motion of car A from t = 0 to t =10 s.

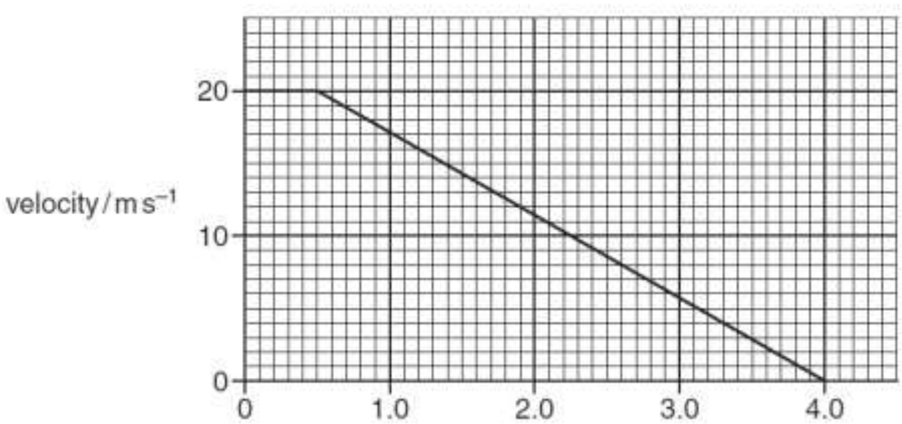
(b) State the time at which both cars have the same velocity.

(c) Determine the time at which car A overtakes car B. Explain your method.

[1.2 s, 2.4 s]

6 STOPPING DISTANCE PROBLEM

A driver travelling in a car on a straight level road sees an obstacle in the road ahead and immediately applies the brakes until the car stops. The initial speed of the car is 20 m s^{-1}. Figure shows the velocity - time graph of the car.



The thinking distance is defined as the distance travelled by the car during the driver's reaction time and the braking distance is the distance in which the car stops after the brakes have been applied.

(a) Use the graph to determine

(i) the reaction time of the driver,

(ii) the thinking distance,

(iii) the braking distance,

(iv) the magnitude of the deceleration of the car.

(b) For the same initial speed of the car, what would be the effects on the thinking distance and the braking distance if

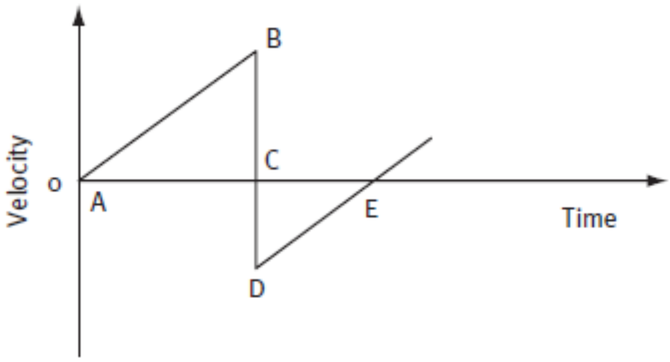
(i) the road is wet?

(ii) the driver is not fully alert?

[0.50 s, 10 m, 35 m, 5.7 m s^{-2}]

7 BOUNCING BALL PROBLEM

A ball is released from rest above a ground.
The ball is released at A and strikes the ground at B. The ball leaves the ground at D and reaches its maximum height at E. The effects of air resistance can be neglected.



(a) Explain

(i) why the velocity at D is negative,

(ii) why the gradient of the line AB is the same as the gradient of line DE,

(iii) why the speeds before and after impact with the ground are unequal,

(iv) why the area of triangle ABC is greater than the area of triangle CDE.

(b) Sketch the corresponding displacement-time and acceleration-time graphs.

Kinematics Equations

8 A metal ball is dropped from rest at a height above a bed of sand. It hits the sand bed one second later and makes an impression of maximum depth 8.0 mm in the sand.

(a) Neglecting air resistance, what is the speed of the ball just before hitting the ground?

(b) What is the average deceleration of the ball inside the sand?

[9.81 m s^{-1}, 6.0 × 10^3 m s^{-2}]

Ans: (a) $v = u + at$

$\downarrow^{+}$ $v = 0 + 9.81(1) = 9.81 m s^{-1}$

(b) $v^2 = u^2 + 2as$

$\downarrow^{+}$ $0 = 9.81^2 + 2a\left(8.0 \times 10^{-3}\right)$

$\Rightarrow a = -6.0 \times 10^3 \, m s^{-2}$

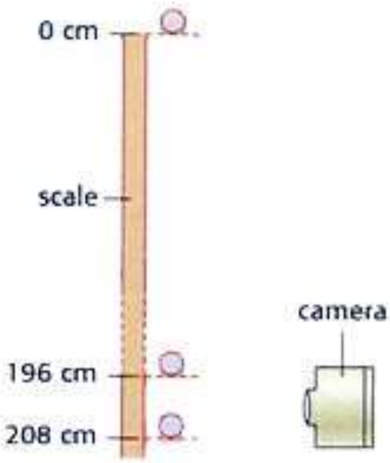
$Thus\, deceleration = 6.0 \times 10^3 \, m s^{-2}$

9 (a) The distance *s* moved by an object in time *t* may be given by the expression

$$s = ½ at^2$$

where *a* is the acceleration of the object.
State <u>two</u> conditions for this expression to apply to the motion of the object.

(a) In order to determine the shutter speed of a camera, a metal ball is held at rest at the zero mark of a vertical scale.
The ball is released. The shutter of a camera is opened as the ball falls



The photograph of the ball shows that the shutter opened as the ball reached the 196 cm mark and closed as it reached the 208 cm mark. Air resistance is negligible and the acceleration of free fall is 9.81 ms-^{2}.

(i) Calculate the time for the ball to fall from rest to the 196 cm mark.

(ii) Determine the time for which the shutter was open.

[0.20 s, 0.006 s, 20 ms^{-1}]

10 A balloonist drops a sandbag from a hot-air balloon that is rising at a constant velocity of 3.25 m s^{-1}.
It takes 8.75 s for the sandbag to reach the ground.

Determine

(a) the height of the balloon when the sandbag is dropped,

(b) the velocity with which the sandbag hits the ground.

(c) the path of the sandbag as seen by an observer on the ground.

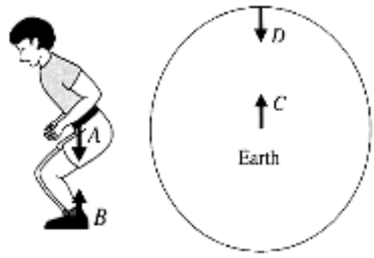
[347 m, 82.6 m s^{-1}]

Newton's Laws

11 Discuss whether the following situations are possible.

(a) An object with a net force is moving at constant speed.
(b) An object is at rest, therefore we conclude there is no force acting on it.
(c) An object is moving in one direction while the net force is in another direction.

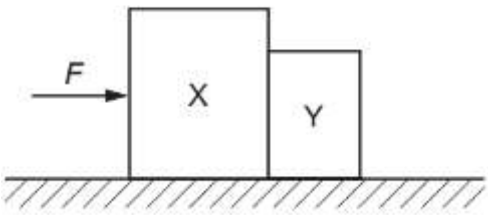
12 Check your understanding of Newton's Laws. A child is crouching at rest on the ground.
Opposite are the free-body force diagrams for the child and the Earth.
Complete the table describing forces A, B and C.



Force	Description of force	Body which exerts force	Body the force acts on
A	Gravitational	Earth	Child
B			
C			

All the forces A, B, C and D are of equal magnitude.
(a) Why are forces A and B equal in magnitude?
(b) Why must forces B and D be equal in magnitude?
(c) The child now jumps vertically upwards. With reference to the forces shown, explain what he must do to jump, and why he moves upwards.

13 A horizontal force *F* is applied to a block X which is in contact with a separate block Y as shown.



The blocks remain in contact as they accelerate along a horizontal frictionless surface. Air resistance is negligible. X has a greater mass than Y.

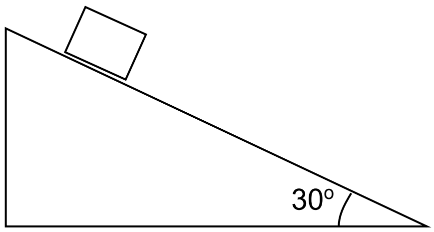
Which statement is correct?

A The acceleration of X is equal to force *F* divided by the mass of X.
B The force that X exerts on Y is equal to *F*.
C The force that X exerts on Y is less than *F*.
D The force that X exerts on Y is less than the force that Y exerts on X.

14 A spring balance carrying a mass of 20.0 kg in a lift registered 250 N. What was the acceleration of the lift? Calculate the balance readings during (a) free fall, (b) movement at constant velocity. [2.69 m s^{-2}, 0 N, 196 N]

15 A light spring has a mass of 0.20 kg suspended from its lower end. A second mass of 0.10 kg is suspended from the first by a thread. The arrangement is allowed to come into static equilibrium and then the thread is burned through. At this instant, what is the upward acceleration of the 0.20 kg mass? (Take g = 10 m s^{-2}.) [5.0 m s^{-2}]

16 A block of mass 2.0 kg moves down along a plane inclined at 30° to the horizontal. The frictional force between the block and the plane is 5.0 N.

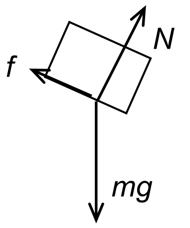


(a) Draw a free body diagram showing the forces acting on the block.

(b) Find the acceleration of the block along the inclined plane.

(c) If a force of 25 N pulls the block up the plane, what will be the acceleration of the block along the plane? [2.4 m s^{-2}, 5.1 m s^{-2}]

(a)



(b) ↘+ $mg \sin\theta - f = ma$

$2.0\,(9.81) \sin 30° - 5.0 = 2.0a$

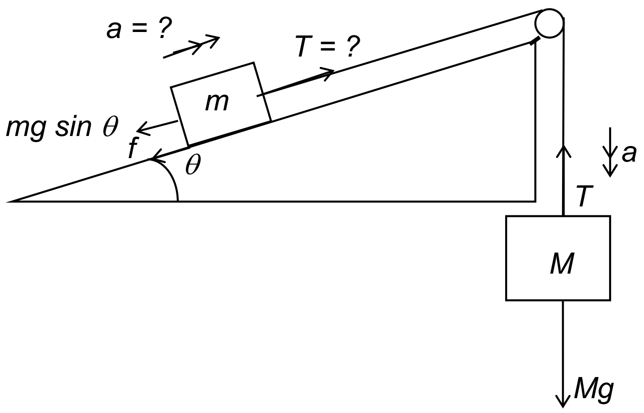
$a = 2.4\ ms^{-2}$

(c) ↖+ $F - f - mg \sin\theta = ma'$

$25 - 5.0 - 2.0\,(9.81) \sin 30° = 2.0a'$

$a' = 5.1\ ms^{-2}$

17 Two objects of masses 10 kg and 5 kg are connected by a light inextensible string that passes over a light frictionless pulley. The 5 kg object lies on a smooth incline of angle 30°. Find the acceleration of the two objects and the tension in the string.

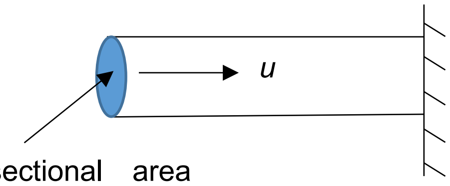


Force due to changing mass

18 A steady wind of 50 m s^{-1} blows against a rigid wall, which is in a plane perpendicular to the wind direction. Estimate the pressure exerted by the wind on the wall. Density of air is 1.25 kg m^{-3}. State any assumption you made in your calculations. [3.13 kN m^{-2}]

Assume no rebound, final velocity of wind = 0

Consider a cylindrical column of wind of cross-sectional area *A* and speed *u* hitting the wall, as shown :



In 1 s, the volume of air hitting the wall $V = A\,u$

and the mass of air hitting wall, $m = \rho A u$

By Newton's 2nd Law,

Force by wall on air, $F_{wa} =$ rate of change of momentum of air

$$= m\frac{\Delta v}{t} = (\rho A u)\times\frac{0-u}{1}$$

$$= -\rho A u^2$$

By Newton's 3rd Law, $F_{aw} = F_{wa} = u^2 \rho A$

$$P = \frac{F_{aw}}{A} = v^2\rho = 50^2(1.25) = 3.13\text{ kNm}^{-2}$$