Tutorial 3: Dynamics

Self Review Questions

Part 1: Newton's Laws, Inertia, Force, Momentum, Impulse

S1 **N86/I/2**

A mass hangs by a string from the ceiling of a carriage in a train and is just above a certain mark on the floor when the train is at rest. When the train is moving forward with constant velocity, the mass

A is behind the mark, so that the string is along the resultant of the forces due to the motion of the train and gravity.

B is behind the mark in a position in which the horizontal force exerted by the train on the mass is balanced by the horizontal component of the tension in the string.

C remains over the mark because the force due to the motion of the train is balanced by the reaction of the string on the support.

D remains over the mark because the motion of the train produces no additional force on the mass.

S2 **N01/P1/Q4**

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.

S3 When a force of 4 N acts on a mass of 2 kg for a time of 2 s, what is the rate of change of momentum?

A 1 kg m s^{-2} B 2 kg m s^{-2} C 4 kg m s^{-2} D 8 kg m s^{-2} E 16 kg m s^{-2}

S4 **N04/P1/Q6**

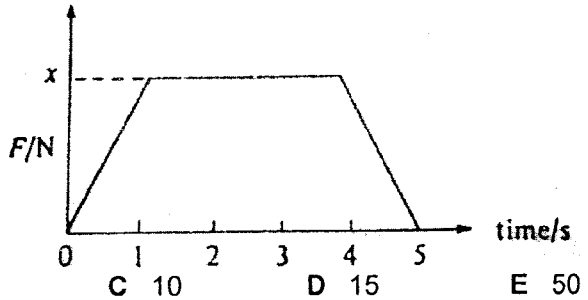
A force 2 *F* acting on a particle of mass 10 kg produces an acceleration of 60 m s^{-2}. A force 5 *F* acting on a particle of mass *M* produces an acceleration of 50 m s^{-2}. What is the mass M?

A 3.3 kg B 4.8 kg C 21 kg D 30 kg

S5 On an aircraft carrier, an F-18 Super Hornet fighter aircraft that is being launched can be catapulted from 0 to 270 km h^{-1} in 2.0 s. For a jet having a mass of 20 000 kg, what is the average force experienced by it?

S6 **N83/P2/2**

When a force, *F*, varying as shown below is applied to a mass of 10 kg, the gain in momentum in 5 s is 40 kg m s^{-1}. What is the value of *x*?



A 4 B 8 C 10 D 15 E 50

S7 **N93/P1/Q3**

Newton's third law concerns the forces of interactions between two bodies. Which of the following statements relating to the third law is **NOT** correct?

A The two forces must be of the same type.
B The two forces must act on different bodies.
C The two forces are always opposite in direction.
D The two forces are at all times equal in magnitude.
E The two forces are equal and opposite so the bodies are in equilibrium.

S8 **N84/P3/Q3**

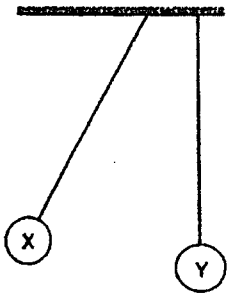
A man is parachuting at constant speed towards the surface of the Earth. The force which, according to Newton's 3rd law, makes an action-reaction pair with the gravitational force on the man is

A The tension in the harness of the parachute.
B The viscous force of the man and his parachute on the air.
C The gravitational force on the Earth due to the man.
D The viscous force of the air on the man and his parachute.
E The tension in the fabric of the parachute.

Part 2: Conservation of Linear Momentum/Collisions

S9 **N02/P1/Q5**

Two steel balls X and Y are suspended on a string. Ball X is pulled to one side as shown. After ball X is released, the balls collide.

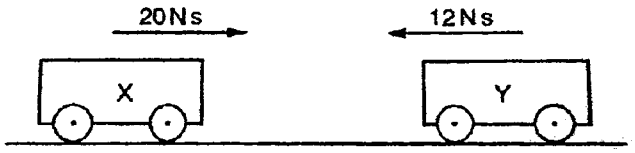


Which quantities must be conserved in the collision?

A Kinetic energy, total energy and momentum
B Kinetic energy and momentum only
C Kinetic energy and total energy only
D Total energy and momentum only

S10 **N98/P1/Q4**

The diagram shows two trolleys, X and Y, about to collide and gives the momentum of each trolley before the collision. After the collision, the directions of the motion of both trolleys are reversed and the magnitude of the momentum of X is then 2 N s.



What is the magnitude of the corresponding momentum of Y?

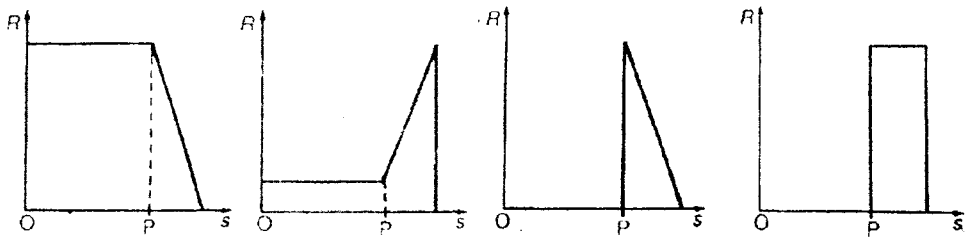
A 6 N s **B** 8 N s **C** 10 N s **D** 30 N s

Discussion Questions

Part 1: Newton's Laws, Inertia, Force, Momentum, Impulse

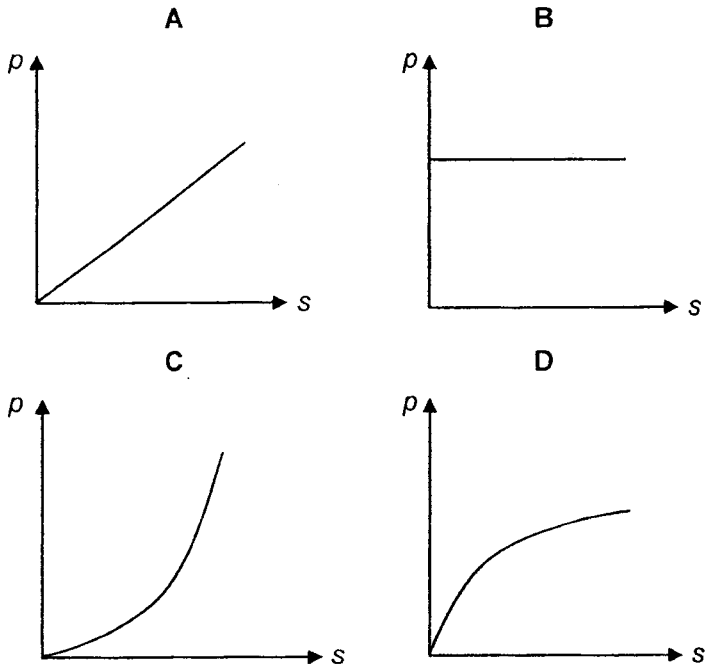
D1 **J88/P1/Q5**

An object falls vertically through air at a constant velocity and then strikes soft ground in which it becomes embedded. Its deceleration during impact is constant. If P represents the point of impact, which of the following graph best represents the variation of the total force R on the object with distance s?



D2 **TJC/2008/P1/Q7**

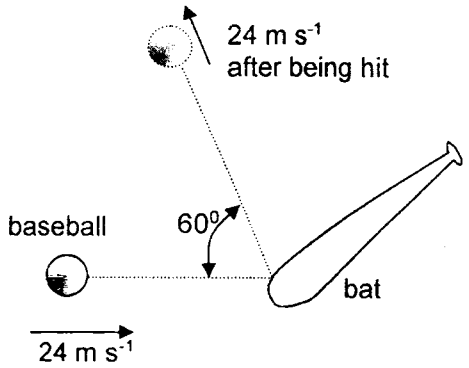
A railway carriage starts from rest and is driven along a straight horizontal track by a motor which exerts a constant force. The effects of friction and air resistance can be neglected. Which of the graphs below best represents the variation of the momentum p with distance travelled s?

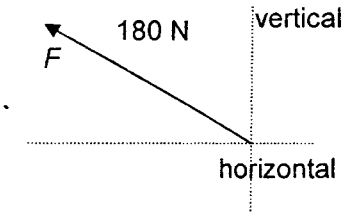


D3 **HCI/2007/P1/Q8**

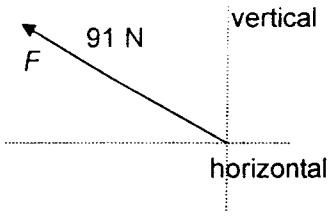
A baseball of mass 0.11 kg is thrown with a horizontal velocity of 24 m s^{-1} towards a batter. After the ball is struck by the bat, it has a speed of 24 m s^{-1} in the direction 60^0 above the horizontal as shown on the right.

If the ball and bat are in contact for 0.025 s, the magnitude and direction of the average force exerted on the ball by the bat is

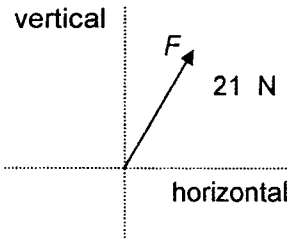




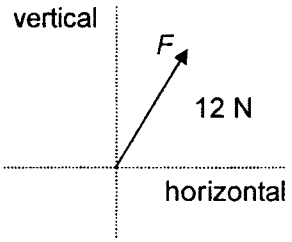
A



B



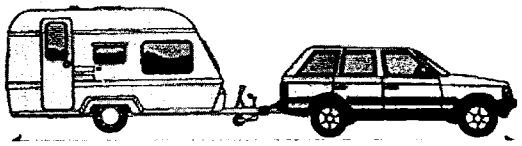
C



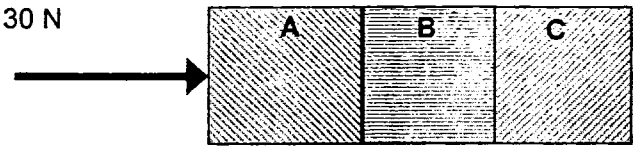
D

D4 A car of mass 1200 kg tows a caravan of mass 1800 kg along a level road. They are linked by a rigid tow-bar. The car accelerates at 1.80 m s^{-2} propelled by a motive force of 5600 N. Assume the resistive force on the car due to friction and air resistance to be a constant value of 65.0 N. Calculate

a) the resistive force *F* on the caravan,
b) the tension in the tow bar.



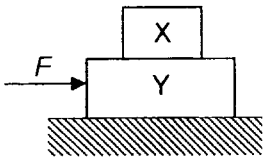
D5 Three blocks A, B and C, of masses 2.0 kg, 4.0 kg and 3.0 kg respectively are pushed along a smooth horizontal surface by a force of 30 N as shown in the diagram.



a) Calculate the net force experienced by each of the blocks, A, B and C.
b) What is the force exerted by block B on (i) block C and
(ii) block A?

D6 **HCI/2008Promo/P1/Q5**

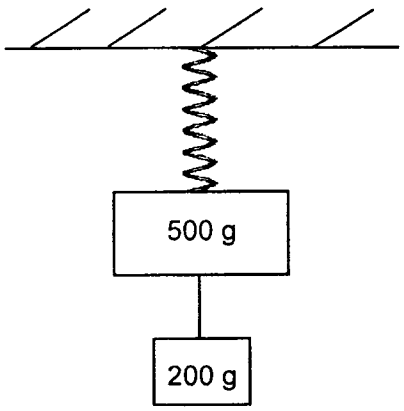
Two blocks, X and Y, of masses m and $3m$ respectively, are accelerated along a smooth horizontal surface by a force F applied to block Y as shown below.



The interface between block X and Y is rough and friction is present. If block X does not slide on block Y, what is the frictional force acting on block X?

D7 **HCI/2007C2-BT2/P1/Q4**

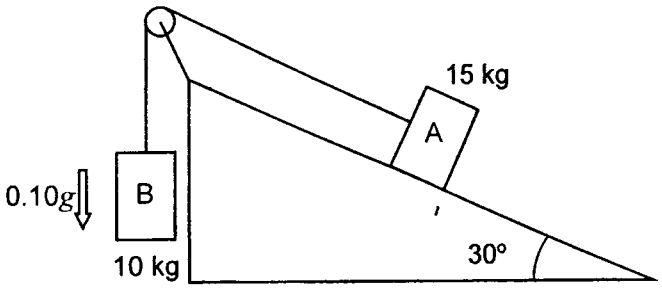
The diagram below shows a system in static equilibrium in which two masses, joined by a light thread, are suspended from a light vertical spring. If the thread is cut, what is the value of the acceleration of the 500 g mass immediately after the thread is cut?



A g **B** $0.4g$ **C** $0.2g$ **D** zero

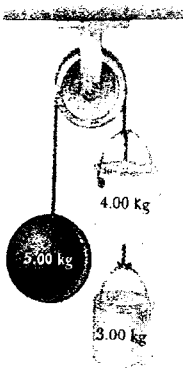
D8 **HCI/2007BT2/P1/Q4**

Two blocks, A and B, of mass 15 kg and 10 kg respectively, are connected by a light cord passing over a light, free-running pulley as shown in the diagram below. When released, block B accelerates downwards at $0.10\,g$. What is the frictional force experienced by block A?



A 0 N **B** 15 N **C** 50 N **D** 90 N

D9 Three objects are connected by light strings as shown in the fig below. The strings connecting the 4.00 kg can and 5.00 kg ball passes over a light frictionless pulley.
Determine
(a) the acceleration of each object and
(b) the tensions in the two strings.



D10 During a rescue operation, a 5500 kg helicopter hovers above a fixed point. The rotating blades of the helicopter's rotor send air downwards with a speed of 60.0 m s^{-1}, producing enough upward force for helicopter to hover.

a) What is the ***net*** force acting on the helicopter?
b) What is the upward force produced by the helicopter's rotor?
c) What mass of air must pass through the blades every second to produce enough thrust for the helicopter to hover?

D11 N2012/P3/Q1

The variation with time t of the vertical speed v of a light ball falling through air is shown in Fig 1.1.

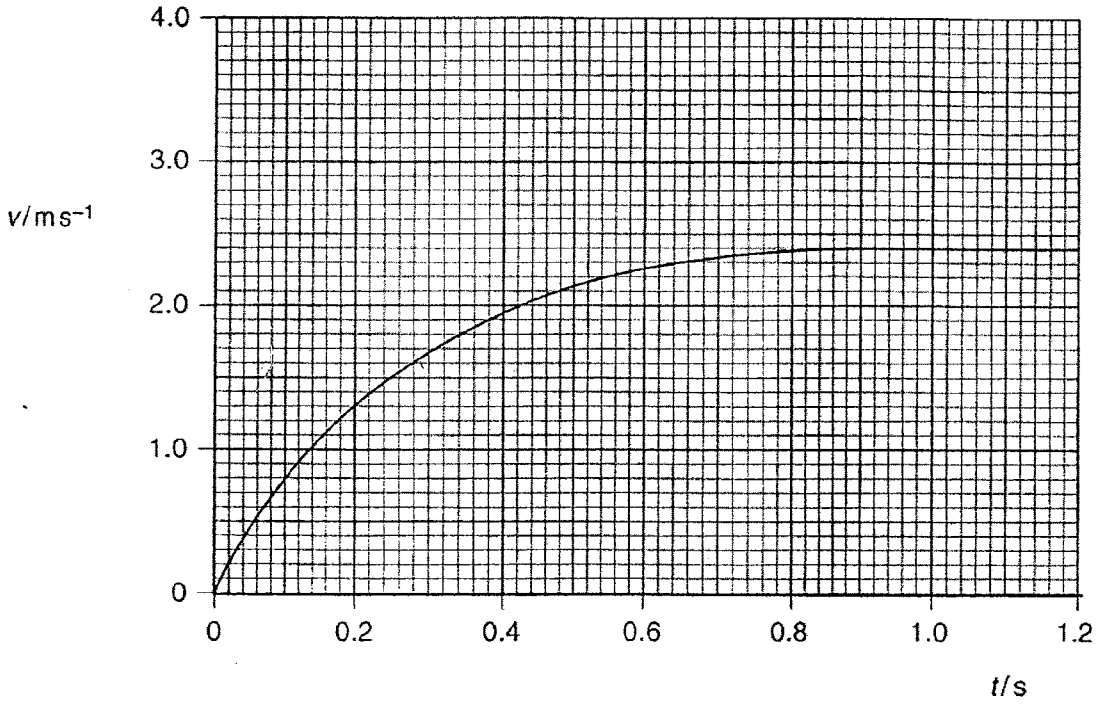


Fig. 1.1

The mass of the ball is 15 g.

(a) On Fig. 1.1 draw a line to show the variation with time t of the vertical speed v of the ball falling from rest in a vacuum.

(b) Use Fig. 1.1 to determine the acceleration of the ball balling through air at time t = 0.20 s. Show your construction on Fig. 1.1.

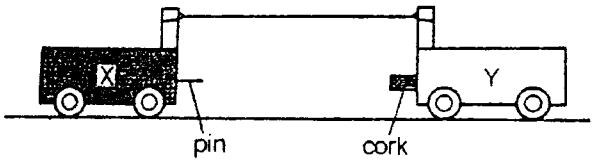
(c) For the air resistance acting on this ball,
(i) calculate the maximum resistive force,
(ii) show that the resistive force at time t = 0.20 s is about 0.083 N.

(d) Without drawing a graph, use Fig. 1.1 and the answers in (c) to suggest whether the magnitude of the air resistance force is proportional to the speed of the ball.

Part 2: Conservation of Linear Momentum/Collisions

D12 **N03/P1/Q4**

The diagram shows held stationary and connected by an extended elastic cord. The mass of X is twice that of Y. The trolleys are released at the same instant. The move towards each other and stick together on impact. Just before the collision, the speed of X is 20 cm s^{-1}.

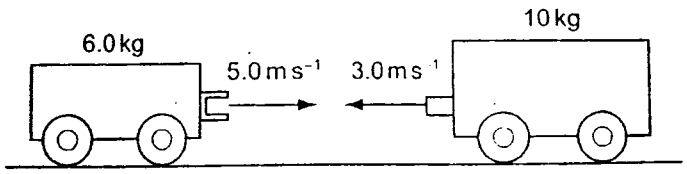


What is the speed of Y after the collision?

A zero **B** 5 cm s^{-1} **C** 7 cm s^{-1} **D** 10 cm s^{-1}

D13 **2008/P1/Q6**

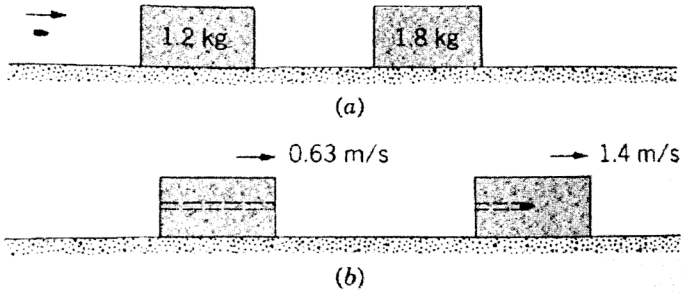
A trolley of mass 6.0 kg travelling at a speed of 5.0 m s^{-1} collides head-on and locks together with another trolley of mass 10 kg which is travelling in the opposite direction at a speed of 3.0 m s^{-1}. The collision lasts for 0.20 s.



What is the total momentum of the two trolleys before the collision and the average force acting on each trolley during this collision?

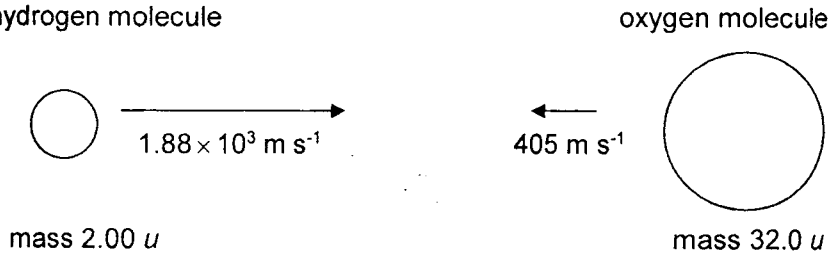
	Total momentum before the collision/ kg m s^{-1}	Average force on each trolley / N
A	0	300
B	60	150
C	0	150
D	60	300

D14 A 3.5 g bullet is fired horizontally at two blocks resting on a smooth table top, as shown in the figure. The bullet passes through the first block, with mass 1.2 kg, and embeds itself in the second, with mass 1.8 kg.
The final speeds of the blocks are 0.63 m s^{-1} and 1.4 m s^{-1} respectively.
Neglecting the mass removed from the first block by the bullet, find
(a) the speed of the bullet immediately after emerging from the first block, and
(b) the original speed of the bullet.



D15 (a) (i) Define linear momentum
(ii) State the principle of conservation of momentum.

(b) In a gas a hydrogen molecule, mass 2.00 *u* and velocity 1.88×10^3 m s^{-1}, collides elastically and head-on with an oxygen molecule, mass 32.0 *u* and velocity 405 m s^{-1}, as illustrated in the figure below.



In qualitative terms, what can be stated about the subsequent motion as a result of knowing that

(i) The collision is elastic.
(ii) The collision is head-on.

(c) Using your answers to (b),

(i) Determine the velocity of separation of the two molecules after the collision. Since collision is elastic,
(ii) Apply the law of conservation of momentum to the collision.
(iii) Determine the velocity of both molecules after the collision.

N00/III/I(part)

D16 **N2007/P3/Q1 (modified)**

A tritium nucleus moves towards a deuterium nucleus as illustrated in Fig. 1.1.

Fig. 1.1

The nuclei initially have the same speed *v*. The tritium nucleus consists of two neutrons and a proton. The deuterium nucleus consists of a neutron and a proton. The proton and the neutron have the same mass *m*.

The two nuclei having like charges, repel one another.

(a) Explain why it is **not** possible for the nuclei to stop at the same instant.

(b) At one instant during the interaction between the nuclei, they are both travelling **in the same direction** with the same speed. Calculate this speed, in terms of *v*.

(c) Fig. 1.2 is a velocity-time sketch graph showing how the velocity of each nucleus varies. The interaction between the nuclei is elastic.

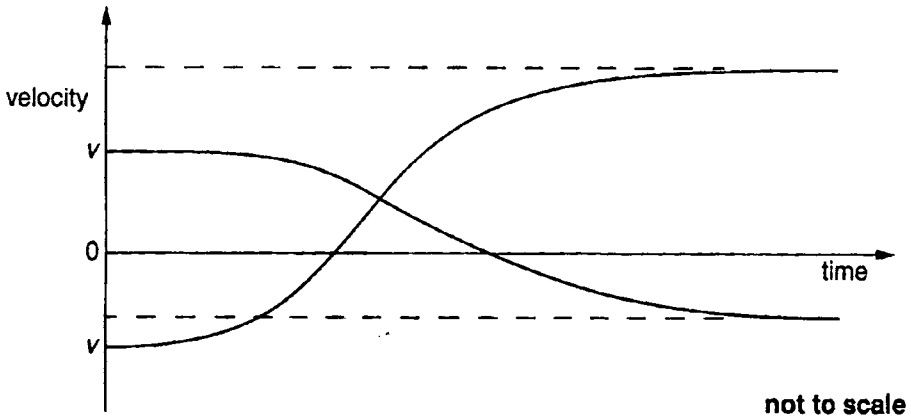


Fig. 1.2

(i) Label the graph to show

1. which curve is for the tritium nucleus,
2. the times at which each nucleus stops,
3. the time at which they are at their distance of closest approach.

(ii) Determine the final speed of each nucleus in terms of *v*.

D17 N2011/P3/Q1

A toy car with a rocket engine moves along a horizontal track, as shown in Fig. 1.1.

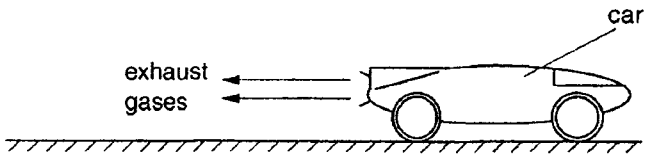


Fig 1.1

The rocket engine produces a constant forward force of 4.6 N. The car loses mass continuously as exhaust gases are produced by the rocket.

(a) Use momentum consideration to explain why the rocket produces a forward force on the car.

(b) The variation with time t of the speed v of the car is shown in Fig. 1.2.

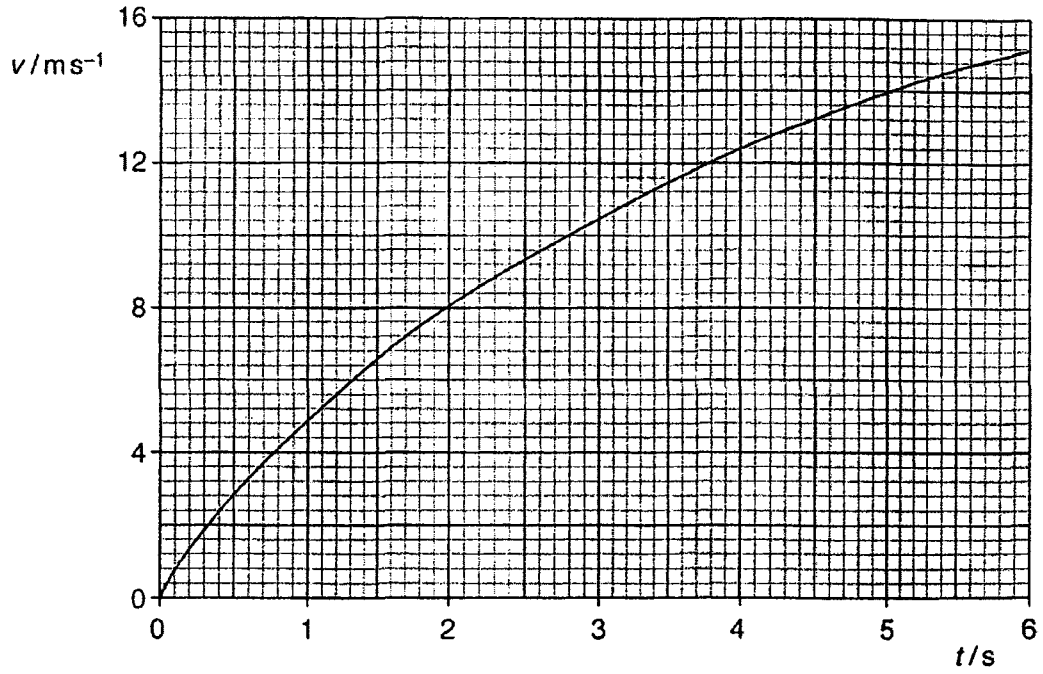


Fig. 1.2

At time t = 2.0 s, the mass of the car is 440 g.

(i) For the time t = 2.0 s,
1. use Fig. 1.2 to determine the acceleration of the car,
2. use your answer in (i) part 1 to determine the magnitude of the resistive force acting on the car.

(ii) Explain how it can be deduced that the resistive forces acting on the car increase with increase of speed.

(c) The toy car is now re-fuelled and then rotated so that it is pointing upwards. It is suggested that the rocket engine produces sufficient force to propel the car vertically. By considering the acceleration of the car at time t = 0 in Fig. 1.2, comment on this suggestion.

Answers to Tutorial 3: Dynamics

S5 750 kN **D4** (a) 135 N, (b) 3380 N

D5 (a) 6.7 N, 13 N, 10 N (b)(i) 10 N, (ii) 23.3 N **D6** $\frac{1}{4}F$

D9 (a) 1.64 m s^{-2} (b) 57.2 N, 24.5 N **D10** (a) 0 N (b) 54.0 kN (c) 899 kg s^{-1}

D11 (b) 4.276 m s^{-2} (c)(i) 0.147 N **D14** (a) 721 m s^{-1} (b) 937 m s^{-1}

D15 (b) (i) 2285 m s^{-1} (iii) -136 m s^{-1}, -2420 m s^{-1}

D16 (b) $v/5$, (c)(ii) $v_{deuterium} = 1.4\ v$, $v_{tritium} = 0.6\ v$

D17 (b)(i) 2.7 m s^{-2}, 3.4 N