JURONG PIONEER JUNIOR COLLEGE
9478 H2 PHYSICS/8867 H1 PHYSICS

MOTION AND FORCES TUTORIAL

Data: $g = 9.81\ \text{m s}^{-2}$ **Formulae**: $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$

Part 1: Motion (Kinematics)

Self-Check Questions:

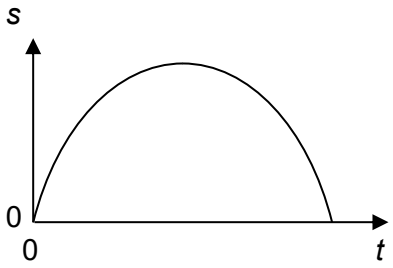
S1 Define displacement, velocity, and acceleration.

S2 What information can be obtained from a displacement-time graph, velocity-time graph and acceleration-time graph? How so?

S3 With the aid of a velocity-time graph, derive equations which represent uniformly accelerated motion in a straight line.

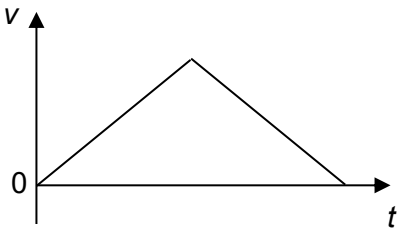
Self-Practice Questions:

1 A ball is thrown vertically upwards and returns along the same path.
The graph shows how its height varies with time.



Which velocity-time graph describes this motion?

A



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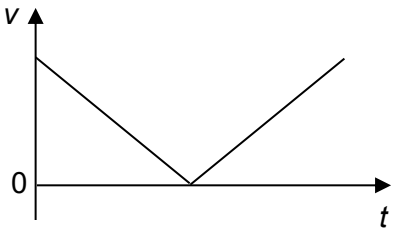

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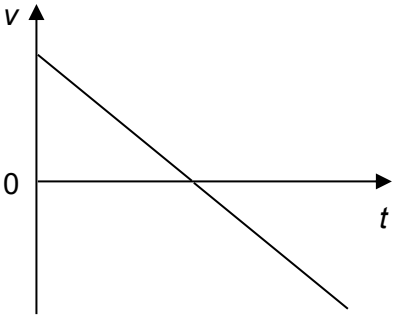

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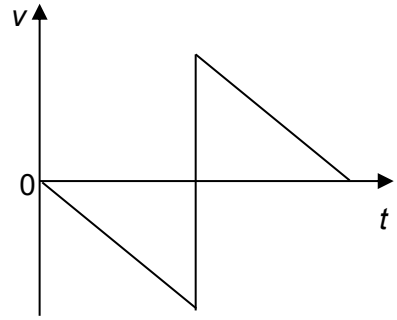
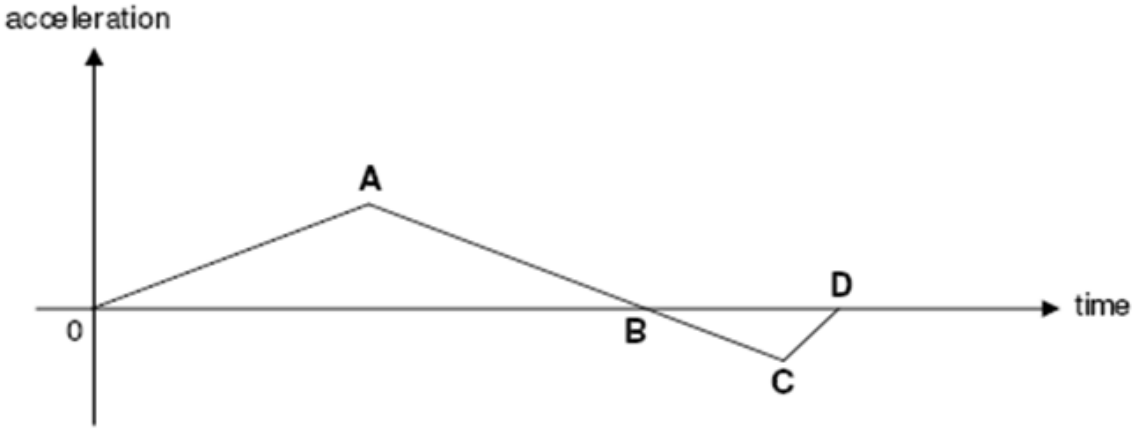


2 The acceleration-time graph of an object moving in a straight line is as shown. The object started its motion from rest.



At which point is the body moving with the largest speed?

3 Drivers need to maintain a minimum safe following distance to avoid colliding with the rear end of the vehicle in front should the latter stop suddenly.

Determine the minimum safe-following-distance for a car driven at a speed of 23.0 m s^{-1}. Assume that the average reaction time for drivers is 0.250 s, the brakes can produce a constant maximum deceleration of 35.0 m s^{-2} and the front vehicle stops instantaneously.

(Hint: Plot the *v*-*t* graph of the car)

4 The variation with time *t* of the velocity *v* of a moving object is shown in Fig. 4.

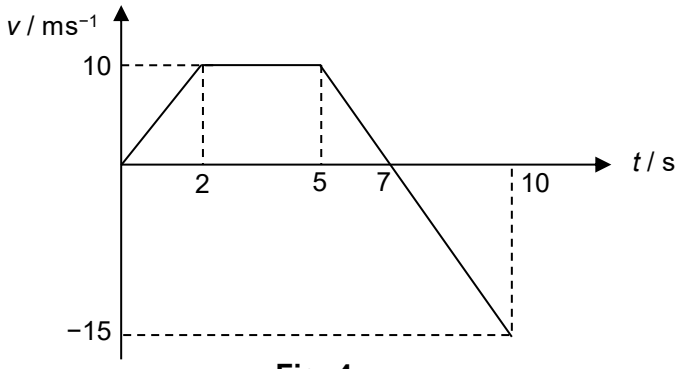


Fig. 4

Sketch the corresponding

(a) displacement-time graph,

(b) acceleration-time graph.

5 This question involves three pebbles being thrown from the top of a cliff 125 m in height.

(a) The first pebble is dropped from rest.

(i) How long does it take to reach the foot of the cliff?

(ii) What velocity does it strike the ground?

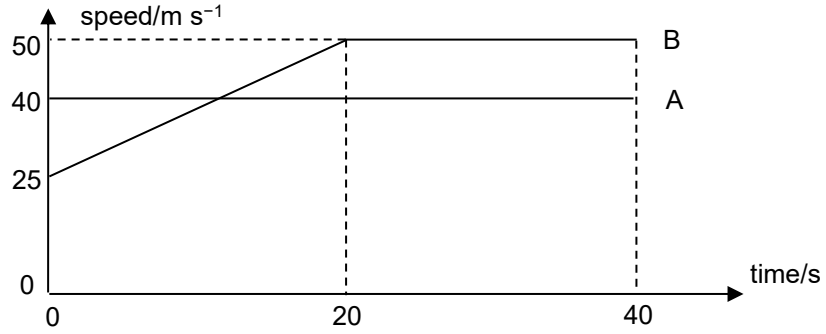
(b) A second pebble is thrown vertically downwards and reaches the bottom of the cliff in 4.0 s. Determine its initial downward velocity.

(c) A third pebble is thrown upwards with an initial velocity of 40.0 m s^{-1}.

(i) Determine the time taken for it to reach the bottom of the cliff.

(ii) Determine the maximum height it attains, from the bottom of the cliff.

6 The figure below shows the speeds of two cars A and B which are travelling in the same direction over a period of time of 40 s. Car A, travelling at a constant speed of 40 m s^{-1}, overtakes car B at time $t = 0$. In order to catch up with car A, car B immediately accelerates uniformly for 20 s to reach a constant speed of 50 m s^{-1}.



(a) How far does car A travel during the first 20 s?

(b) Calculate the acceleration of car B in the first 20 s.

(c) How far does car B travel in this time?

(d) What additional time will it take for car B to catch up with car A?

(e) How far will each car have then travelled since $t = 0$?

(f) What is the maximum distance between the cars before car B catches up with car A?

Answers:

1	**C**	**5**	**(a)(i)** 5.05 s **(a)(ii)** 49.5 m s^{-1} **(b)** 11.6 m s^{-1} **(c)(i)** 10.6 s **(c)(ii)** 207 m
2	**B**	**6**	**(a)** 800 m **(b)** 1.25 m s^{-2} **(c)** 750 m **(d)** 5.0 s **(e)** 1000 m **(f)** 90 m
3	**13.3 m**		

Discussion Questions

Rectilinear Motion

1 State if the following cases are possible and if so, give an example.

(a) A particle experiencing non-zero velocity and zero acceleration.

(b) A particle experiencing zero velocity and non-zero acceleration.

(c) A particle experiencing opposite velocity and acceleration.
Sketch a velocity-time graph for this case.

2 A ball is released from rest above a horizontal surface. The graph shows the variation with time of its velocity.

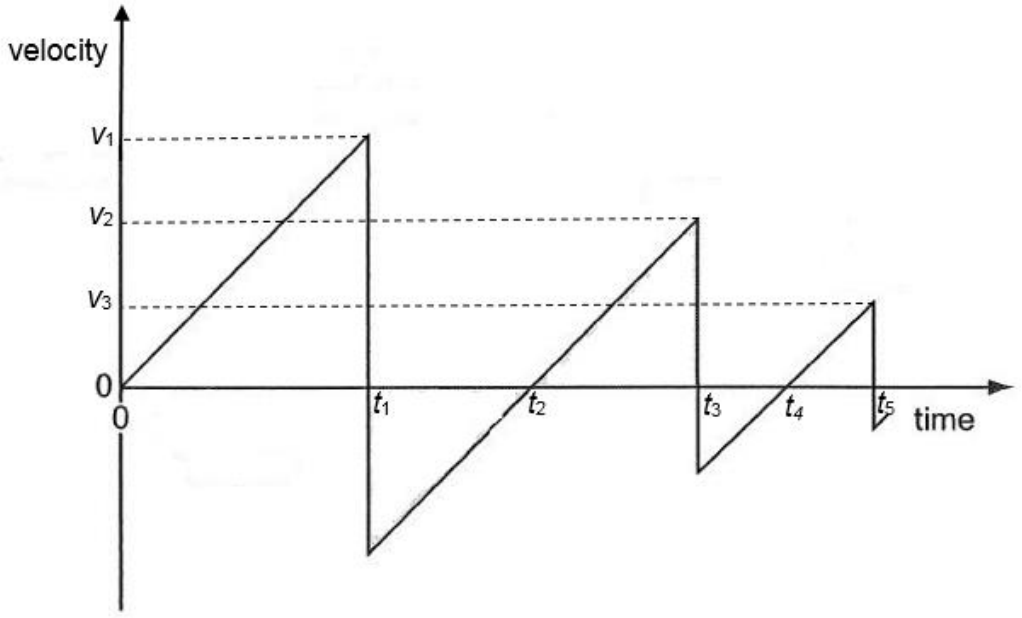
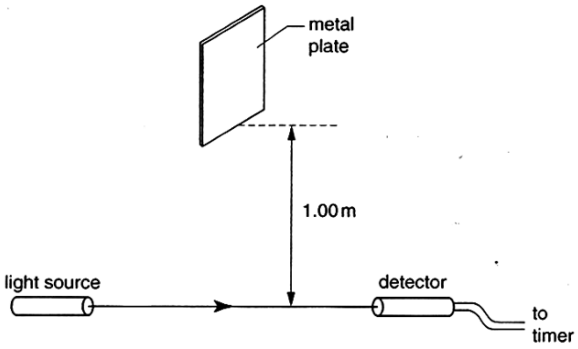


Fig. 5

(a) Using the graph in Fig. 5,
(i) Explain how the height from which the ball was first dropped may be determined.
(ii) State the time at which the ball was at the maximum height of its second rebound.
(b) Sketch a displacement-time graph for the ball's journey up to time t_3.

3 [2005 P2 Q1]
A student wishes to measure the length of a metal plate. The only equipment available is an electronic timer controlled by a light beam and a rod 1.00 m long.
Using the rod, the student positions the plate so that its lower edge is 1.00 m above the light beam, as shown below.



The metal plate is released and the timer starts to record as the light beam is cut. The total time for the plate to pass through the beam is 0.052 s.
The student is told that the local value for the acceleration of free fall is 9.79 m s^{-2}.

(a) **(i)** Show that the time for the bottom edge of the plate to reach the light beam is 0.452 s.
(ii) Calculate the length of the metal plate, giving your answer to an appropriate number of significant figures.
(b) Suggest two reasons why the time for the bottom edge of the plate to reach the light beam may differ from that quoted in **(a)(i)**.

4 **(a)** A man throws a ball vertically upwards with a velocity of 20.0 m s^{-1}. Neglecting air resistance, determine
(i) the maximum height reached,
(ii) the time taken for the ball to return to the man's hand.

(b) Sketch graphs showing how **(i)** the velocity, and **(ii)** the displacement of the ball depends on time during its flight.
Mark on your graphs the times at which
(i) the ball leaves the person's hand (t_1),
(ii) it comes to its maximum height (t_2),
(iii) it reaches his hands again (t_3).

Numerical Answers:

3	**(a)(ii)** 0.24 m
4	**(a)(i)** 20.4 m **(a)(ii)** 4.08 s

Part 2: Forces (Dynamics)

Self-Check Questions

S1 State Newton's Laws of Motion.

S2 Discuss what is meant by *mass* and *weight* of an object.

S3 State the conditions which make two forces an action-reaction pair.

S4 What is meant by the linear momentum of a body? List down two expressions of the unit of momentum.

S5 Discuss the relationship between force and momentum.

S6 What is meant by the *impulse* of a force? How is it obtained from the force-time graph?

Self-Practice Questions

P1 An aircraft in level flight is moving with constant velocity relative to the ground.

The resultant force acting on the aircraft is equal to

A the weight of the aircraft.

B the resultant of the air resistance and the thrust of the engines.

C the resultant of the air resistance and the weight of the aircraft.

D zero.

P2 A trolley runs down a slope with a constant acceleration *a*. The mass of the trolley is doubled and the trolley is allowed to run down the same slope. In both cases the effects of friction and air resistance are negligible.

Which statement is correct for the second experiment?

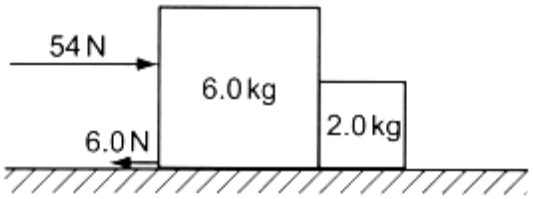
A The acceleration is 0.5*a*.

B The acceleration is *a*.

C The acceleration is 2*a*.

D The accelerating force is the same.

P3 A force of 54 N pushes two touching blocks of masses 6.0 kg and 2.0 kg along a flat surface. The frictional force between the blocks and the surface is 6.0 N.



What is the magnitude of the resultant force on the 6.0 kg mass?

A 12 N **B** 36 N **C** 45 N **D** 48 N

P4 A ball of mass 70 g collides with a vertical wall. The ball has a velocity of 23 m s^{-1} in a horizontal direction. After hitting the wall the ball moves with a velocity of 18 m s^{-1} in the opposite direction.

What is the impulse provided by the wall?

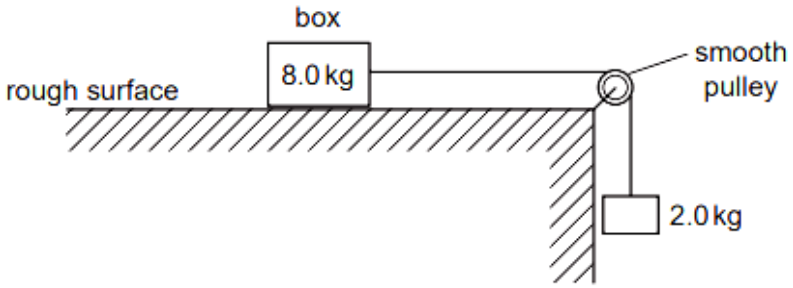
A 0.35 N s in a direction away from the wall

B 2.9 N s in a direction away from the wall

C 29 N s in a direction towards from the wall

D 2900 N s in a direction towards from the wall

P5 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 m s^{-2} **B** 1.7 m s^{-2} **C** 2.0 m s^{-2} **D** 2.5 m s^{-2}

Answer Key

P1 D P2 B P3 B P4 B

P5 A

Discussion Questions

Newton's Laws of Motion

1 A school bus comes to a sudden stop, and all the backpacks on the floor start to slide forward.

Explain this phenomenon.

2 A force $2F$ acting on an object of mass 10 kg produces an acceleration of 60 m s^{-2}. A force of $5F$ acting on an object of mass M produces an acceleration of 50 m s^{-2}.

Determine the value of mass M.

3 [2013 P2 Q1]

A cable car is used to carry a man of 95 kg through a vertical height, as shown in Fig. 3.1.

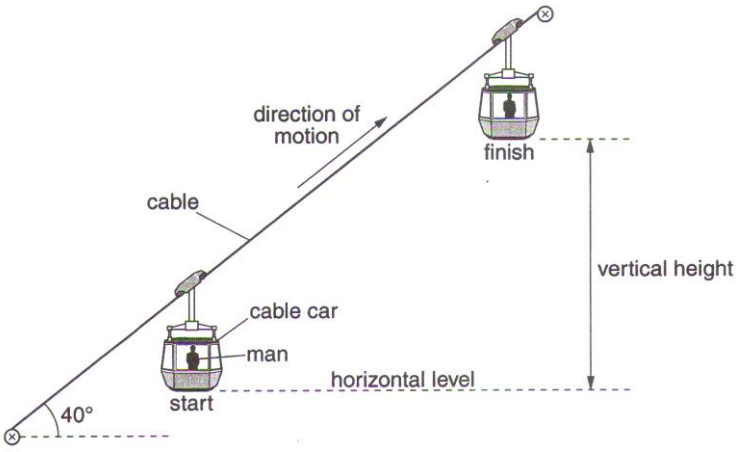


Fig. 3.1

The cable car is attached to a cable and moves at an angle of 40° to the horizontal. Initially, the cable car starts from rest and accelerates at 1.5 m s^{-2} for a time of 2.0 s. The cable car then moves at constant speed of 3.0 m s^{-1} for 120 s. Finally the cable car decelerates to rest in 3.0 s.

The floor of the cable car is horizontal at all times.

(a) Calculate the vertical height moved by the man during the acceleration of the cable car.

(b) (i) Calculate the normal reaction force acting on the man from the floor of the cable car when the cable car is moving at constant speed.

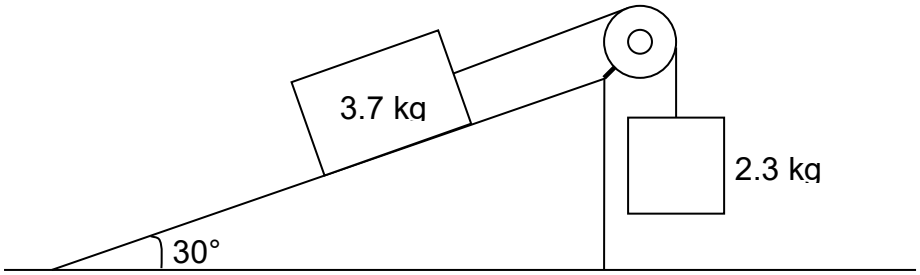
(ii) Explain your working in **(b)(i)**.

(c) Forces act on the man through the floor of the cable car.

(i) State the forces for the man as the cable car accelerates.

(ii) Explain how these forces produce the acceleration of the man.

4 A block of mass 3.7 kg on a frictionless incline of angle 30° is connected by a massless cord over a frictionless pulley to a second block of mass 2.3 kg hanging vertically.



Drawing the force diagrams of both blocks separately, determine

(a) the magnitude of the acceleration of the blocks,

(b) the direction of the acceleration of the 2.3 kg block,

(c) the tension in the cord.

5 A man of mass 75 kg stands on a spring scale in a lift.

Determine the reading on the scale if

(a) the lift is moving at constant speed,

(b) the lift is accelerating upward at 2.0 m s^{-2},

(c) the lift is accelerating downward at 4.0 m s^{-2},

(d) the lift cable breaks and it falls freely.

6 A helicopter of mass 1000 kg hovers by imparting a downward velocity *v* to the air swept by its rotors. The area swept out by the rotor blades is 80 m^2. The density of air is 1.3 kg m^{-3}.

(a) Considering the air swept downwards per second, determine in terms of *v*,

(i) the volume of air swept,

(ii) the mass of air swept,

(iii) the momentum of the air swept,

(iv) the change in momentum of the air swept,

(v) the force exerted on the air by the rotor blades,

(vi) the force exerted on the rotor blades by the air and its direction.

(c) Determine the value of v.

7 A steady stream of water strikes a wall horizontally with a speed of 7.2 m s^{-1} without rebounding and as a result, exerts a force on the vertical wall. The water arrives at the wall at a rate of 18 kg s^{-1}.

(a) Calculate the change in momentum of the water in one second.

(b) Calculate the force exerted by the water on the wall.

(c) Explain the effect on the magnitude of the force in **(b)** if the water rebounds after striking the wall.

Challenging Question:

8 The two blocks, m = 1.6 kg and M = 8.8 kg are free to move, as shown in Fig. 11.1. The coefficient of static friction μ_s between the blocks is 0.38, but the surface beneath M is smooth.

[Note: The maximum static friction f_{max} acting on an object is given by $f_{max} = \mu_s N$ where N is the normal reaction on then object.]

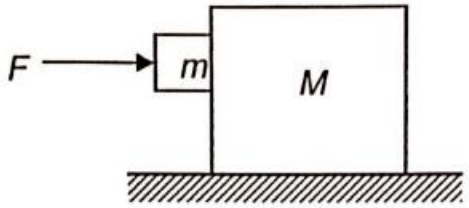


Fig. 11.1

(a) Draw free-body diagrams of forces on m and M.

(b) Determine the minimum force F needed to hold m against M.

(c) Determine the minimum acceleration produced by the force in **(b)**.

2	30 kg	**5(b)**	886 N	**6(a)(v)(vi)**	$104v^2$ N
3(a)	1.9 m	**5(c)**	436 N	**6(b)**	9.71 m s^{-1}
3(b)(i)	930 N	**5(d)**	0 N	**7(a)**	− 130 kg m s^{-1}
4(a)	0.736 m s^{-2}	**6(a)(i)**	$80v$ m^3	**7(b)**	130 N
4(c)	20.9 N	**6(a)(ii)**	$104v$ kg	**8(b), (c)**	4.7 m s^{-2}, 49 N
5(a)	736 N	**6(a)(iii)(iv)**	$104v^2$ kg m s^{-1}		