JURONG PIONEER JUNIOR COLLEGE
9478 H2 PHYSICS

PROJECTILE MOTION TUTORIAL

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

Self-Check Questions:

S1 Which component of a projectile's velocity remains constant during flight? Assume no air resistance.

S2 At the highest point of a projectile's path, what is its vertical velocity and acceleration?

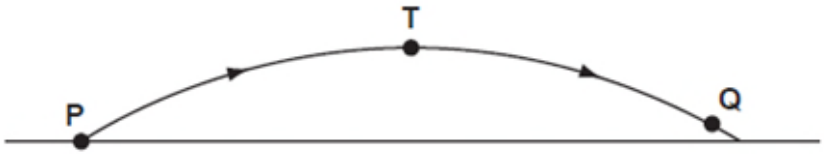
S3 In projectile motion, which quantity: range, maximum height and time of flight, is independent of the projectile's mass?

S4 What is the condition for an object to fall with terminal velocity?

S5 Sketch the v-t graph for an object projected vertically up if air resistance is significant.

Self-Practice Questions:

1 In the absence of air resistance, a stone is thrown from **P** and follows a parabolic path in which the highest point reached is **T**. The stone reaches point **Q** just before landing.



Which of the following options is correct?

	Horizontal component of velocity	Vertical component of velocity	Acceleration
A	Minimum at T	Maximum at T	Zero at T
B	Maximum at P	Maximum at P	Maximum at T
C	The same at P, Q and T	The same at P, Q and T	Minimum at P
D	The same at P, Q and T	Zero at T	The same at P, Q and T

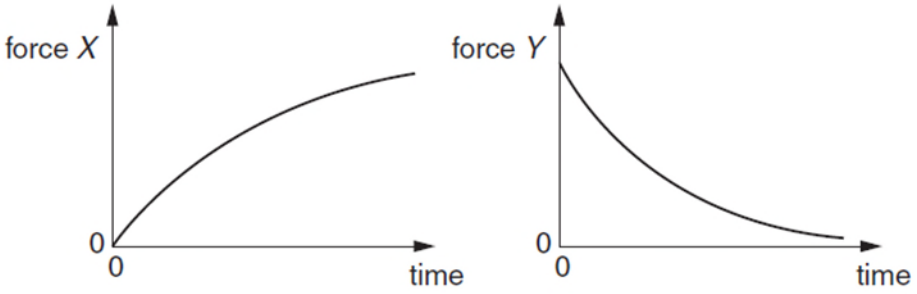
2 A mass is projected at an angle of 45° above the horizontal level. Which change will decrease the range but increase the maximum height of the projectile.

A. Decrease the mass
B. Decrease the launch angle
C. Increase the launch angle
D. Increase the initial speed

3 A projectile is launched horizontally from a height *h*. If air resistance is present, which of the following is true compared to the case without air resistance?

A. The horizontal range decreases, and the time of flight increases.
B. The horizontal range decreases, and the time of flight decreases.
C. The horizontal range increases, and the time of flight increases.
D. The horizontal range remains the same, but the time of flight decreases.

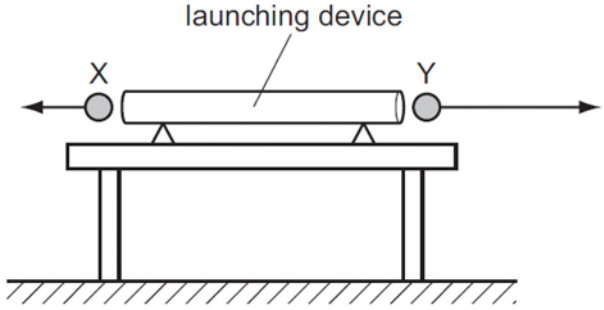
4 A ball falls from rest through air and eventually reaches a constant velocity. For this fall, forces *X* and *Y* vary with time as shown.



What are forces *X* and *Y*?

	force *X*	force *Y*
A	air resistance	resultant force
B	air resistance	weight
C	upthrust	resultant force
D	upthrust	weight

5 A double-ended launching device fires two identical steel balls X and Y at exactly the same time. The diagram shows the initial velocities of the balls. They are both launched horizontally, but Y has greater speed.



Which statement explains what an observer would see?

A X reaches the ground before Y, because X lands nearer to the launcher.

B Y reaches the ground before X, because Y has greater initial speed.

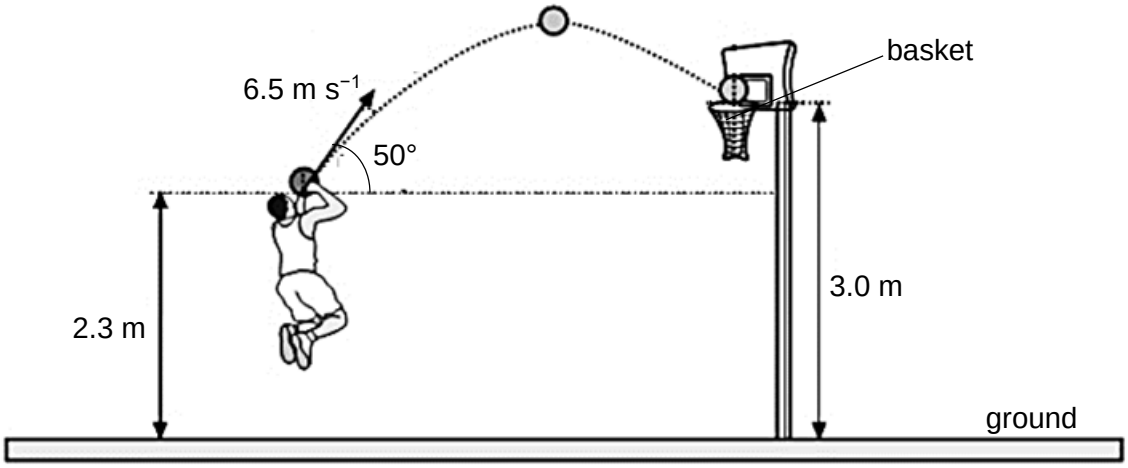
C Both X and Y reach the ground simultaneously, because gravitational acceleration is the same for both.

D Both X and Y reach the ground simultaneously, because air resistance will cause both to have the same final speed.

Discussion Questions

1 A ball is thrown from the top of a cliff with a velocity of 15 m s^{-1}, making an angle of 40° above the horizontal. The height of the cliff above the ground is 45 m.
Calculate
(a) the time taken to reach the ground,
(b) the horizontal distance from the cliff to the point where the ball hits the ground, and
(c) the velocity of the ball just before hitting the ground.
(d) Sketch a graph showing how the gravitational potential energy, kinetic energy and total energy change with time, assuming that there is no air resistance.

2 A basketball player throws a ball of mass 600 g with an initial velocity of 6.5 m s^{-1} at an angle of 50° to the horizontal. The ball is 2.3 m above the ground when released and passes through the basket on its way down.



Ignoring air resistance, calculate
(a) the time taken for the ball to reach the top of the basket which is 3.0 m above the ground.

(b) the maximum height reached by the basketball.

(c) the kinetic energy of the ball at the highest point.

(d) the horizontal distance from the basket to the initial launch position of the ball.

(e) the velocity of the ball when it hits the basket.

3 **(a)** Can a goalkeeper at his goal kick a soccer ball into the opponent's goal without the ball touching the ground? The distance is 95 m and the initial ball speed is 30 ms^{-1}.

(b) The world long jump record is 8.95 m (Mike Powell, USA, 1991). Treated as a projectile, what is the maximum range obtainable by a person if he has a take-off speed of 9.5 m s^{-1}?

(c) In 2007, Michael Carter (U.S.) set a world record in the shot put with a throw of 24.77 m. What was the initial speed of the shot if he released it at a height of 2.10 m and threw it at an angle of 38° above the horizontal?

4 **(a)** A man throws a ball vertically upwards in air. Air resistance provides a retarding force which is approximately proportional to the square of the speed of the ball. Without carrying out any calculations, explain, how air resistance would affect

(i) the time taken for the ball to reach its maximum height,

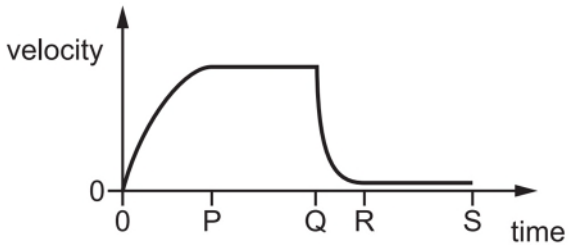
(ii) the maximum height to which it rises.

(b) Discuss also whether, with air resistance, the time t_d for the ball to come down is greater than, equal to or less than t_u, the time for it to go up.

(c) Sketch the shape of a projectile path if air resistance is not negligible. State the key differences between this path and the case without air resistance.

(d) Sketch 2 graphs showing how the gravitational potential energy, kinetic energy and total energy vary with time for a projectile motion with and without air resistance.

5 A parachutist falls from a stationary balloon at time t = 0. The velocity–time graph for the parachutist from time t = 0 until the time when he is just above the ground is shown.



(a) Sketch the variation of the acceleration with time.

(b) Explain qualitatively the variation of the velocity-time graph from O to S.

(c) Sketch another graph showing how the velocity change with time for a second parachutist with a heavier weight.

6 (2017 P3Q1) An object is dropped from a hot-air balloon. The variation with time t of the vertical velocity v of the object for the first 8.0s of its descent is shown below.

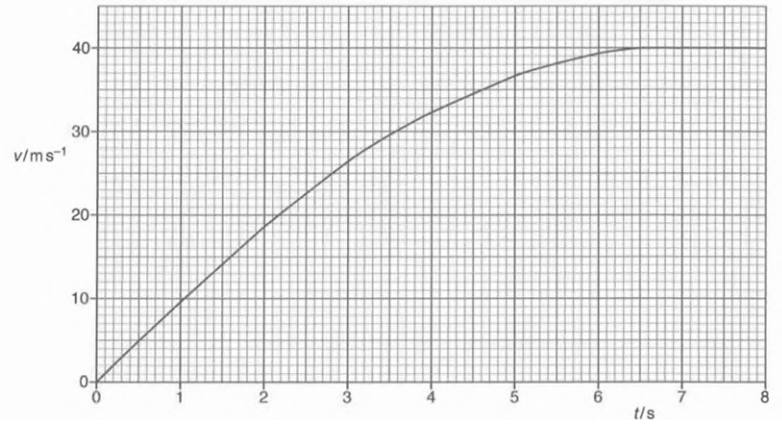


Fig 6.1

(a) Explain why the object reaches a constant velocity. [3]

(b) A student suggests that the resistive force F acting on the object of mass m is proportional to its velocity. That is $F = kv$ where k is a constant. At speed v, the acceleration of the object is a.

(i) Show that, based on the suggestion of the student, and without using data from the graph of Fig 6.1.

$$(g - a) = \frac{kv}{m}$$

where g is the acceleration of free fall. [2]

(ii) Use information from Fig. 6.1 or otherwise to complete the table.

velocity v/ms^{-1}	acceleration a/ms^{-2}	$(g - a)$/ms^{-2}
0	.....	.....
20	8.2	1.6
30	.....	.....
40	.....	.....

Fig 6.2

(iii) Use the completed Fig. 6.2 to deduce whether the student's suggestion for velocities of 20 m s^{-1} and 30 m s^{-1} is correct. [2]

7 [2009 P3 Q6]

A ball is thrown vertically upwards from ground level. Air resistance is not negligible. The variation with time t of the vertical velocity v of the ball is shown in Fig. 7.

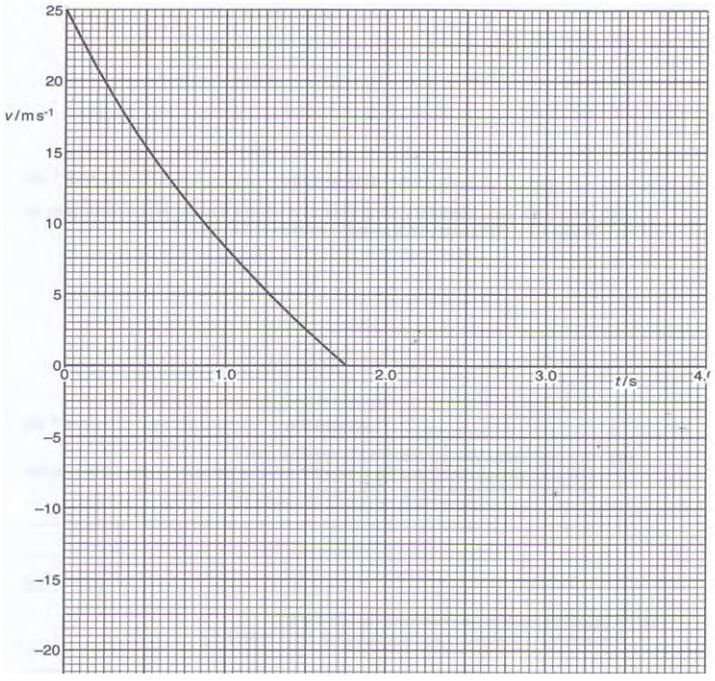


Fig. 7

(a) Use Fig. 7 to explain how it may be deduced that air resistance varies with speed.
(b) State and explain, without any calculation, the feature of Fig. 7 that enables the magnitude of the acceleration of free fall to be determined.
(c) **(i)** Use Fig. 7 to determine the maximum height reached by the ball.
(ii) Use your answer in (i) to calculate the ratio

$$\frac{\text{energy lost from the ball due to air resistance during the ball's upward motion}}{\text{initial kinetic energy of the ball}}$$

(d) The ball has mass 350 g. For the instant when this ball is travelling at 10 m s^{-1},
(i) use Fig. 7 to show that the acceleration of the ball is approximately -13 m s^{-2},
(ii) calculate the magnitude of the force due to air resistance on the ball.
(e) On Fig. 7, sketch the graph to show the variation with time *t* of the velocity *v* of the ball as it falls back to ground level.

8 A daredevil plans to jump over the 40 m wide gap as shown in Fig. 8, which also involves a 10 m descent.

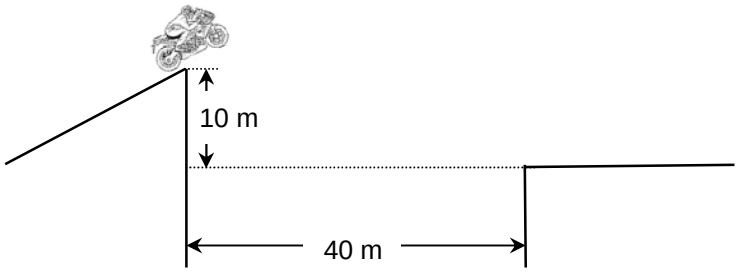


Fig. 8

Assuming that air resistance can be neglected, if the flight time is 3.0 s, calculate
(a) the angle of his launch ramp,
(b) his launch speed, and
(c) his velocity just before he lands.

9 [2011 P2 Q1]
(a) A ball is thrown from point S, as shown on Fig. 9.1.

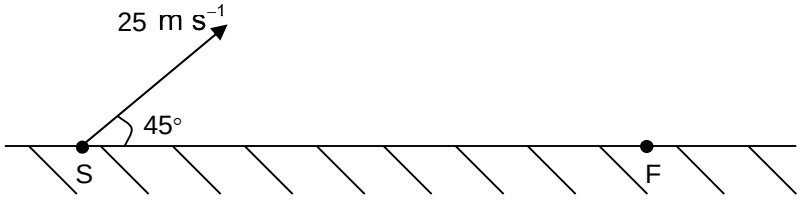


Fig. 9.1

The initial velocity of the ball is 25 m s^{-1} at an angle to the horizontal of 45°. The mass of the ball is 6.0×10^{-2} kg. The ball lands at point F. The points S and F are at the same horizontal level.

(i) Calculate the vertical component of the ball's initial velocity.
(ii) Show that the maximum height reached by the ball is 16 m, assuming no dissipative forces.

(iii) The kinetic energy of the ball at S is *K*. Calculate the kinetic energy and the potential energy of the ball in terms of *K* at a height of

1. 16.0 m

2. 8.0 m

(b) The horizontal distance from S towards F is *x.*

(i) On Fig. 9.2, sketch the variation with *x* of the potential energy, E_p of the ball.

Fig. 9.2

(ii) On Fig. 9.3, sketch the variation with *x* of the kinetic energy, E_k of the ball.

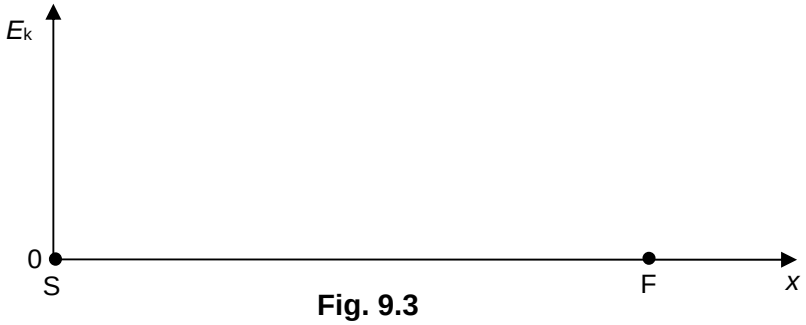


Fig. 9.3

Self-Practice Questions Answers:

1 D	**2 C**	**3 A**	**4 A**	**5 C**

Discussion Questions Numerical Answers:

1	(a) 4.17 s (b) 47.9 m **(c)** 33.3 m s^{-1} (d) 69.8^0 below horizontal	**7**	19 m, 0.40 -13 m s^{-2}, 1.1 N
2	(a) 0.847 s (b) 3.56 m (c) 5.24 J (d) 3.54 m (e) 5.34 ms^{-1}, 38.5^0 below horizontal	**8**	**(a)** 40.5° **(b)** 17.5 m s^{-1} **(c)** 22.4 m s^{-1}, 53.5° below the horizontal
3	(a) 91.6 m (b) 9.2 m (c) 15.0 m s^{-1}	**9**	**(a)(i)** 17.7 m s^{-1}
6	9.8,0; 5.7,4.1; 0, 9.8		