12 Projectile Motion Problems 1

Object projected from a horizontal surface

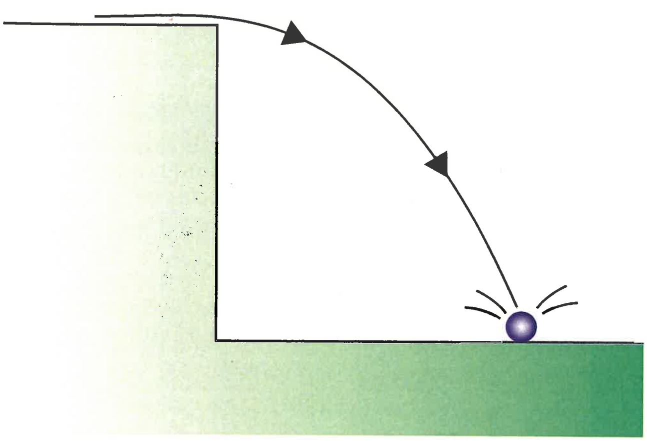
Special considerations:

- Initial vertical velocity = 0
- $\theta = 0°$

QUESTIONS

For each of the problems below, consider a projectile dropped vertically out of a moving object such as a plane, thrown horizontally out from the top of a cliff, or fired horizontally and landing on a surface as shown in the diagram. For each find any of the quantities which are not in the given data (not necessarily in the order given).

(a) The initial velocity of the projectile.
(b) Its initial horizontal velocity.
(c) Its initial vertical velocity.
(d) Its range.
(e) Its final horizontal velocity.
(f) Its final vertical velocity.
(g) Its final velocity.
(h) The time taken to fall.
(i) The height from which it was thrown or dropped.
(j) Its velocity 3 seconds after dropping.
(k) Its height 5 seconds after dropping.



1. A lifeboat is dropped from a plane moving at 140 m s^{-1} from a height of 1102.5 m.
2. A box of supplies is dropped from a helicopter moving at 80 m s^{-1}. They hit the ground 9.0 s later.
3. A ball is thrown horizontally from the top of a building and lands in a bucket on the ground 50 m in front of the building 3.0 s later.
4. A rock is thrown horizontally out from the top of a 147 m cliff. It hits the ground 80 m from the base of the cliff.
5. A ball thrown horizontally out from the top of a cliff hits the ground 6 s later at 30° to the vertical, and moving at 67.9 m s^{-1}.
6. A cannonball is fired horizontally from a castle. It hits its target 150 m away after 7.5 s.
7. An arrow is fired horizontally at the centre of a target 50 m away. Unfortunately, the archer made no allowance for gravity, and the arrow hit 0.8 m below centre.
8. A cannon fires a ball at 150 m s^{-1} which hits its target 675 m away.
9. A lifeboat is dropped from a plane moving at 80 km h^{-1}. It lands in the water 8 s later.
10. A projectile hits the centre of a target at an angle of 15° to the vertical 15 s after being dropped from a helicopter.

Now answer these questions

11. A car, moving at 30 m s^{-1}, goes over the edge of a cliff and into the water 58.8 m below.
    (a) Calculate the time it takes the car to hit the water.
    (b) Calculate the distance from the cliff that the car hits the water.
    (c) Calculate the speed of the car just as it hits the water.
12. A group of lemmings run over the edge of a 200 m cliff at 0.6 m s^{-1}.
    (a) Calculate their time to fall to the bottom of the cliff.
    (b) Calculate their velocity halfway down.
    (c) Calculate the time their speed will be 30.0 m s^{-1}.
    (d) Calculate the speed at which they hit the ground.

4. (a) From $F_{parallel} = mg \sin \theta = 6 \times 9.8 \times \sin 35° = 33.73$ N
   (b) From $F_N = mg \cos \theta = 6 \times 9.8 \times \cos 35° = 48.2$ N up, perpendicular to the surface
   (c) From $F = ma$, net force $= 6 \times 3.4 = 20.4$ N down the incline
   (d) From net force = parallel component – friction, 20.4 = 33.73 – friction, so friction = 13.33 N up the slope
5. (a) From $F_{parallel} = mg \sin \theta = 200 \times 9.8 \times \sin 35° = 1124.2$ N
   (b) From $F_N = mg \cos \theta = 200 \times 9.8 \times \cos 35° = 1605.5$ N up, perpendicular to the surface
6. (a) From $F = ma = 735 \times 0.15 = 110.25$ N up the slope
   (b) Tension = friction + net force = 510.25 N both ways in the rope
   (c) From $F_N = mg \cos \theta = 735 \times 9.8 \times \cos 15° = 6957.6$ N up at 90° to the surface
7. (a) From $F = ma = 73 \times 0.75 = 54.75$ N down the slope
   (b) From $F_{parallel} = mg \sin \theta = 73 \times 9.8 \times \sin 12° = 148.74$ N
   (c) Net force = component down the slope – friction = 54.75 = 148.75 – friction, so friction = 94 N up the slope
8. (a) From $F = ma = 5000 \times 0$ = zero (constant velocity)
   (b) From $F_{parallel} = mg \sin \theta = 5000 \times 9.8 \times \sin 7.5° = 6395.8$ N
   (c) 6395.8 up the slope
   (d) Slow down, stop momentarily and then accelerate down the incline, all at 1.28 m s^{-2}
9. (a) From $F_{parallel} = mg \sin \theta = 40 \times 9.8 \times \sin 37° = 235.9$ N down the slope
   (b) From $F = ma = 40 \times 0.6 = 24$ N up the slope
   (c) Tension = net force + component down slope = 24 + 235.9 = 259.9 N (acting both ways)
   (d) If acceleration is the same, the net force acting will be the same = 32 N up the slope
   (e) Tension in the rope will also include 5.0 N to overcome friction, so, tension = 331.3 + 32 + 5 = 368.3 N
10. (a) From $F = ma = 80 \times 0.4 = 32$ N up the slope
   (b) From $F_{parallel} = mg \sin \theta = 80 \times 9.8 \times \sin 25° = 331.3$ N down the slope
   (c) Total force to move block up slope = component down + net = 331.3 + 32 = 363.3 N
   But rope is inclined at 20°, so tension in rope = total force/cos 20° = 386.6 N acting both ways

11 Projectile Motion

1. For projectile at 30° to horizontal:
   $u_y = 40 \sin 30° = 20$ m s^{-1}
   From $v_{top} = 0 = u_y + gt = 34.641 - 9.8t$
   Time to rise = 2.0408 s
   So, time of flight = 4.0816 s
   Therefore range, $= u_x \times t_{flight} = 40 \cos 30° \times 4.0816 = 141.39$ m
   For projectile at 60° to horizontal:
   $u_y = 40 \sin 60° = 34.641$ m s^{-1}
   From $v_{top} = 0 = u_y + gt = 34.641 - 9.8t$
   Time to rise = 3.5347 s
   So, time of flight = 7.0796 s
   Therefore range, $= u_x \times t_{flight} = 40 \cos 30° \times 7.0696 = 141.39$ m
   Therefore, on the basis of this one calculation, Galileo's prediction is supported.

12 Projectile Motion Problems 1

All answers in order of information requested in the chapter (answers may differ slightly due to rounding errors).

1. 140 m s^{-1}, 140 m s^{-1}, 0, 2100 m, 140 m s^{-1}, 147 m s^{-1}, 203 m s^{-1} at 46.4° to horizontal, 15 s, 1102.5 m, 143.1 m s^{-1} at 11.9° to horizontal, 980 m
2. 80 m s^{-1}, 80 m s^{-1}, 0, 720 m, 80 m s^{-1}, 88.2 m s^{-1}, 119.1 m s^{-1} at 47.8° to horizontal, 9 s, 396.9 m, 85.2 m s^{-1} at 20.2° to horizontal, 274.4 m
3. 16.7 m s^{-1}, 16.7 m s^{-1}, 0, 50 m, 16.7 m s^{-1}, 29.4 m s^{-1}, 33.8 m s^{-1} at 60.4° to horizontal, 3 s, 44.1 m, 33.8 m s^{-1} at 60.4° to horizontal, 0 m
4. 14.6 m s^{-1}, 14.6 m s^{-1}, 0, 80 m, 14.6 m s^{-1}, 53.6 m s^{-1}, 55.6 m s^{-1} at 74.8° to horizontal, 5.5 s, 147 m, 32.8 m s^{-1} at 63.6° to horizontal, 24.5 m
5. 33.95 m s^{-1}, 33.95 m s^{-1}, 0, 203.7 m, 33.95 m s^{-1}, 58.8 m s^{-1}, 67.9 m s^{-1} at 60° to horizontal, 6.0 s, 176.4 m, 44.9 m s^{-1} at 40.9° to horizontal, 53.9 m
6. 20 m s^{-1}, 20 m s^{-1}, 0, 150 m, 20 m s^{-1}, 73.5 m s^{-1}, 76.2 m s^{-1} at 74.8° to horizontal, 7.5 s, 275.6 m, 35.6 m s^{-1} at 55.8° to horizontal, 153.1 m
7. 125 m s^{-1}, 125 m s^{-1}, 0, 50 m, 125 m s^{-1}, 3.92 m s^{-1}, 125.1 m s^{-1} at 1.8° to horizontal, 0.4 s, 0.8 m, 0, 0 m
8. 150 m s^{-1}, 150 m s^{-1}, 0, 675 m, 150 m s^{-1}, 44.1 m s^{-1}, 156.3 m s^{-1} at 16.4° to horizontal, 4.5 s, 99.2 m, 152.9 m s^{-1} at 11.1° to horizontal, 0 m
9. 22.2 m s^{-1}, 22.2 m s^{-1}, 0, 177.8 m, 22.2 m s^{-1}, 78.4 m s^{-1}, 81.5 m s^{-1} at 74.2° to horizontal, 8 s, 313.6 m, 36.8 m s^{-1} at 52.9° to horizontal, 191.1 m
10. 39.4 m s^{-1}, 39.4 m s^{-1}, 0, 590.8 m, 39.4 m s^{-1}, 147 m s^{-1}; 152.2 m s^{-1} at 75° to horizontal, 15 s, 1102.5 m, 49.2 m s^{-1} at 36.7° to horizontal, 980 m
11. (a) 3.46 s
   (b) 103.9 m
   (c) 45.3 m s^{-1}
12. (a) 6.4 s
   (b) 44.3 m s^{-1} at 89.2° down from horizontal
   (c) 3.06 s
   (d) 62.72 m s^{-1} at 89.5° (If you forgot to take the initial horizontal component into account your answer will be 62.610.)