# Projectiles and Circular Motion Review

## 1.3 Projectiles

**Be able to:**

- solve simple free fall problems using kinematics
- describe the path of a projectile as resulting from the combination of constant horizontal velocity and constant vertical acceleration
- draw free body diagrams for a projectile at various points along its path
- calculate position and velocity components of a projectile at various points along its path
- solve projectile motion problems for objects launched horizontally or at an angle
  - time in air
  - height reached
  - range

## 1.4 Circular Motion

**Be able to:**

- explain why an object moving in a circle is accelerating towards the center
- explain the centrifugal effect with respect to Newton's laws
- draw free body diagrams of an object undergoing uniform circular motion
- define period and frequency for circular motion
- solve problems involving horizontal and vertical circles
  - object on a string
  - car on a level curve
  - car on a banked curve
  - rotor ride
  - loop-the-loop
  - plane in a dive
  - etc.

**Review Problems**

1. An archer stands 40.0 *m* from the target. If the arrow is shot horizontally with a velocity of 90.0 m/s, how far above the bullseye must he aim to compensate for gravity pulling his arrow downward? (0.97 *m*)

2. A bridge is 176.4 *m* above a river. If a lead-weighted fishing line is thrown from the bridge with a horizontal velocity of 22.0 *m/s*, how far has it moved horizontally when it hits the water? (132 *m*)

3. A golf ball is hit with a velocity of 24.5 *m/s* at $35°$ above the horizontal. Find

   a) the range of the ball. (57.6 *m*)

   b) the maximum height of the ball. (10.1 *m*)

4. A cannon is fired at $30°$ above the horizontal with a velocity of 200 *m/s* from the edge of a cliff 125 *m* high. Calculate where the cannonball lands on the level plain below. (3739 *m*)

5. A bomber, diving at an angle of 53° with the vertical, releases a bomb at an altitude of 730 *m*. The bomb hits the ground 5.0 *s* after being released.

   a) What was the velocity of the bomber? (202 *m/s*)

   b) How far did the bomb travel horizontally during its flight? (806 *m*)

   c) What were the horizontal and vertical components of its velocity just before striking the ground? (161 *m/s*, –171 *m/s*)

6. A baseball, thrown from shortstop position to first base, travels 32 *m* horizontally, and reaches a maximum height of 3.0 *m*. Find the initial velocity of the ball. (21.8 *m/s* $[20.6° \; ATH]$)

7. If you can hurl a ball so that its initial speed is 30 *m/s*, what is the widest river you can throw it across? (91.8 *m*)

8. An airplane flying at a constant speed of 1000 *km/h* executes a slow, level turn that changes its direction from west to east. If the turn takes 80 *s*, calculate the plane's average acceleration. ($10.9 \; m/s^2$)

9. A car, traveling at 25 *m/s* around a circular curve, has a centripetal acceleration of $8.3 \; m/s^2$. What is the radius of the curve? (75.3 *m*)

10. A child on a merry-go-round is moving with a speed of 1.25 *m/s* when 11.0 *m* from the center. Calculate

    a) the centripetal acceleration of the child. ($0.14\ m/s^2$)

    b) the net horizontal force exerted on the child (mass = 25 *kg*). (3.55 *N*)

11. A horizontal force of 26.0 *N* is applied to a 0.80 *kg* stone to keep it rotating uniformly in a horizontal circle of radius 0.50 *m*. Calculate its speed. (4.03 m/s)

12. A $4.0\ kg$ mass is tied to a light rope $1.5\ m$ long and swung in a horizontal circle. The rope is at an angle of $20°$ to the horizontal.

    a) What is the tension in the rope? (114.6 *N*)

    b) What is the speed of the mass? (6.2 *m/s*)

13. A $0.875\ kg$ ball is suspended from a cord. The ball swings in a horizontal circular path of radius $0.625\ m$ at 0.75 revolutions per second.

    a) What is the tension in the cord? (14.9 *N*)

    b) What is the angle between the cord and the vertical? ($55°$)

14. What is the maximum speed with which a 1000 *kg* car can round a turn of radius 85 *m* on a flat road if the coefficient of friction between tires and road is 0.60? Is this result independent of the mass of the car? (22.4 *m/s*, yes)

15. How large must the coefficient of friction be between the tires and the road if a car is to round a level curve of radius 68 *m* at a speed of 55 *km/h*? (0.35)

16. A 60.0 *kg* speed skater with a velocity of 18.0 *m/s* comes into a curve of 20.0 *m* radius. How much friction must be exerted between the skates and the ice to negotiate the curve? (972 *N*)

17. A race track designed for average speeds of $240\ km/h$ $(66.7\ m/s)$ is to have a turn with a radius of $975\ m$. To what angle must the track be banked so that cars traveling $240\ km/h$ have no tendency to slip sideways? (25°)

18. A carnival clown rides a motorcycle down a ramp and around a "loop-the-loop." If the loop has a radius of 18 *m*, what is the slowest speed the rider can have at the top of the loop to avoid falling? **Hint**: At this slowest speed, at the top of the loop, the clown's weight (gravitational force) is equal to the centripetal force. (13.3 *m/s*)

19. A 2.0 *kg* object is attached to a 1.5 *m* long string and swung in a vertical circle at a constant speed of 12 *m/s*.

    a) What is the tension in the string when the object is at the bottom of its path? (211.6 *N*)

    b) What is the tension in the string when the object is at the top of its path? (172.4 *N*)

20. A jet pilot takes his aircraft in a vertical loop. If the jet is moving at a speed of 700 *km/h* at the lowest point of the loop, determine

    a) the minimum radius of the circle so that the acceleration at the lowest point does not exceed 6 g's. (643 *m*)

    b) the 80 *kg* pilot's apparent weight at the bottom of the circle. (5488 *N*)