

Show equations, substitutions, units, and vector directions. Explain your reasoning. Use sensible rounding.

Answers appear below each question beside a vertical bar. Equivalent correct reasoning is acceptable.

Constants	$g = 9.8 \text{ m/s}^2$ $a_y = -g$ when up is positive
Equations	$v_{fy} = v_{iy} + a_y t$ $\Delta y = v_{iy} t + \frac{1}{2}a_y t^2$ $v_{fy}^2 = v_{iy}^2 + 2a_y \Delta y$ $A_x = A \cos \theta$ $A_y = A \sin \theta$ $A = \sqrt{A_x^2 + A_y^2}$ $\Delta x = v_x t$ $v = 2\pi r/T$ $a_c = v^2/r$ $F_{\text{net, inward}} = mv^2/r$

Ignore air resistance. Angles are measured from horizontal unless stated otherwise.

3.1 Free Fall

1. A ball is tossed straight upward. State the directions of velocity and acceleration while it rises and falls. What are velocity and acceleration at its highest point?

| Rising: velocity up, acceleration down. Falling: velocity down, acceleration down. At the top, $v = 0$ momentarily, but $a = 9.8 \text{ m/s}^2$ downward. Gravity acts throughout the flight.

2. A rock is dropped from rest and falls for 2.5 s. Find its vertical displacement and final velocity. Use up as positive.

| $\Delta y = \frac{1}{2}(-9.8)(2.5)^2 = -30.625 \text{ m} \approx -31 \text{ m}$. $v_{fy} = (-9.8)(2.5) = -24.5 \text{ m/s} \approx -25 \text{ m/s}$.

3.2 Vector Components

3. A ball launches at 24.0 m/s at 35.0° above horizontal. Find its initial horizontal and vertical velocity components. Sketch the velocity vector and its components.

| $v_x = 24.0 \cos 35.0^\circ = 19.7 \text{ m/s}$. $v_{iy} = 24.0 \sin 35.0^\circ = 13.8 \text{ m/s}$. Draw a right triangle with the resultant 35° above +x, horizontal component right, and vertical component up.

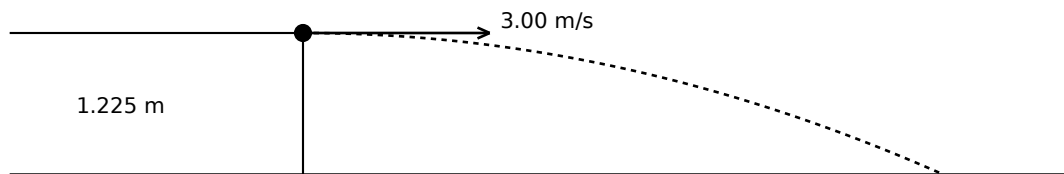
4. A hiker travels 90 m west and then 120 m north. Find the displacement magnitude and direction. Explain why 210 m is not the displacement magnitude.

| $R = \sqrt{(90^2 + 120^2)} = 150 \text{ m}$. $\theta = \tan^{-1}(120/90) = 53^\circ$ north of west. The 210 m value is total path length. Displacement is the straight line from start to finish.

ANSWER KEY

3.3 Horizontal Projectiles

5. A ball rolls horizontally off a 1.225 m high table at 3.00 m/s. Find flight time, horizontal range, and vertical impact velocity.



$-1.225 = \frac{1}{2}(-9.8)t^2$ gives $t = 0.500$ s. $\Delta x = (3.00)(0.500) = 1.50$ m. $v_y = (-9.8)(0.500) = -4.90$ m/s.

6. Two balls leave the same height simultaneously. One is dropped and the other is launched horizontally. Compare their landing times. If the horizontal launch speed doubles, what changes about flight time and range?

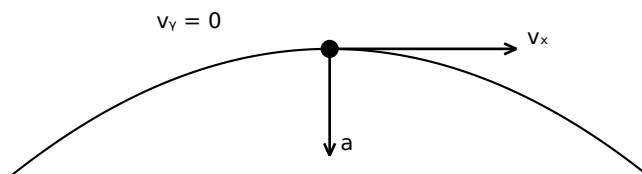
Both have $v_{iy} = 0$ and the same vertical acceleration and drop, so they land together. Doubling horizontal speed leaves flight time unchanged and doubles range. Horizontal motion does not change vertical motion.

3.4 Angled Projectiles

7. A ball launches at 20.0 m/s at 30.0° above level ground and returns to the same height. Find v_x , v_{iy} , total flight time, maximum height, and range.

$v_x = 20.0 \cos 30^\circ = 17.3$ m/s. $v_{iy} = 10.0$ m/s. $t = 2(10.0)/9.8 = 2.04$ s. $H = 10.0^2/(2 \times 9.8) = 5.10$ m. Range = $(17.3)(2.04) = 35.3$ m (using unrounded values).

8. At the highest point of an angled projectile's path, label v_x , v_y , and acceleration. For equal launch speeds and equal launch/landing heights, compare ranges at 30° and 60°. Which launch angle gives maximum range?

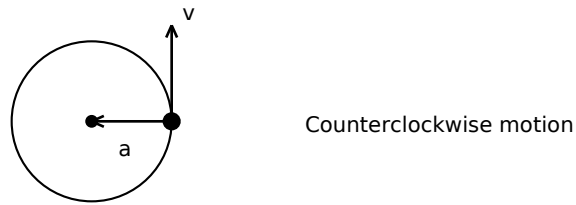


At the top, v_x remains its nonzero initial value, $v_y = 0$, and $a = 9.8$ m/s² downward. The 30° and 60° launches have equal range, but different flight times and heights. Maximum range occurs at 45°.

ANSWER KEY

3.5 Uniform Circular Motion

9. A rider moves counterclockwise at constant speed around a circle. At the rightmost point, draw the velocity and acceleration vectors. Explain how constant speed can occur with nonzero acceleration.



At the rightmost point, velocity is tangent upward and acceleration points left toward the center. Speed stays constant, but velocity changes direction, so acceleration is nonzero.

10. A ride has radius 4.0 m and makes one revolution every 8.0 s. Find the speed and centripetal acceleration.

$v = 2\pi(4.0)/8.0 = 3.14 \text{ m/s} \approx 3.1 \text{ m/s}$. $a_c = v^2/r = 3.14^2/4.0 = 2.47 \text{ m/s}^2 \approx 2.5 \text{ m/s}^2$ inward.

3.6 Centripetal Force

11. A 0.40 kg puck moves in a horizontal circle of radius 0.80 m on a frictionless table at 4.0 m/s. A horizontal string pulls it inward. Find tension and draw its free-body diagram.

$F_T = mv^2/r = (0.40)(4.0)^2/0.80 = 8.0 \text{ N}$ inward. FBD: tension toward center, weight down, normal up. Normal and weight balance vertically. Do not add a separate centripetal-force arrow.

12. A 1200 kg car travels at 12 m/s around a flat curve of radius 48 m. Find the inward net force and name the force that provides it. How does the required force change if speed doubles?

$F = mv^2/r = (1200)(12^2)/48 = 3600 \text{ N}$ inward. Static friction from the road provides it. Doubling speed multiplies force by four, to 14,400 N for the same radius.

ANSWER KEY**Unit 3 Review**

13. A ball is tossed straight up at 19.6 m/s and caught at its launch height. Find time to the top, maximum height, total flight time, and velocity just before the catch.

| $t_{\text{up}} = 19.6/9.8 = 2.00 \text{ s}$. $H = 19.6^2/(2 \times 9.8) = 19.6 \text{ m}$. Total time = 4.00 s. Final velocity = -19.6 m/s with up positive.

14. A projectile leaves a ledge horizontally at 8.0 m/s and lands 16 m from its base. Find flight time and ledge height.

| $t = \Delta x/v_x = 16/8.0 = 2.0 \text{ s}$. Height = $\frac{1}{2}gt^2 = \frac{1}{2}(9.8)(2.0)^2 = 19.6 \text{ m} \approx 20 \text{ m}$.

15. A string breaks while a puck travels in a horizontal circle. Sketch the puck's immediate path as seen from above. Explain why it does not initially move directly outward from the center.

| The puck leaves along a straight tangent in the direction of its instantaneous velocity. Removing the inward force removes centripetal acceleration. It does not create a radial outward force.

16. Name the real force that provides the inward net force for (a) a satellite in orbit, (b) a car on a flat curve, and (c) a person pressed against a rotating ride's vertical wall. For (c), what force can hold the person up?

| (a) Gravity. (b) Static friction. (c) The wall's normal force points inward. Static friction from the wall can point upward and balance the rider's weight.