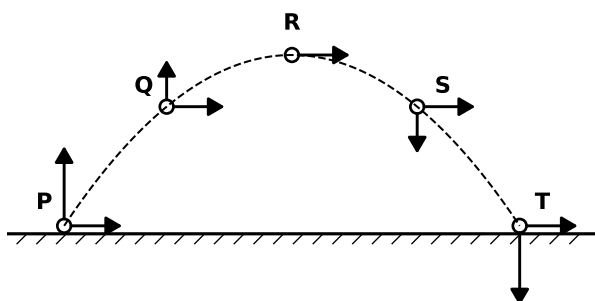


Part A: Concepts

Ignore air resistance. The ground is level in every problem.

1. A soccer ball is kicked from P and lands at T. Points Q and S are at the same height, and R is the top of the path.



- At which point is the vertical velocity zero? Is the ball's speed zero there? Explain.
- What is the ball's acceleration at R (size and direction)?
- Compare the ball's speed at Q and at S, and its speed at P and at T.
- On the diagram, draw the horizontal and vertical velocity components at each point.
 - At **R**, the top. The speed is **not zero**: the ball still has its horizontal velocity v_x , which never changes. At the top the velocity is all horizontal.
 - 9.8 m/s^2 downward** ($a = -9.8 \text{ m/s}^2$), the same as everywhere else on the path.
 - The path is symmetric, so the speed at Q **equals** the speed at S, and the speed at P **equals** the speed at T (it lands with its launch speed).
 - Every horizontal arrow is the same length. Vertical arrows point up and shrink from P to Q, are zero at R, and point down and grow from S to T (P and T match, Q and S match).

Part B: Launch Calculations

$v_x = v_i \cos \theta$, $v_{iy} = v_i \sin \theta$, $a = -9.8 \text{ m/s}^2$, $v_y = 0$ at the top. Show your knowns, equation, substitution, and answer with units.

2. A long jumper leaves the ground at 9.00 m/s at 20.0° above the horizontal.
- How long is she in the air?
 - How far does she jump?
 - Her coach says she would jump farther at a launch angle closer to 45° . Explain why.

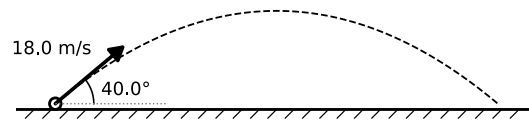
Components: $v_x = (9.00 \text{ m/s})(\cos 20.0^\circ) = 8.46 \text{ m/s}$, $v_{iy} = (9.00 \text{ m/s})(\sin 20.0^\circ) = 3.08 \text{ m/s}$

a. $t_{\text{up}} = (0 - 3.08 \text{ m/s}) / (-9.8 \text{ m/s}^2) = 0.314 \text{ s}$, so $t_{\text{total}} = 2(0.314 \text{ s}) = \mathbf{0.628 \text{ s}}$

b. $\Delta x = v_x \times t_{\text{total}} = (8.46 \text{ m/s})(0.628 \text{ s}) = \mathbf{5.31 \text{ m}}$

c. At 20.0° she moves forward fast but lands quickly because v_{iy} is small. A steeper angle gives more hang time. On level ground, 45° is the best balance between forward speed and time in the air, so it gives the maximum range.

3. Diego kicks a ball from the ground at 18.0 m/s at 40.0° above the horizontal.



- Find v_x and v_{iy} .
 - How long does the ball take to reach the top? What is its total hang time?
 - What is the ball's maximum height?
 - How far away does it land (its range)?
- a.** $v_x = (18.0 \text{ m/s})(\cos 40.0^\circ) = \mathbf{13.8 \text{ m/s}}$ $v_{iy} = (18.0 \text{ m/s})(\sin 40.0^\circ) = \mathbf{11.6 \text{ m/s}}$ (up)
b. $v_{fy} = v_{iy} + at$ with $v_{fy} = 0$: $t_{up} = (0 - 11.6 \text{ m/s}) / (-9.8 \text{ m/s}^2) = \mathbf{1.18 \text{ s}}$. Symmetric path: $t_{total} = 2(1.18 \text{ s}) = \mathbf{2.36 \text{ s}}$
c. $\Delta y = (v_{fy}^2 - v_{iy}^2) / 2a = (0 - (11.6 \text{ m/s})^2) / 2(-9.8 \text{ m/s}^2) = (-134 \text{ m}^2/\text{s}^2) / (-19.6 \text{ m/s}^2) = \mathbf{6.83 \text{ m}}$
d. $\Delta x = v_x \times t_{total} = (13.8 \text{ m/s})(2.36 \text{ s}) = \mathbf{32.6 \text{ m}}$

4. A water fountain shoots two streams at the same speed, 6.00 m/s. Stream A leaves at 60.0° and stream B leaves at 30.0° above the horizontal.
- Find the range of stream A.
 - Without a full calculation, predict the range of stream B. Explain.
 - Which stream goes higher? Explain using v_{iy} .
- a.** $v_x = (6.00 \text{ m/s})(\cos 60.0^\circ) = 3.00 \text{ m/s}$, $v_{iy} = (6.00 \text{ m/s})(\sin 60.0^\circ) = 5.20 \text{ m/s}$
 $t_{total} = 2 \times (5.20 \text{ m/s} \div 9.8 \text{ m/s}^2) = 1.06 \text{ s}$, so $\Delta x = (3.00 \text{ m/s})(1.06 \text{ s}) = \mathbf{3.18 \text{ m}}$
b. $\mathbf{3.18 \text{ m}}$, the same range. 30° and 60° add up to 90°, and angles that add to 90° give the same range at the same speed. (Check: $v_x = 5.20 \text{ m/s}$, $t = 0.612 \text{ s}$, $\Delta x = 3.18 \text{ m}$.)
c. Stream A. Its $v_{iy} = 5.20 \text{ m/s}$ is larger than stream B's 3.00 m/s, and only the vertical component decides how high a projectile rises.