NAME ______________ DATE __________ CLASS ____________

Holt Physics

Problem 3E

PROJECTILES LAUNCHED AT AN ANGLE

PROBLEM

A flying fish leaps out of the water with a speed of 15.3 m/s. Normally these fish use winglike fins to glide about 40 m before reentering the ocean, but in this case the fish fails to use its "wings" and so only travels horizontally about 17.5 m. At what angle with respect to the water's surface does the fish leave the water? Use the trigonometric identity 2(sinθ)(cosθ) = sin (2θ) to solve for θ.

SOLUTION

1. DEFINE

Given:

$v_i = 15.3$ m/s

$\Delta x = 17.5$ m

$g = 9.81$ m/s^2

Unknown: $\theta = ?$

Diagram:

2. PLAN

Choose the equation(s) or situation: The horizontal component of the fish's initial velocity, v_x, is equal to the horizontal displacement divided by the time of the jump.

$$v_x = v_i(\cos\theta) = \frac{\Delta x}{\Delta t}$$

The vertical displacement of the fish is given by the equation for falling bodies, with the vertical component of the initial velocity, v_y, used.

$$\Delta y = v_y \Delta t - \frac{1}{2} g \Delta t^2$$

Because the fish lands at the same vertical position from which it started, $\Delta y = 0$.

$$\Delta y = 0$$
$$v_y = v_i(\sin\theta) = \frac{1}{2} g \Delta t$$

Rearrange the equation(s) to isolate the unknowns: Substitute for Δt using the equation for horizontal velocity.

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$$

$$v_i(\sin\theta) = \frac{1}{2} g \left[\frac{\Delta x}{v_i(\cos\theta)}\right]$$

$$(\sin\theta)(\cos\theta) = \frac{g\Delta x}{2v_i^2}$$

Using the trigonometric identity allows a solution for θ to be found.

$$(\sin\theta)(\cos\theta) = \frac{1}{2}[\sin(2\theta)]$$

$$\sin(2\theta) = \frac{g\Delta x}{v_i^2}$$

3. CALCULATE

$$\theta = \frac{\sin^{-1}\left(\frac{g\Delta x}{v_i^{\,2}}\right)}{2}$$

$$\theta = \frac{\sin^{-1}\left[\frac{(9.81\ \text{m/s}^2)(17.5\ \text{m})}{(15.3\ \text{m/s})^2}\right]}{2}$$

$$= \boxed{23.6° \text{ above the horizontal}}$$

4. EVALUATE

Substituting the value for θ into the original equations and solving for Δt produces a time of 1.25 s for both, thus confirming the result for θ.

ADDITIONAL PRACTICE

1. A baseball is thrown with an initial speed of 15.0 m/s. If the ball's horizontal displacement is 17.6 m, at what angle with respect to the ground is the ball pitched? Use the trigonometric identity $2(\sin\theta)(\cos\theta) = \sin(2\theta)$ to solve for θ.

2. A football is kicked so that its initial speed is 23.1 m/s. If the football reaches a maximum height of 16.9 m, at what angle with respect to the ground is the ball kicked?

3. Jackie Joyner-Kersee's record long jump is 7.49 m. Suppose she ran 9.50 m/s to jump this horizontal distance. At what angle above the horizontal did she jump? Use the trigonometric identity $2(\sin\theta)(\cos\theta) = \sin(2\theta)$ to solve for θ.

4. The small jumping spiders make up for their size by their ability to leap relatively large distances. Some can jump fifty times the length of their bodies. Suppose a jumping spider leaps a horizontal distance of 18.5 cm with an initial speed of about 141 cm/s. At what angle above the horizontal would a spider with this speed have to leap in order to travel a range of 18.5 cm? Use the trigonometric identity $2(\sin\theta)(\cos\theta) = \sin(2\theta)$ to solve for θ.

5. Olympic platform divers jump from a diving board that is 10.0 m above the water. Suppose a diver jumps from the board with an initial speed of 6.03 m/s. The diver reaches a maximum height of 11.7 m above the water, and lands in the water at a horizontal distance of 3.62 m from the end of the board. At what angle with respect to the board does the diver leave the board?

6. A ball is thrown from a roof with a speed of 10.0 m/s and an angle of 37.0° with respect to the horizontal. What are the vertical and horizontal components of the ball's displacement 2.5 s after it is thrown?

7. A downed pilot fires a flare from a flare gun. The flare has an initial speed of 250 m/s and is fired at an angle of 35° to the ground. How long does it take for the flare to reach its maximum altitude?

8. In the sport of ski jumping, a skier travels down the slope of a hill until he or she reaches the takeoff. The takeoff is slanted slightly below the horizontal, so that the skier is able to travel in the air just above the ground. Suppose a skier leaves the takeoff and lands 73.0 m horizontally beyond the takeoff and –52.8 m below the takeoff. If the takeoff angle is –8.00° below the horizontal, what is the skier's initial speed?

9. A shingle slides down a roof having a 30.0° pitch and falls off with a speed of 2.0 m/s. How long will it take to hit the ground 45 m below?

10. A hole at a miniature golf course requires the ball to roll up a ramp, fly over a small stream, and then land on the green beyond the stream. The stream is 0.46 m wide, and the cup is 4.00 m beyond the stream's edge. The ramp makes an angle of 41.0° with the horizontal, and its upper edge is 0.35 m above the green. What must the ball's initial speed be in order for the ball to fly over the water and land directly in the cup?