NOTE: I avoided my usual "$d=\frac{1}{2}at^2$" and calling down +

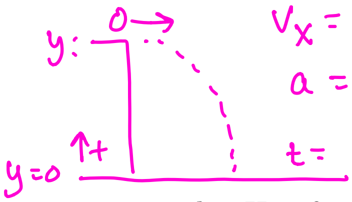
ABRHS Physics (H) NAME: KEY

Projectile Motion Problems

In each of these problems, unless otherwise noted, use $|g| = 10\ m/s^2$. Ignore air resistance.

1. A ball rolls off the edge of a table. It has an initial horizontal velocity of 3 m/s and is in the air for 0.75 seconds before hitting the floor.

   a. How high is the table?



given: $v_x = 3\ m/s$, $v_{y_i} = 0\ m/s$, $a = -10\ m/s^2$, $t = 0.75\ s$

$y = \frac{1}{2}at^2 + v_{y_i}t + y_i$

to land: $0 = \frac{1}{2}(-10)(.75)^2 + y_i$

$y_i = 2.81\ m$

   b. How far away from the edge of the table does the ball land?

$x = v_x t$

$x = (3)(.75)$

$x = 2.25\ m$

   c. What are the horizontal and vertical components of the ball's velocity when it lands?

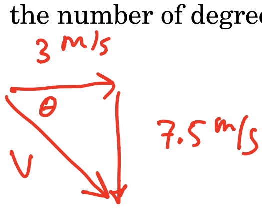
$v_x = 3\ m/s$ ← doesn't change!

$v_y = at + v_{y_i}$

$v_y = -10(.75)$

$v_y = -7.5\ m/s$

   d. What is the magnitude and direction of the ball's velocity when it lands? Give the angle as the number of degrees below the horizontal.



$v^2 = 3^2 + 7.5^2$

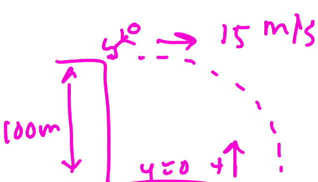
$v = 8.1\ m/s$

$\tan\theta = \frac{7.5}{3}$

$\theta = 68.2°$

2. The Coyote is chasing the Road Runner when the Road Runner suddenly stops at the edge of a convenient cliff. The Coyote, traveling with a speed of 15 m/s, does not stop and goes flying off the edge of the cliff, which is 100 meters high.

   a. How long is the Coyote in the air?



given: $v_x = 15\ m/s$, $a = -10\ m/s^2$, $v_{y_i} = 0\ m/s$, $y_i = 100\ m$

$y = \frac{1}{2}at^2 + v_{y_i}t + y_i$

$0 = \frac{1}{2}(-10)t^2 + 100$

$5t^2 = 100$

$t = 4.47\ s$

   b. Where does the Coyote land?

$x = v_x t$

$x = (15)(4.47)$

$x = 67.1\ m$

Projectile Motion Problems

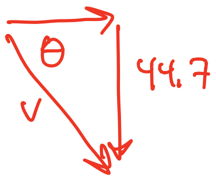
c. What are the horizontal and vertical components of the Coyote's velocity when he lands?

$V_y = at + V_{y_i}$

$V_y = -10(4.47)$

$V_y = -44.7$ m/s & $V_x = 15$ m/s

d. What is the magnitude and direction of the Coyote's velocity when he lands? Give the angle as the number of degrees below the horizontal.



$v^2 = 15^2 + 44.7^2$

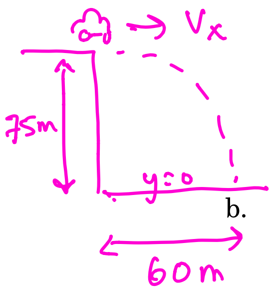
$v = 47.2$ m/s

$\tan\theta = \frac{44.7}{15}$

$\theta = 71.5°$

3. A car full of bad guys goes off the edge of a cliff. If the cliff was 75 meters high, and the car landed 60 meters away from the edge of the cliff, calculate the following:

a. The total time the car was in the air.



$V_{y_i} = 0$ m/s

$y_i = 75$ m

$a = -10$ m/s^2

$x_{land} = 60$ m

$y = \frac{1}{2}at^2 + V_{y_i}t + y_i$

$0 = \frac{1}{2}(-5)t^2 + 75$

$5t^2 = 75$

$t = 3.87$ s

b. The initial velocity of the car.

$x = V_x t$

$60 = V_x(3.87)$

$V_x = 15.5$ m/s & $V_{y_i} = 0$ m/s

could also say $15.5\hat{i} + 0\hat{j}$ m/s

c. The final velocity of the car just as it hits the ground. (Give the components.)

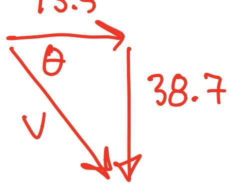
$V_y = at + V_{y_i}$

$V_y = -10(3.87)$

$V_y = -38.7$ m/s

$V_x = 15.5$ m/s

d. The final velocity of the car just as it hits the ground. (Give the magnitude and direction.)



$v^2 = 38.7^2 + 15.5^2$

$v = 41.7$ m/s

$\tan\theta = \frac{38.7}{15.5}$

$\theta = 68.2°$

Projectile Motion Problems

Now these include up and down motion!

4. Mary throws a ball to Suzy, who is standing 25 meters away. Suzy catches the ball from the same height at which it was thrown. If the ball was in the air for 4 seconds, calculate the following:

   a. Horizontal velocity.

$y_i = 0$

$x_{land} = 25$ m

$t_{land} = 4$ s

$a = -10$ m/s²

$x = v_x t$

$25 = v_x(4)$

$v_x = 6.25$ m/s

   b. Maximum height of the ball.

Make the problem easier: If something were dropped how far would it fall in 2 seconds? → $0 = \frac{1}{2}(-10)(2)^2 + y_i$ → $y_i = 20$ m

→ OR do part c first, then $y = \frac{1}{2}at^2 + v_{y_i}t + y_o$

$y = \frac{1}{2}(-10)(2^2) + (20)(2)$

$y = 20$ m

   c. Initial vertical velocity.

$v_y = 0$ @ max height

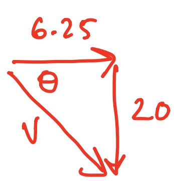
$t = 2$ to max height

∴ $v_y = at + v_{y_i}$

$0 = -10(2) + v_{y_i}$

$v_{y_i} = 20$ m/s

   d. The magnitude and direction of the ball's velocity when caught by Suzy. Give the angle as the number of degrees below the horizontal.



$v^2 = 6.25^2 + 20^2$

$v = 21$ m/s

$\tan\theta = \frac{20}{6.25}$

$\theta = 72.6°$

   e. What happens to the components of the velocity and the acceleration as the ball flies through the air?

v_x stays constant the entire time $(6.25\hat{i})$

the acceleration also stays constant $(-10\hat{j})$

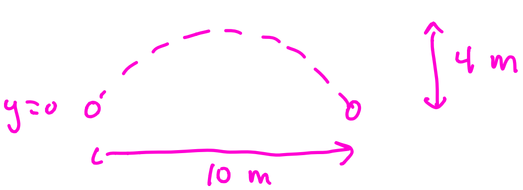
v_y changes @ constant rate – @ second –10 m/s

5. Larry tosses a volleyball to his wife, Lise, who catches it at the same height from which it was tossed. The volleyball travels a horizontal distance of 10 meters, and has a maximum height of 4 meters (above from where it was hit.)

   a. How long was the volleyball in the air?

$y_i = 0$ m

$a = -10$ m/s²



How long would it take to fall 4 m? (i.e. $v_{y_i} = 0$)

$y = \frac{1}{2}at^2 + v_{y_i}t + y_i$

$0 = \frac{1}{2}(-10)t^2 + 4$

$5t^2 = 4$

$t = 0.89$ s

so total time = 2(.89) = 1.79 s

Projectile Motion Problems

b. What was the initial horizontal velocity?

$X = V_x t$

$10 = V_x (1.79)$

$V_x = 5.59$ m/s

OR

$4 = \frac{1}{2}(-10)t^2 + V_{y_i} t$

&

$0 = -10t + V_{y_i}$

2 equations, 2 unknowns

c. What was the initial vertical velocity? → OR $V_f^2 = V_i^2 + 2a\Delta x$

$0 = V_{y_i}^2 + 2(-10)(4)$

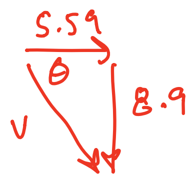
$V_y = 0$ @ Max Height

$t = 0.89$ to Max Height

$V_y = at + V_{y_i}$ → $0 = -10(0.89) + V_{y_i}$

$V_{y_i} = 8.9$ m/s

d. What was the magnitude and direction of the ball's velocity when caught by Lise. Give the angle as the number of degrees below the horizontal.



$v^2 = (5.59)^2 + (8.9)^2$

$V = 10.5$ m/s

$\tan\theta = \frac{8.9}{5.59}$

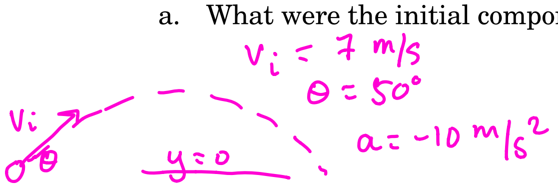
$\theta = 58°$

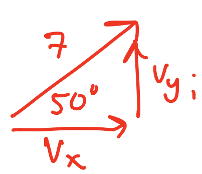
e. What was the acceleration of the volleyball after 1 second? Give the magnitude and direction.

10 m/s² DOWN it's just gravity :)

6. A student tosses an eraser to his friend. The initial velocity of the eraser was 7 m/s at an angle of 50° above the horizontal. The friend catches the eraser at the same level from which it was tossed.

a. What were the initial components of the eraser's velocity?





$V_x = 7\cos 50$

$V_x = 4.5$ m/s

$V_{y_i} = 7\sin 50$

$V_{y_i} = 5.36$ m/s

b. How long was the eraser in the air?

$V_y = -5.36$ when it lands, so

$V_y = at + V_{y_i}$

$-5.36 = -10t + 5.36$

$t = 1.07$ s

c. How far apart were the two friends?

$X = V_x t$

$X = (4.5)(1.07)$

$X = 4.83$ m

Projectile Motion Problems

d. What was the maximum height of the eraser?

t to the max height = $\frac{1}{2}$ total time

∴ t = 0.536 s

$y = \frac{1}{2}at^2 + v_{y_i}t + y_i$

$y = \frac{1}{2}(-10)(.536)^2 + (5.36)(.536) =$ **1.44 m**

e. What were the components of the velocity at the top of its flight?

$V_y = 0$ m/s

$V_x = 4.5$ m/s

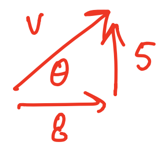
7. A kangaroo is jumping across a field in the outback. The kangaroo jumps with an initial horizontal velocity of 8 m/s and an initial vertical velocity of 5 m/s.

a. What was the initial velocity of the kangaroo? (Magnitude and direction)

$v_x = 8$ m/s

$v_{y_i} = 5$ m/s

$a = -10$ m/s²



$v^2 = 5^2 + 8^2$

V = 9.43 m/s

$\tan\theta = \frac{5}{8}$ **θ = 32°**

b. How long was the kangaroo in the air?

$V_y = 0$ @ Max Height

$0 = -10t + 5$

$t = .5$ (to top) So total time: $2(.5) =$ **1 s**

c. What was the maximum height of the kangaroo?

$y = \frac{1}{2}at^2 + v_{y_i}t + y_i$

$y = \frac{1}{2}(-10)(.5)^2 + (5)(.5)$ **y = 1.25 m**

d. What was the horizontal distance of the kangaroo's jump?

$X = V_x t$

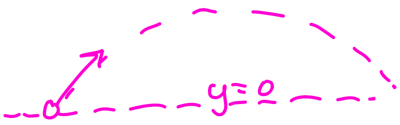
$X = (8)(1)$

X = 8 m

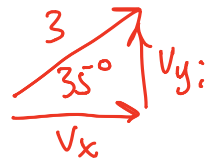
Projectile Motion Problems

8. An astronaut on the moon tosses a rock with an initial velocity of 3 m/s at an angle of 35° above the horizontal. The acceleration due to gravity on the moon is 1.7 m/s^2.

a. What are the components of the initial velocity?



$v_i = 3$ m/s
$\theta_i = 35°$
$a = -1.7$ m/s^2



$v_x = 3\cos 35$
$v_x = 2.46$ m/s

$v_{yi} = 3\sin 35$
$v_{yi} = 1.72$ m/s

b. How long was the rock "in the air?"

$v_y = at + v_{yi}$

$-1.72 = (-1.7)t + 1.72$

$t = 2.02$ s

c. What was the maximum height of the rock?

So time to top $= 2.02/2 = 1.01$ s

$y = \frac{1}{2}at^2 + v_{yi}t + y_i$

$y = \frac{1}{2}(-1.7)(1.01)^2 + (1.72)(1.01)$

$y = 0.87$ m

d. What was the horizontal distance traveled by the rock?

$x = v_x t$

$x = (2.46)(2.02)$

$x = 4.97$ m

Projectile Motion Problems

Answers:

1. a) 2.81 m
   b) 2.25 m
   c) v_x = 3 m/s & v_y = 7.5 m/s down
   d) v = 8.1 m/s at an angle of 68.2° below the horizontal

2. a) 4.47 s
   b) 67.1 m from the base of the cliff
   c) v_x = 15 m/s & v_y = 44.7 m/s down
   d) v = 47.2 m/s at an angle of 71.5° below the horizontal

3. a) 3.87 s
   b) v_x = 15.5 m/s & v_y = 0 m/s
   c) v_x = 15.5 m/s & v_y = 38.7 m/s down
   d) v = 41.7 m/s at an angle of 68.2° below the horizontal

4. a) 6.25 m/s
   b) 20 m
   c) 20 m/s up
   d) v = 21 m/s at an angle of 72.7° below the horizontal
   e) v_x = constant = 6.25 m/s & acceleration = constant = 10 m/s^2 down & v_y starts positive 20 m/s (up) decreases to 0 m/s at top and continues to decrease to -20 m/s (down) when finally caught

5. a) 1.79 s
   b) 5.6 m/s
   c) 8.9 m/s up
   d) v = 10.5 m/s at an angle of 57.8° below the horizontal
   e) acceleration = gravity = 10 m/s^2 down

6. a) v_x = 4.5 m/s & v_y = 5.36 m/s up
   b) 1.07 s
   c) 4.82 m
   d) 1.44 m
   e) v_x = 4.5 m/s & v_y = 0 m/s

7. a) v = 9.43 m/s at an angle of 32° above the horizontal
   b) 1.0 s
   c) 1.25 m
   d) 8 m

8. a) v_x = 2.46 m/s & v_y = 1.72 m/s up
   b) 2.02 s
   c) 0.87 m
   d) 4.97 m