PHYSICS 11
Projectile Motion Worksheet

1- You stand on a cliff 30. m high. You throw 3 rocks off the cliff. The first rock is thrown straight up at 10. m/s. The second rock is dropped off the cliff. The third rock is thrown straight down at 10. m/s. Calculate the time of flight and the final velocity of each rock as it strikes the ground at the bottom of the cliff.

Case 1: thrown up at 10. m/s (assume up is positive)

$$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\vec{d} \;\therefore\; \vec{v}_f = \sqrt{\vec{v}_i^{\,2} + 2\vec{a}\vec{d}} = \sqrt{(10.\ \text{m}\bullet\text{s}^{-1})^2 + 2(-9.8\ \text{m}\bullet\text{s}^{-2})(-30.\ \text{m})} = -26\ m\bullet s^{-1}$$

$$t = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}} = \frac{-26\ m\bullet s^{-1} - 10.\ m\bullet s^{-1}}{-9.8\ m\bullet s^{-2}} = 3.7\ s$$

Case 2: dropped off the cliff (assume up is positive)

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2 \textit{ where } v_i = 0 \textit{ so that the equation becomes}$$

$$\vec{d} = \frac{1}{2}\vec{a}t^2 \;\therefore\; t = \sqrt{\frac{2\vec{d}}{\vec{a}}} = \sqrt{\frac{2(-30.\ \text{m})}{-9.8\ \text{m}\bullet\text{s}^{-2}}} = 2.5\ \text{s}$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t = 0\ m\bullet s^{-1} + (-9.8\ m\bullet s^{-2} x\ 2.5s) = -24\ m\bullet s^{-1}$$

Case 3: thrown down at 10. m/s (assume down is positive)

$$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\vec{d} \;\therefore\; \vec{v}_f = \sqrt{\vec{v}_i^{\,2} + 2\vec{a}\vec{d}} = \sqrt{(10.\ \text{m}\bullet\text{s}^{-1})^2 + 2(9.8\ \text{m}\bullet\text{s}^{-2})(30.\ \text{m})} = 26\ m\bullet s^{-1}$$

$$t = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}} = \frac{26\ m\bullet s^{-1} - 10.\ m\bullet s^{-1}}{9.8\ m\bullet s^{-2}} = 1.6\ s$$

2- A car drives off a wharf at 15 m/s. If the wharf is 25 m above water, calculate…
   a) the time of flight. Assume down is positive.

$$\vec{d}_y = \vec{v}_{yi}t + \frac{1}{2}\vec{a}t^2 \ \textit{where}\ \vec{v}_{yi} = 0 \ \textit{so that the equation becomes}$$

$$\vec{d}_y = \frac{1}{2}\vec{a}t^2 \ \therefore\ t = \sqrt{\frac{2\vec{d}_y}{\vec{a}}} = \sqrt{\frac{2(25\ m)}{9.8\ m\bullet s^{-2}}} = 2.3\ s$$

b) the horizontal distance traveled

$$\vec{d}_x = \vec{v}_x \bullet t = 15\ m\bullet s^{-1}\ x\ 2.3\ s = 34\ m$$

c) the velocity at which the car hits the water.

Find $\vec{v}_{yf}$, then combine that vector with $\vec{v}_x$.

$$\vec{v}_{yf}^{\ 2} = \vec{v}_{yi}^{\ 2} + 2\vec{a}\vec{d} \ \therefore\ \vec{v}_{yf} = \sqrt{\vec{v}_{yi}^{\ 2} + 2\vec{a}\vec{d}} = \sqrt{(0\ \text{m}\bullet\text{s}^{-1})^2 + 2(9.8\ \text{m}\bullet\text{s}^{-2})(25\ \text{m})} = 22\ m\bullet s^{-1}$$

$$\vec{v}_f^{\ 2} = \vec{v}_{yf}^{\ 2} + \vec{v}_x^{\ 2} \ \therefore\ \vec{v}_f = \sqrt{\vec{v}_{yf}^{\ 2} + \vec{v}_x^{\ 2}} = \sqrt{(22\ \text{m}\bullet\text{s}^{-1})^2 + (15\ \text{m}\bullet\text{s}^{-1})^2} = 26\ m\bullet s^{-1}$$

Angle relative to the water = 90°-θ

$$\tan\theta = \frac{15m\bullet s^{-1}}{22m\bullet s^{-1}} \ \therefore\ \theta = \tan^{-1}\left(\frac{15}{22}\right) = 34°$$

So that $\vec{v}_f = 26\ m\bullet s^{-1}\ \textit{at}\ 56°\ \textit{relative to the water}$ v

3- A golfer strikes her tee shot at 125 m/s with an angle of 32° above the horizontal. Assuming the golf hole is level, calculate
   a) the time of flight. Assume up is positive.

Find v_x and v_{yi}.

$$v_x = 125\ m\bullet s^{-1}(\cos\ 32°) = 106\ m\bullet s^{-1}\ \textit{and}\ v_{yi} = 125\ m\bullet s^{-1}(\sin\ 32°) = 66.2\ m\bullet s^{-1}$$

$$\vec{d}_y = \vec{v}_{yi}t + \frac{1}{2}\vec{a}t^2 \text{ where } \vec{d}_y = 0\ m \text{ so that the equation becomes}$$

$$t = -\frac{2\vec{v}_{yi}}{\vec{a}} = -\frac{2(66.2 m\bullet s^{-1})}{-9.8 m\bullet s^{-2}} = 14\ s$$

b) the horizontal distance traveled

$$\vec{d}_x = \vec{v}_x \bullet t = 106\ m\bullet s^{-1} \ x\ 14\ s = 1.5 \ x\ 10^3\ m$$

4- A marble with a speed of 20.0 cm/s rolls off the edge of a table 80.0 cm high.

a) How long does it take it to hit the floor? Assume down is positive

$$\vec{d}_y = \vec{v}_{yi}t + \frac{1}{2}\vec{a}t^2 \text{ where } \vec{v}_{yi} = 0 \text{ so that the equation becomes}$$

$$\vec{d}_y = \frac{1}{2}\vec{a}t^2 \ \therefore\ t = \sqrt{\frac{2\vec{d}_y}{\vec{a}}} = \sqrt{\frac{2(0.800\ m)}{9.8\ m\bullet s^{-2}}} = 0.40\ s$$

b) How far from the table will it hit the floor?

$$\vec{d}_x = \vec{v}_x \bullet t = 0.200\ m\bullet s^{-1} \ x\ 0.40\ s = 0.080\ m$$

5- A Frisbee is thrown at a speed of 40.0 m/s at an angle to the horizontal. If it strikes the ground 3.00 seconds after being thrown, and it covers a distance of 65.0 m, at what angle was it thrown with respect to the ground? Assume no air resistance.

Find the horizontal velocity.

$$\vec{d}_x = \vec{v}_x \bullet t \ \therefore\ \vec{v}_x = \frac{\vec{d}_x}{t} = \frac{65.0m}{3.00s} = 21.7\ m\bullet s^{-1}$$

To find the angle θ: $\cos\ \theta = \frac{21.7m\bullet s^{-1}}{40.0m\bullet s^{-1}} \ \therefore\ \theta = \cos^{-1}(\frac{21.7}{40.0}) = 57.1°$

6- A terrorist throws a grenade with a 3.00 second fuse off a building 170.0 m high at a speed of 7.50 m/s. If the angle at which the grenade is thrown is 35° below the horizontal, will the grenade explode before hitting the ground? Assume down is positive.

Find $\vec{v}_{yi}$: $\vec{v}_{yi} = 7.5\ m\bullet s^{-1}\ (\sin 35°) = 4.3\ m\bullet s^{-1}$

Now find the time it would take for the grenade to hit the ground:

$$\vec{v}_{yf}^{\ 2} = \vec{v}_{yi}^{\ 2} + 2\vec{a}\vec{d} \ \therefore\ \vec{v}_{yf} = \sqrt{\vec{v}_{yi}^{\ 2} + 2\vec{a}\vec{d}} = \sqrt{(4.3\ \text{m}\bullet\text{s}^{-1})^2 + 2(9.8\ \text{m}\bullet\text{s}^{-2})(170.0\ \text{m})} = 57\ m\bullet s^{-1}$$

$$t = \frac{\vec{v}_{yf} - \vec{v}_{yi}}{\vec{a}} = \frac{57\ m\bullet s^{-1} - 4.3\ m\bullet s^{-1}}{9.8\ m\bullet s^{-2}} = 5.4\ s$$

The grenade will explode 2.4 seconds before hitting the ground.