Projectile Motion Assignment 1 ***SOLUTIONS***

1. a)

$v_{0_V} = v_0 \sin\theta \qquad a_V = \text{-9.81ms}^{-1} \qquad s_V = 0\text{m} \qquad t = ?$

$= 20\sin 20°$

$= 6.84\text{ms}^{-1}$

$s_V = v_{0_V} t + \frac{1}{2} a_V t^2$

$\therefore 0 = v_{0_V} t + \frac{1}{2} a_V t^2$

$\therefore 0 = t\left(v_{0_V} + \frac{1}{2} a_V t\right)$

$\therefore t = 0$ or $v_{0_V} + \frac{1}{2} a_V t = 0$

Consider $v_{0_V} + \frac{1}{2} a_V t = 0$

$\therefore t = \dfrac{-v_{0_V}}{\frac{1}{2} a_V}$

$\therefore t = \dfrac{-6.84}{\frac{1}{2}(-9.8)} = 1.4 \text{ s}$

b)

$v_H = v_{0_H} = v_0 \cos\theta \quad t = 1.4\ s \qquad s_H = ?$

$= 20\cos 20°$

$= 18.79\text{ms}^{-1}$

$s_H = v_H t$

$= 18.79 \times 1.4$

$= 26.2$

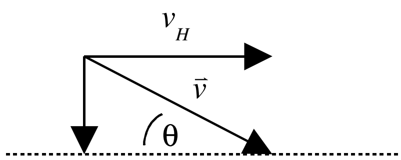
The distance between the players is 26m

c)

$v_V = v_{0_V} + a_V t \qquad v_H = v_{0_H} = 18.79\text{ms}^{-1}$

$= 6.84 + \text{-}9.8 \times 1.4$

$= -6.8\text{ms}^{-1}$



$v = \sqrt{(\text{-}6.8)^2 + 18.79^2}$

$= 20\ \text{ms}^{-1}$

$\theta = \tan^{-1}\left(\dfrac{v_V}{v_H}\right)$

$= \tan^{-1}\left(\dfrac{\text{-}6.8}{18.79}\right)$

$= \text{-}20°$ {Negative sign means below horizontal.}

So the velocity of the ball on hitting the second player's toes is 20ms^{-1} at 20° below the horizontal.

2.

a) $s_H = 10$ m $v = ?$ $\theta = 70°$ $a_V = -g$

$v_{0_V} = v_0 \sin 70°$

Since the object lands at its launch height, $v_V = -v_{0_V}$

$$v_V = v_{0_V} + a_V t$$
$$\therefore -v_{0_V} = v_{0_V} - gt$$
$$\therefore 2v_{0_V} = gt$$
$$\therefore t = \frac{2v_{0_V}}{g}$$
$$\therefore t = \frac{2v_0 \sin 70°}{g}$$

b) $s_H = v_H t$

$$\therefore v_H = \frac{s_H}{t}$$
$$\therefore v_H = \frac{s_H\, g}{2v_0 \sin 70°}$$

c) Initial and final horizontal components of velocity are the same, so $v_H = v_{0_H} = v_0 \cos\theta$

From part b, $v_H = \dfrac{s_H\, g}{2v_0 \sin 70°}$

$$\therefore v_0 \cos 70° = \frac{s_H\, g}{2v_0 \sin 70°}$$
$$\therefore v_0{}^2 = \frac{s_H\, g}{2\cos 70° \sin 70°}$$

Speed can't be negative, so $v_0 = \sqrt{\dfrac{s_H\, g}{2\cos 70° \sin 70°}}$

$$\therefore v_0 = \sqrt{\frac{10 \times 9.8}{2\cos 70° \sin 70°}} = 12.34 \text{ ms}^{-1}$$

The boule's initial velocity will need to be 12 ms^{-1} at 70° above the horizontal.

3.

a) In order to find the horizontal range of the projectile, in this case we need the time of flight first.

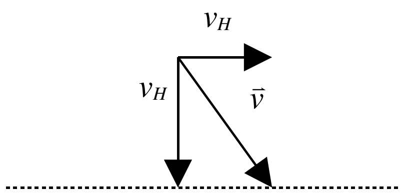
$a_V = -9.8\text{ms}^{-2}$ $s_V = -10\text{m}$ $v_{0_V} = 0 \text{ ms}^{-1}$ $v_H = 7.0 \text{ ms}^{-1}$ $t = ?$

$$s_V = v_{0_V} t + \tfrac{1}{2} a_V t^2$$
$$\therefore s_V = \tfrac{1}{2} a_V t^2$$
$$\therefore t = \sqrt{\frac{s_V}{\frac{1}{2} a_V}}$$
$$\therefore t = \sqrt{\frac{-10}{\frac{1}{2} \times (-9.8)}} = 1.4 \text{ s}$$

$$s_H = v_H t$$
$$= 7.0 \times 1.4$$
$$= 10 \text{ m}$$

It is very likely the rock will hit the soldier.

b)



$$v_V = v_{0_V} + a_V t$$
$$= 0 + \text{-}9.8 \times 1.4$$
$$= \text{-}14 \text{ ms}^{-1}$$

$$v_H = v_{0_H} = 7.0 \text{ ms}^{-1}$$

$$v = \sqrt{(\text{-}14)^2 + 7.0^2}$$
$$= 16 \text{ ms}^{-1}$$

So the speed of the rock on impact is 16 ms^{-1}

4. $v_0 = 50 \text{ ms}^{-1}$ $\theta = 70°$ $v_V = 0 \text{ ms}^{-1}$ $s_V = ?$

$$v_{0_V} = v_0 \sin\theta = 50 \sin 70° = 47 \text{ ms}^{-1}$$
$$v_{0_H} = v_0 \cos\theta = 50 \cos 70° = 17 \text{ ms}^{-1}$$

$$v_V{}^2 = v_{0_V}{}^2 + 2a_V s_V$$
$$\therefore s_V = \frac{v_V{}^2 - v_{0_V}{}^2}{2a_V}$$
$$\therefore s_V = \frac{0^2 - 47^2}{2(-9.8)} = 113 \text{ m}$$

The maximum height the student reaches is 113 + 10 = 123 m

5.

$t = 5.62\,s$ $v_V = 0 \text{ ms}^{-1}$ $s_V = ?$

In half the time of flight, the Vortex would free fall the same distance as the maximum displacement here

$$s_V = \tfrac{1}{2} a_V \left(\frac{t}{2}\right)^2$$
$$\therefore s_V = \tfrac{1}{2} \times (-9.8) \times \left(\frac{5.62}{2}\right)^2 = 38.69 \text{ m}$$

The maximum height is 1.59+38.69 = 40.3 m