PHY 101 Homework # 4 Solutions

Chapter 6 Exercises

(30) Since we can "break up" the motion in terms of x and y coordinates with $V_y = -gt + V_{yi}$ and $V_x = V_{xi}$, so the hang time only depends on the vertical component of your intial velocity, V_{yi}. The equation for V_x has no time in it. If running first helps you push off the ground harder, then your V_{yi} will increase and thus the time to reach $V_y = 0$ (half your hang time) is longer.

(34) The vertical position allows the rocket to get through the densest part of the Earth's atmosphere more quickly. The denser the air, the larger the air resistance, which slows the rocket down. Eventually, the rocket needs to have some tangential speed in order to start off in orbit where the satellite is continuously falling towards the center of the Earth such that it is matching the curvature of the Earth.

(35) The curvature in the projectile's trajectory must match the curvature of Earth. Once this happens, the projectile moves perpendicularly to the direction of gravity such that the gravitational force can no longer change the projectile's speed.

Chapter 6 Problems

(5) (a) The engine is a projectile! So let's use the equations of motion for a projectile: $\Delta y = -\frac{1}{2}gt^2 + v_{iy}\Delta t$ and $\Delta x = v_{ix}\Delta t$. Since the engine's initial velocity is horizontal, $v_{iy} = 0$ and $v_{ix} = 280\,m/s$ (the same as the plane). If $\Delta t = 30\,s$, then $\Delta y = 0 - y_i = -\frac{1}{2}g(\Delta t)^2 \rightarrow y_i = \frac{1}{2}(10\,m/s^2)(30\,s)^2$

$y_i = \underline{4500\,m}$.

(b) $\Delta x = v_{ix}(\Delta t) = (280\,m/s)(30\,s) = \underline{8400\,m}$.

(c) Neglecting air resistance, the airplane and the engine will remain "track" each other's horizontal distance since they have the same horizontal velocity, i.e. the airplane will be directly above the engine when it hits the ground.

(7) The work-energy theorem tells us that $W = \Delta KE$ (the work done on an object equals the object change in kinetic energy). Thus, $W = 8 \times 10^9\,J - 5 \times 10^9\,J$
$= \underline{3 \times 10^9\,J}$.

Since, $KE_f > KE_i$, $PE_f < PE_i$ since the total energy $PE + KE$ stays constant by the conservation of energy.

(9) From class and from problem 8, we know that $\underbrace{F_g}_{\text{only force}} = \frac{G m_E M_S}{r_{ES}^2} = \frac{m_E v^2}{r_{ES}}$, where r_{ES} is the Earth-Sun distance. So, $\sqrt{\frac{G m_S}{r_{ES}}} = v$. Using the numbers from the book $m_S = 1.99 \times 10^{30}$ kg and $r_{ES} = 1.5 \times 10^{11}$ m and $G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$, we arrive at

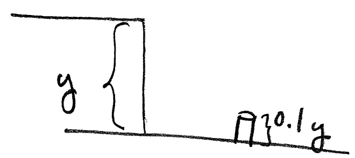
$$v = \sqrt{\frac{\left(6.67\times10^{-11} \frac{Nm^2}{kg^2}\right)\left(1.99\times10^{30} kg\right)}{1.5\times10^{11} m}} \approx 3000 \text{ m/s}.$$

(12) (a) By definition, $\vec{g} = \frac{\vec{F_g}}{m_1}$. So, $\vec{g} = \frac{\left(\frac{G m_1 m_E}{r^2}\right)\hat{r}}{m_1}$ direction is between the centers

$$\vec{g} = \frac{G m_E \hat{r}}{r^2} = \underbrace{\frac{G m_E \hat{r}}{d^2}}_{\text{using the notation from the book}}.$$

(b) If $r = 4r_E$, then $\vec{g} = \frac{1}{16}\underbrace{\left(\frac{G M_E}{r_E^2}\right)}_{g = 9.8 m/s^2}\hat{r} = \frac{1}{16} 9.8 \text{ m/s}^2 \hat{r} = \underline{.6 \text{ m/s}^2}\ \hat{r}$

(1b)



Let's use our equations of motion for a projectile,

$$\Delta y = -\tfrac{1}{2} g (\Delta t)^2 + v_{iy} \Delta t \quad ; \quad \Delta x = v_{ix} \Delta t.$$

(a) We know $\Delta y = 0.1y - y = -0.9y = -\tfrac{1}{2} g (\Delta t)^2 + \cancel{v_{iy}} \Delta t$, since $v_{iy} = 0$

So $\Delta t = \sqrt{\dfrac{2(.9y)}{g}}$. Next, we can plug this time Δt into the equation for Δx to arrive at

$$\underline{\Delta x = v_{ix} \sqrt{\dfrac{2(.9y)}{g}}}.$$

(b) If we plug in $y = 1.5\,m$, $g = 10\,m/s^2$ and $v_{ix} = 4\,m/s$, we arrive at $\underline{\Delta x = 2.1\,m}$ (<u>not</u> $.52\,m$)!

(It appears that the book forgot the v_{ix}.)

<u>Extra Credit</u>: Use the conservation of energy: $KE_i + GPE_i = KE_f + GPE_f$.

Initially, $GPE_i = -\dfrac{GmM_E}{r_E}$ and $KE_i = \tfrac{1}{2} m v^2$. If the object escapes the Earth's gravitational pull, $GPE_f = 0 = \dfrac{-GmM_E}{\infty}$. Also, let's assume that no extra KE remains, So $KE_f = 0$. Then, we have $GPE_i + KE_i = 0 \Rightarrow GPE_i = KE_i$

$$\frac{GmM_E}{r_E} = \frac{1}{2}mv^2.$$

Solving for v yields $v = \sqrt{\dfrac{2GM_E}{r_E}}$.