Name____
Physics 110 Quiz #2, April 7, 2023

Please show all work, thoughts and/or reasoning to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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1. An action hero is trying to catch his bus. He starts off $15m$ away from the back of the bus and runs at a constant speed of $6.5\frac{m}{s}$. Unbeknownst to our hero the bus is being driven by his archnemesis. If the bus starts from rest and can accelerate at a rate of $1\frac{m}{s^2}$, *will our action hero catch the bus?* Assume that if the action hero reaches the back of the bus he can grab on and climb on board.

   Taking the origin to be at the action hero and to the right as the positive x-direction we have

   $$x_{f,bus} = x_{i,bus} + v_{i,bus}t + \frac{1}{2}a_{bus}t^2 \to x_{f,bus} = 15m + \frac{1}{2}\left(1\frac{m}{s^2}\right)t^2$$
   $$x_{f,AH} = x_{i,AH} + v_{i,AH}t + \frac{1}{2}a_{AH}t^2 \to x_{f,AH} = +\left(6.5\frac{m}{s}\right)t$$

   If the AH catches the bus, there will be a time when $x_{f,AH} = x_{f,bus}$.

   $$x_{f,AH} = x_{f,bus} \to \left(6.5\frac{m}{s}\right)t = 15m + \frac{1}{2}\left(1\frac{m}{s^2}\right)t^2 \to 0.5\frac{m}{s^2}t^2 - 6.5\frac{m}{s}t + 15m = 0$$

   $$t = \begin{cases} 3s \\ 10s \end{cases}$$

   The AH catches the bus after a time of $3s$.

2. If our action hero does in fact catch the bus, how far down the road does he grab the back of the bus?

   $$x_{f,AH} = +\left(6.5\frac{m}{s}\right)t = 6.5\frac{m}{s} \times 3s = 19.5m$$

   or
   $$x_{f,bus} = 15m + \frac{1}{2}\left(1\frac{m}{s^2}\right)t^2 = 15m + \frac{1}{2}\left(1\frac{m}{s^2}\right)(3s)^2 = 19.5m$$

3. If our action hero does in fact reach the back of the bus, what will be both the speed of the bus and the speed of our action hero?

$$v_{f,AH} = v_{i,AH} + a_{AH}t = v_{i,AH} = 6.5\frac{m}{s}$$

$$v_{f,bus} = v_{i,bus} + a_{bus}t = a_{bus}t = 1\frac{m}{s^2} \times 3s = 3\frac{m}{s}$$

4. Suppose that a rock is dropped from the edge of a cliff $90m$ high. One second later, a second rock is thrown straight down with just the right velocity to ensure that the two rocks hit the ground at the same time. What is the initial velocity of the second rock?

Taking the origin to be at the rock and up away from the ground as the positive y-direction we have for the time it takes the first rock to hit the ground

$$y_f = y_i + v_{iy}t + \tfrac{1}{2}a_y t^2 \rightarrow y_f = \tfrac{1}{2}a_y t^2 \rightarrow t = \sqrt{\frac{2y_f}{a_y}} = \sqrt{\frac{2(-90m)}{-9.8\frac{m}{s^2}}} = 4.29s.$$

The second rock must hit the ground at the same time as the first, but it was thrown $1s$ later. Thus, the time of flight for the 2nd rock is $4.29s - 1.00s = 3.29s$.

$$y_f = y_i + v_{iy}t + \tfrac{1}{2}a_y t^2 \rightarrow v_{i,2} = \frac{y_{f,2} - \frac{1}{2}a_y t_2^2}{t_2} = \frac{-90m - \frac{1}{2}\left(-9.8\frac{m}{s^2}\right)(3.29s)^2}{3.29s} = -11.2\frac{m}{s}$$

5. What is the impact velocity of the second rock with the ground?

$$v_{fy,2} = v_{iy,2} + a_y t_2 = -11.2\frac{m}{s} - 9.8\frac{m}{s^2} \times 3.29s = -43.5\frac{m}{s}$$

or

$$v_{fy,2}^2 = v_{iy,2}^2 + 2a_y\Delta y \rightarrow v_{fy,2} = \sqrt{v_{iy,2}^2 + 2a_y\Delta y}$$

$$v_{fy,.2} = \sqrt{\left(-11.2\frac{m}{s}\right)^2 + 2\left(-9.8\frac{m}{s^2}\right)(-90m - 0m)} = \pm 43.5 \rightarrow v_{fy,2} = -43.5\frac{m}{s}$$