Type equation here.

Physics 2211 GPS Week 3

Problem #1

(a) On a clear blue day you observe a feather, at time $t = 0$, located at position $< 0, h, 0 >$ falling toward the ground with velocity $< 0, -v, 0 >$. Here both h and v are constant known quantities. Likewise, the mass m of the feather is also known. Assume the net force on the feather is zero. Determine the position of the feather at time $t = T$. Briefly explain how the feather can be moving if the net force acting on it is zero.

Apply Newton's 2nd law:

$$\vec{v}_f = \vec{v}_i + \cancel{(\vec{F}_{net}/m)}\,\Delta t = \vec{v}_i = \vec{v}_{Avg} \quad \text{(constant velocity)}$$

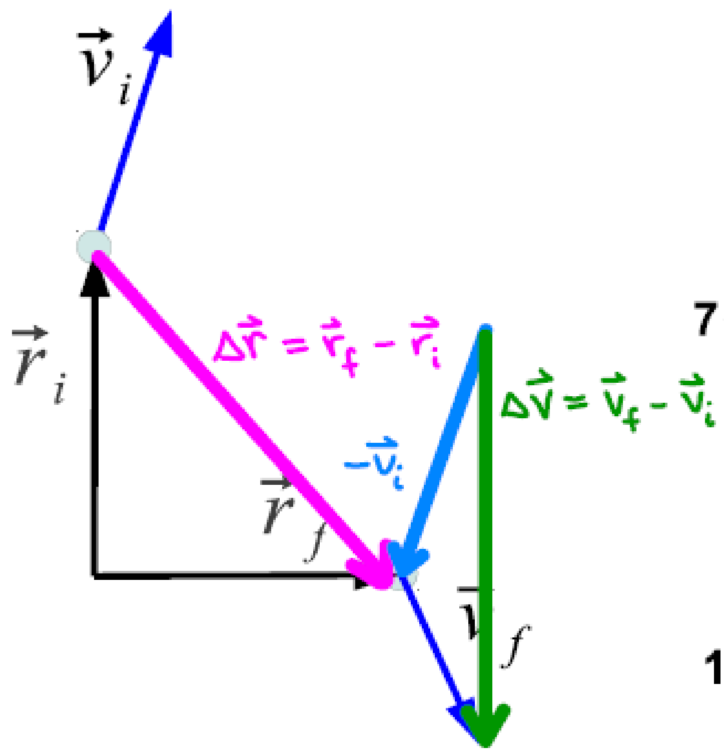
Position update:

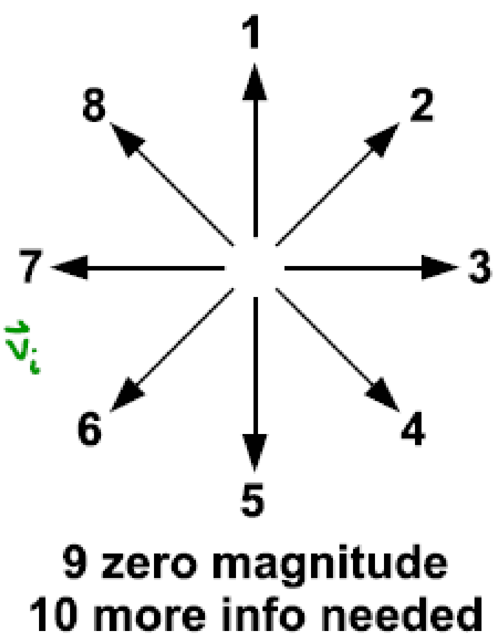
$$\vec{r}_f = \vec{r}_i + \vec{v}_{Avg}\,\Delta t = \vec{r}_i + \vec{v}_i\,\Delta t =$$

$$= <0, h, 0> + <0, -vT, 0> = \boxed{<0,\ h-vT,\ 0>}$$

Even though the net force on the feather is zero, the feather still moves b/c Newton's 1st law (inertia)

(b) An object's initial position and velocity ($\vec{r}_i$, $\vec{v}_i$) and final position and velocity ($\vec{r}_f$, $\vec{v}_f$) are shown on the figure below. Using the numbered direction arrows shown, indicate (by number) which arrow best represents the direction of the quantities listed below. If the quantity has zero magnitude or if more information is needed to determine the direction, indicate using the corresponding number listed below.





The displacement $\Delta\vec{r}$ 4 See diagram

The initial position vector $\vec{r}_i$ 1 See diagram

The average velocity $\vec{v}_{avg}$ 4 because $\vec{v}_{Avg} = \frac{\Delta\vec{r}}{\Delta t}$

The change in velocity $\Delta\vec{v}$ 5 See diagram

The change in momentum $\Delta\vec{p}$ 5 because $\vec{p} = m\vec{v}$, so $\Delta\vec{p} = m\Delta\vec{v}$

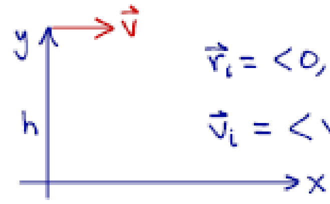
The acceleration $\vec{a}$ 5 because $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$

The net force $\vec{F}_{net}$ 5 because $\vec{F}_{net} = \frac{\Delta\vec{p}}{\Delta t} = m\vec{a}$

The change in the net force $\vec{F}_{net}$ 10 because we don't have enough information

Problem #2

A man standing at the top of a building kicks a small rock of mass m. The height of the building is h and initial velocity of the rock after the kick is $\vec{v} = < v, 0, 0 >$. Assume no air resistance and let g be the magnitude of the acceleration due to gravity.



$\vec{r}_i = \langle 0, h, 0 \rangle$

$\vec{v}_i = \langle v, 0, 0 \rangle$

(a) Find the time taken by the rock to hit the ground.

Motion in x-direction is constant velocity ($F_{net,x} = 0$)

Motion in y-direction is constant acceleration ($F_{net,y} = -mg$)

Momentum principle, y-component:

$$F_{net,y} = \frac{m \Delta v_y}{\Delta t}$$

$$-\cancel{m}g = \frac{\cancel{m}(v_{y,f} - \cancel{v_{y,i}})}{\Delta t}$$

$$-g = \frac{v_{y,f}}{\Delta t} \Longrightarrow v_{y,f} = -g\Delta t$$

Finding average velocity (y-component):

$$v_{y,Avg} = \frac{v_{yi} + v_{yf}}{2} = \frac{0 - g\Delta t}{2} = -\frac{1}{2}g\Delta t$$

Using the position-update formula (y-component):

$$r_{yf} = r_{yi} + v_{y,Avg}\Delta t$$

$$0 = h + \left(-\frac{1}{2}g\Delta t\right)\Delta t$$

$$0 = h - \frac{1}{2}g\Delta t^2$$

$$\frac{1}{2}g\Delta t^2 = h$$

$$\Delta t^2 = \frac{2h}{g} \Longrightarrow \boxed{\Delta t = \sqrt{\frac{2h}{g}}}$$

(b) How far away from the building did the rock travel before hitting the ground?

Motion in x-direction is constant velocity ($F_{net,x} = 0$)

$$r_{x,f} = r_{x,i} + v_{x,i}\,\Delta t$$

$$r_{x,f} = 0 + v\,\Delta t$$

$$r_{x,f} = v\,\Delta t = \boxed{v\sqrt{\frac{2h}{g}}}$$

(c) (c) Determine the magnitude of velocity of the rock before hitting the ground.

x-component: $v_{xf} = v_{xi} = v$ (b/c $F_{net,x} = 0$)

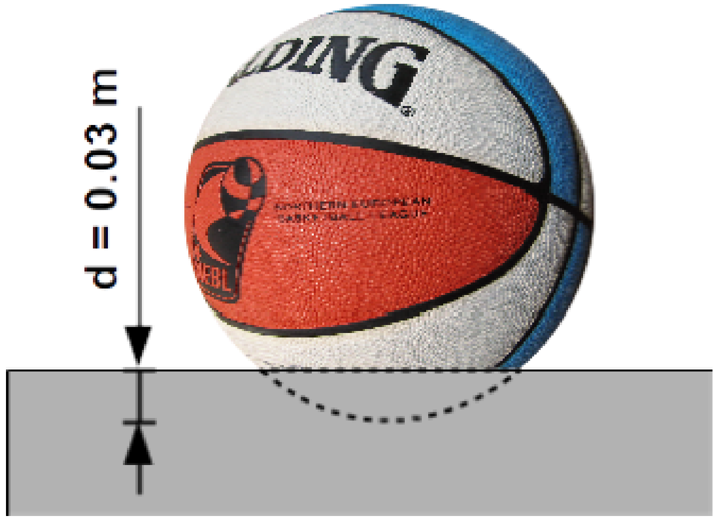
y-component: $v_{yf} = \underbrace{-g\,\Delta t}_{\text{from part (a)}} = -g\sqrt{\frac{2h}{g}}$

$$\Rightarrow \vec{v}_f = \left\langle v, -g\sqrt{\frac{2h}{g}}, 0 \right\rangle$$

$$\Rightarrow |\vec{v}_f| = \sqrt{v^2 + \left(-g\sqrt{\frac{2h}{g}}\right)^2} = \sqrt{v^2 + g^2\frac{2h}{g}} = \boxed{\sqrt{v^2 + 2gh}}$$

Problem #3

A basket ball has a mass of 0.625 kg. A basketball resting on the rim of the hoop falls to the ground a distance 3.048 m below. The ball moves down, hits the floor and bounces straight back up with almost the same speed. As indicated in the diagram, high-speed photography shows that the ball is compressed about $d = 3$ cm at the instant when its speed is momentarily zero, before rebounding.



(a) Determine the approximate average speed of the ball during the period from first contact with the floor to the moment the ball's speed is momentarily zero. You can assume that the force of contact is constant.

✓ Rim to floor: need to find impact speed (easy to do with conservation of energy, but we haven't learned that yet!)

$$\vec{v}_{rim} = 0$$

$$\vec{v}_{Avg} = \frac{1}{2}(\cancel{\vec{v}_{rim}}^{\,0} + \vec{v}_{floor}) = \frac{1}{2}\vec{v}_{floor}$$

$$\vec{v}_{Avg} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\cancel{\vec{r}_{floor}}^{\,0} - \vec{r}_{rim}}{\Delta t} = \frac{-\vec{r}_{rim}}{\Delta t}$$

$$\frac{1}{2}\vec{v}_{floor} = \frac{-\vec{r}_{rim}}{\Delta t}$$

$$\frac{1}{2}v_{floor}(\cancel{-}\hat{y}) = \frac{\cancel{-}r_{rim}\,\hat{y}}{\Delta t}$$

$$v_{floor} = \frac{2r_{rim}}{\Delta t} \Rightarrow \Delta t = \frac{2r_{rim}}{v_{floor}}$$

$$\Rightarrow \vec{v}_{floor} = \cancel{\vec{v}_{rim}}^{\,0} + (\vec{F}_{net}/m)\,\Delta t = \frac{\cancel{m}g(-\hat{y})}{\cancel{m}}\Delta t$$

$$v_{floor}\,\cancel{(-\hat{y})} = g\Delta t\,\cancel{(-\hat{y})}$$

$$v_{floor} = g\Delta t = g\frac{2r_{rim}}{v_{floor}} \Longrightarrow v_{floor}^2 = 2gr_{rim}$$

$$v_{floor} = \sqrt{2gr_{rim}} = \sqrt{(2)(9.8)(3.048)} = \boxed{7.73 \text{ m/s}}$$ IMPACT SPEED

✓ Impact to stopping:

$$v_i = v_{floor} = 7.73 \text{ m/s}$$

$$v_f = 0$$

$$\Rightarrow v_{Avg} = \frac{1}{2}(v_i + \cancel{v_f}) = \frac{1}{2}(7.73) = \boxed{3.865 \text{ m/s}}$$

(b) How much time elapses between first contact with the wall, and coming to a stop?

$$V_{Avg} = \frac{\Delta r}{\Delta t} \Rightarrow \Delta t = \frac{\Delta r}{V_{Avg}} = \frac{d}{V_{Avg}} = \frac{3e\text{-}2}{3.865} = \boxed{0.00776 \text{ sec} = 7.76e-3 \text{ sec}}$$

(c) What is the magnitude of the average force exerted by the wall on the ball during contact?

$$\vec{F} = \vec{F}_{ground} + \vec{F}_{grav} = \frac{\Delta \vec{p}}{\Delta t}$$

$$|\vec{F}| = \frac{|\Delta \vec{p}|}{\Delta t} = \frac{m|\Delta \vec{v}|}{\Delta t} = \frac{m|\cancel{v_f}^{0} - v_i|}{\Delta t} = \frac{mv_i}{\Delta t} = \frac{(0.625)(7.73)}{7.76e-3} = 622.58\ N$$

$$|\vec{F}_{ground}| = |\vec{F} - \vec{F}_{grav}| = 622.58\ N - (-6.13\ N) = \mathbf{628.71\ N}$$

(d) How much larger is the magnitude of the contact force from the wall compared with the weight of the ball (i.e. gravity)?

$$\frac{|\vec{F}_{ground}|}{|\vec{F}_{grav}|} = \frac{628.71\ N}{6.13\ N} \approx 103$$