General Physics B 1- Homework Set 1

Due on 10/07/2022, 5:00PM sharp. Please hand in your homework via eLearn.

1 points for each problem. Total:5 points.

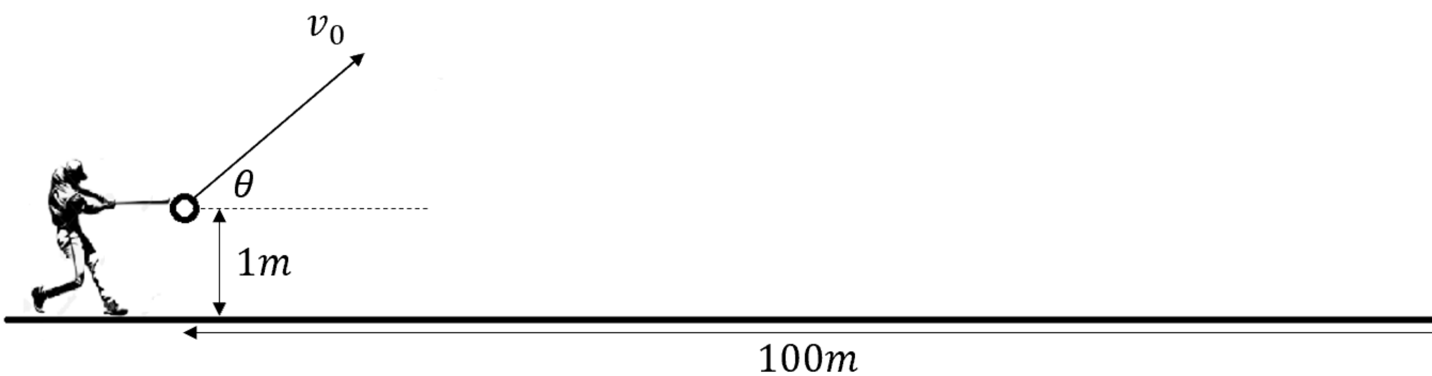
1.Safety Distance on a Highway

On a dry road, a car with good tires may be able to brake with a constant deceleration of $5m/s^2$. Now a car break down at the middle of a high way. The driver wants to put a warning sign at the back of the car. Assuming other drivers start to brake their car right after passing the warning sign. If the speed limit of the road is $100km/hr$, how far should the driver put the warning sign? (1point)

Solution To be sure other cars have sufficent distance to stop($v_f = 0m/s$), the warning sign need to put at a distance s that the other cars start to decelerate with $a = -5m/s^2$ with initial velocity $v_0 = 100km/hr = 27.8m/s$. We can use the formula $v_f^2 = v_0^2 + 2as$ to find out the distance s. Thus, $s = -\frac{v_0^2}{2a} = 77m$. (For the significant figure, the acceleration only has significant up to integer. Therefore, the significant figure of the answer should also only up to integer.)

2. Projectile Motion - Home Run of Baseball

As shown in the figure, a baseball player hit the ball at $1m$ height and the launching angle θ =30°. The home run fence is $100m$ away from the home base, and the fence is $2m$ high. Assuming the air drag force can be neglected. What is the minimum initial velocity v_0 of the ball to be a homerun (that is, the baseball can pass right above the home run fence)? (1point)



Solution Let's set a coordinate system with origin at the postion that the bat just hit the baseball. The baseball performs a projectile motion. The condition to have homerum is $y \geq 2 - 1 = 1m$ when the x-position is at $x = 100m$. The time for the ball to reach $x = 100m$ is $t = \frac{x}{v_0 cos\theta}$. The y coordinate is $y = v_0 sin\theta t - \frac{1}{2}gt^2 = xtan\theta - \frac{1}{2}g(\frac{x}{v_0 cos\theta})^2 \geq 1m$. Thus we can get $v_0 \geq 33.9m/s$ with $g = 9.8m/s^2$.

3.Relative Motion

Ship A is located 4.0 km north and 2.5 km east of ship B. Ship A has a velocity of 20 km/h toward the south, and ship B has a velocity of 30 km/h in a direction 37° north of east. Assuming the unit-vector toward the east $\hat{i}$ and the unit-vectortoward the north is $\hat{j}$. (a) Write an expression (in terms of $\hat{i}$ and $\hat{j}$) for the position of A relative to B as a function of t, where t = 0 when the ships are in the positions described above. (0.5point) (b) What is that least separation of the these two ship? (0.5point)

Solution (a)The velocity A respect to rest frame:$\overrightarrow{V_A} = (0km/h)\widehat{i} - (20km/h)\widehat{j}$, The velocity B respect to rest frame:$\overrightarrow{V_B} = 30cos37\widehat{i} + 30sin37\widehat{j} = (24km/h)\widehat{i} + (18km/h)\widehat{j}$.

Assuming the ship B's position at t=0 is the origin of the cooridnate.

The position of ship A $\overrightarrow{r_A} = \overrightarrow{r_A}(t = 0) + \overrightarrow{V_A}t = [(2.5km)\widehat{i} + [4.0km - (20km/h)t]\widehat{j}]$.

The position of ship B $\overrightarrow{r_B} = \overrightarrow{r_B}(t=0) + \overrightarrow{V_B}t = [(24km/h)t\widehat{i} + (18km/h)t\widehat{j}]$

The relative position of A relavtive to B is

$\overrightarrow{r_{AB}} = \overrightarrow{r_A} - \overrightarrow{r_B} = [(2.5km)\widehat{i} + [4.0km - (20km/h)t]\widehat{j}] - [(24km/h)t\widehat{i} + (18km/h)t\widehat{j}] = [(2.5km) - (24km/h)t]\widehat{i} + [(4.0km) - (38km/h)t]\widehat{j}$

(b)The separation between the ships is $|\overrightarrow{r_{AB}}| = \{[(2.5km) - (24km/h)t]^2 + [(4.0km) - (38km/h)t]^2\}^{\frac{1}{2}} = [(6.25 - 120t + 576t^2) + (16 - 304t + 1444t^2)]^{\frac{1}{2}} = [22.25 - 424t + 2020t^2]^{\frac{1}{2}}$

The least seperation happen when the derivative of seperation respect to t is 0. Therefore, it is $t = 424/(2 \cdot 2020) = 0.105h$.

Therefore, the least seperation is $|\overrightarrow{r_{AB}}|(t = 0.105h) = 0.022km$

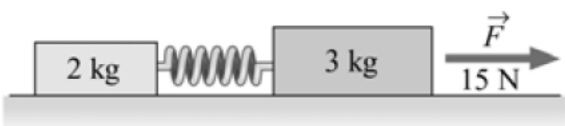
4.Weight Difference Due to Uniform Circular Motion ot the Earth

When you stand on a scale, the scale reading shows the force with which it's pusing. A person stand on a scale at Earth's north pole and the scale reads $50.00kg$. What is the reading if the same person stand on the same scale at Earth's equator? (1point) Assuming the radius of the earth is $6400km$, the tangant velocity at Earth's equator is $465m/s$, and $g = 9.8m/s^2$

Solution At the Earth's equator, the net force acting on a person needs to provide centripal acceleration for spinning with the earth. Therefore, we have $mg - F_N = m\frac{v^2}{R_E}$, where F_N is the normal force provided by the sacle. The reading of the scale thus will be $\frac{F_N}{g} = \frac{m(g - \frac{v^2}{R_E})}{g} = 49.83kg$.

5.Spring Force Between Blocks

A 2.0kg mass and a 3.0kg mass are on a horizontal frictionless surface connected by a massless spring with spring constant $k = 180N/m$. A $15N$ force is applied to the larger mass, as shown in the following figure. How much does the spring stretch from its equilibrium length? (1point)



Solution We first treat the two block as one system. Therefore, the acceleration of this system due to force F is $a_{tot} = \frac{F}{m_1+m_2} = 3m/s^2$

Since the two blocks will move together and thus $a_{tot} = a_1 = a_2$. Now if we focus on the second block with 2.0kg, the net force on this block is to the right due to spring force. This results in an acceleration $a_2 = 3m/s^2$. Thus, the spring force exerting on the second block with 2.0kg is $m_2a_2 = 6N$. Following with Hooke's law, we kno the spring stretch from its equilibrium length with $\Delta x = m_2a_2/k = 0.033m$.