Physics 195 **Fall 2009** **Problem Set 3**

Show all calculations. Explain all assumptions. Answer in standard MKS units.
Explicitly substitute units into your symbolic equations to verify solution.
Express answers in 5 or fewer digits. Use scientific notation as appropriate.

Conceptual Questions: **Place the letter corresponding to your answer in the box.**

Limit your explanation to the space provided. Please write legibly.

1. Suppose a bullet is fired from a rifle horizontally at high speed. At the same instant the bullet leaves the barrel of the rifle, an identical bullet is dropped from rest starting at the same height. Which bullet will strike the ground first?

$\boxed{C}$

a) the fired bullet
b) the dropped bullet
c) both bullets will reach the ground at the same time

Explain:

with same V_{oy} and same g acceleration then time of flight must be identical...

2. Suppose you are driving along in a convertible car and you throw a ball straight up into the air. While the ball is still in the air, you step on the brakes and stop the car. Relative to the position of the stopped car, the ball lands...

$\boxed{C}$

a) behind the car
b) inside the car
c) ahead of the car

Explain:

since the ball has the same forward speed as the car then it has a forward speed wrt the ground. Thus, it will behave as a projectile launched with $V_x > \emptyset$ and it will land ahead of the car

Due on or before 9/25

Show all calculations. Explain all assumptions. Answer in standard MKS units.
Explicitly substitute units into your symbolic equations to verify solution.
Express answers in 5 or fewer digits. Use scientific notation as appropriate.

3 You observe that the vertically falling rain makes slanted streaks on the side windows of your linearly moving automobile. If the streaks make an angle of 30 degrees with respect to the vertical, what does this tell you about the relative speed of the falling rain and the moving car?

$\boxed{B}$

a) The car is moving faster than the rain.
b) The rain is moving faster than the car.
c) Both are moving at the same speed.
d) More information is required.
Explain

with $\vec{V}_f = V_{car}(\hat{x}) + V_{rain}(\hat{y})$

since $\tan\theta = \frac{V_r}{V_c}$ then with $\theta = 30°$

$V_{rain} > V_{car}$

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4 Suppose you are traveling on the back of a flatbed truck that is moving at a constant speed in a horizontal straight line, and drop a ball from your hand. You see the motion of the ball as a vertical straight line. How would the path of the ball appear to your friend standing by the side of the road as you pass?

$\boxed{C}$

a) Horizontal straight line
b) Vertical straight line
c) Parabola extending towards front of truck
d) Parabola extending towards back of truck
e) Depends on other information.
Explain

since the ball has V_{rel} to ground in direction of truck travel, then it will follow a parabolic path towards the front of the truck

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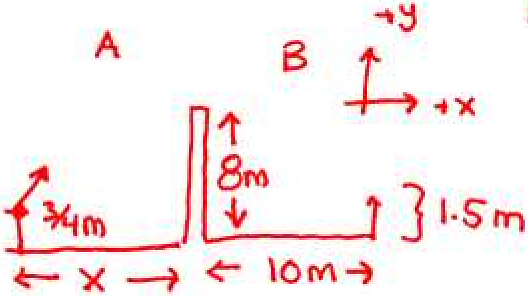


start w/ part B and work backwards...

$V_{oy} = \emptyset \quad a_y = 9.81\,m/s^2(-\hat{y}) \quad y_f = 1.5m(+\hat{y}) \quad y_o = 8m(+\hat{y})$

$y_f - y_o = \frac{1}{2} g t_B^2 \quad \Rightarrow \quad t_B = \left[\frac{2}{-g}[1.5-8]\right]^{\frac{1}{2}} \simeq 1.152\,sec$

so - it takes 1.152s for pumpkin to fall from top of hedge to height of middle of window... in that time the 'kin must also travel 10m to the right...

$V_x = \frac{10m}{1.152s} = 8.68\,m/s\,(+\hat{x})$

Now look at part A... we know that $V_{fy} = \emptyset$ @ hedge top.

$\Delta y = (8 - 3/4)m(+\hat{y}) \quad V_{fy}^2 = \emptyset \quad V_{oy} = V_L \sin\theta_L$ and so

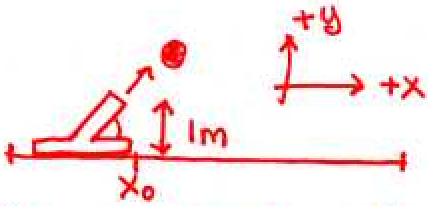
$V_{fy}^2 = V_{oy}^2 - 2g(7.25) \quad \therefore \quad V_{oy} = \sqrt{142.1} \simeq 11.92\,m/s(+\hat{y})$

since $\frac{V_{oy}}{V_{ox}} = \tan\theta_L$ then $\frac{11.92}{8.68} = \tan\theta_L$, $\theta_L \sim 53.94°$

$V_L = \sqrt{V_x^2 + V_y^2} = \boxed{14.75\,m/s}\ \theta_L \simeq \boxed{53.94° \text{ wrt } +\hat{x}}$

with $V_{fy} = \emptyset$ $V_{oy} = 11.92\,m/s$ then $t_A = \frac{11.92}{\cancel{2}(9.81)} \simeq$ ~~[illegible]~~ oops. $1.22s$

$\Delta x = 10m + (1.22s)(8.68\,m/s) = \boxed{20.55\,m}$ from window



to find ranges wrt ground need to transform to the ground FOR...

V_y wrt ground $= V_L \sin\theta$ $\quad$ V_x wrt ground $= V_{\text{ball-}\cancel{\text{ground}}\,\text{cart}} + V_{\text{cart-g.}}$

V_x wrt ground $= V_L \cos\theta + V_{CART}$

CASE 1. V_{CART} moving in $(+\hat{x})$ direction...

$V_y = 25\,\text{m/s} \sin 30 = 12.5\,\text{m/s}\,(+\hat{y})$

$V_x = 25\,\text{m/s} \cos 30 + 10\,\text{m/s} \simeq 31.7\,\text{m/s}\,(+\hat{x})$

find time of flight... $y_f = \emptyset \quad y_0 = 1\text{m}(+\hat{y})$,

$\emptyset = 1\text{m}(+\hat{y}) + 12.5\,\text{m/s}(+\hat{y})t + 4.91\,\text{m/s}^2(-\hat{y})t^2$

$\emptyset = 1 + 12.5t - 4.91t^2$ - quadratic in time...

$$t = \frac{-12.5 \pm \sqrt{156.25 + 4(4.91)(1)}}{-9.81} \simeq \frac{-12.5 \pm 13.3}{-9.81} = 2.63\,\text{s}$$

so - horizontal displacement of cannonball wrt ground...

$\Delta x = (31.7\,\text{m/s})(+\hat{x})(2.63\,\text{s}) \simeq \boxed{83.25\,\text{m}\,(+\hat{x})}$

CASE 2. V_{CART} moving in $(-\hat{x})$ direction

since V_y same then time of flight is the same...

$\Delta x = (11.7\,\text{m/s})(+\hat{x})(2.63\,\text{s}) \simeq \boxed{30.77\,\text{m}\,(+\hat{x})}$

for both cases $\Delta x_{CART-BALL} = x_{f\,BALL} - x_{f\,CART}$

1) $83.25\,\text{m}(+\hat{x}) - 10\,\text{m/s}(2.63\,\text{s})(+\hat{x}) = \boxed{56.95\,\text{m}\,(+\hat{x})}$

2) $30.77\,\text{m}(+\hat{x}) - 10\,\text{m/s}(2.63\,\text{s})(-\hat{x}) = \boxed{57.0\,\text{m}\,(+\hat{x})}$

basically same - differences from rounding...

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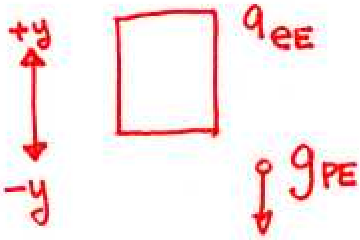

Transforming to the elevator FOR involves finding velocities, distances and accelerations wrt the elevator...

acceleration of pencil wrt elevator... CASE a)

$$a_{PE} - a_{eE} = a_{pe} \Rightarrow 9.81\,\text{m/s}^2(-\hat{y}) - \emptyset$$

if elevator @ rest then $a_{pe} = 9.8\,\text{m/s}^2(-\hat{y})$

$\therefore$ time to fall $\rightarrow$ $\Delta y_e = V_{ope}t + \frac{1}{2}a_{pe}t^2$

with $y_{fe} = \emptyset$ $y_{oe} = 1\text{m}\,(+\hat{y})$; $V_{ope} = \emptyset$; $a_{pe} = 9.8\,\text{m/s}^2(-\hat{y})$

$$\emptyset = 1 + \emptyset - \frac{1}{2}(9.8)t^2 \quad \sqrt{\frac{2}{9.8}} = t \sim .452\,\text{s}$$

$$V_{fe} = V_{oe} + a_{pe}t \Rightarrow 9.8\,\text{m/s}^2(-\hat{y})(\emptyset.452\,\text{s}) \simeq 4.43\,\tfrac{\text{m}}{\text{s}}(-\hat{y})$$

so... elevator @ rest...

$$\boxed{\begin{array}{l} t = \emptyset.452\,\text{s} \\ V_f = 4.43\,\tfrac{\text{m}}{\text{s}}(-\hat{y}) \end{array}}$$

if elevator moves @ constant speed then everything has the same velocity and thus the solutions to the problem are exactly the same since all the relative quantities are exactly the same...

$$\boxed{\begin{array}{l} t = \emptyset.452\,\text{s} \\ V_f = 4.43\,\tfrac{\text{m}}{\text{s}}(-\hat{y}) \end{array}}$$

now $a_{eE} = 5\,m/s^2(+\hat{y})$ and now we get some new events...

$a_{pE} - a_{eE} = a_{pe} \Rightarrow 9.8\,m/s^2(-\hat{y}) - 5\,m/s^2(+\hat{y}) = 14.8\,m/s^2(-\hat{y})$

time to "fall" is thus $\sqrt{\frac{2m}{14.8\,m/s^2}} = Ø.368\,s$

$v_{f_{pe}} = Ø + 14.8\,m/s^2(-\hat{y})(Ø.368\,s) \simeq 5.44\,m/s(-\hat{y})$

elevator accelerates upwards @ $5\,m/s^2$...

$$\boxed{\begin{array}{l} t = Ø.368\,s \\ v_f = 5.44\,m/s(-\hat{y}) \end{array}}$$

$a_{eE} = 9\,m/s^2(-\hat{y})$ ...

$a_{pe} = 9.8\,m/s^2(-\hat{y}) - 9\,m/s^2(-\hat{y}) = Ø.8\,m/s^2(-\hat{y})$

time to 'fall' is thus $\sqrt{\frac{2m}{Ø.8\,m/s^2}} = 1.58\,s$

$v_{f_{pe}} = Ø + Ø.8\,m/s^2(-\hat{y})(1.58\,s) \simeq 1.26\,m/s(-\hat{y})$

elevator accelerated downward @ $9\,m/s^2$...

$$\boxed{\begin{array}{l} t = 1.58\,s \\ v_f = 1.26\,m/s(-\hat{y}) \end{array}}$$