Name____________________________________

Physics 110 Quiz #2, April 11, 2020

Please show all work, thoughts and/or reasoning in order 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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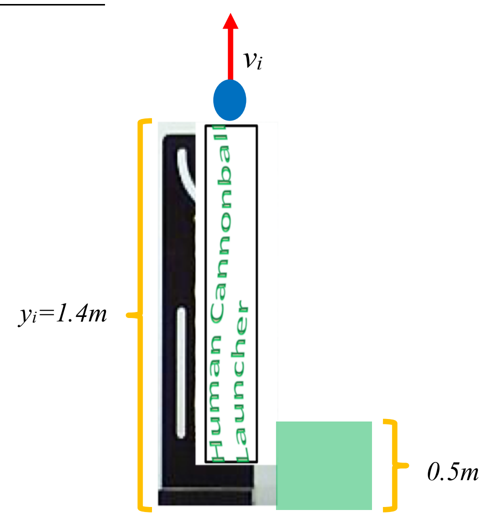
A retired movie stuntman decides one day, that ever since retirement, his life has no thrill. So, to put some thrill back into his life, he decides to build himself a human cannonball launcher in his backyard. Suppose that the stuntman sets up his human cannonball launcher vertically and launches himself into the air with an initial speed v_i. The stuntman leaves the launcher at a height of $y_i = 1.4m$ above the ground and reaches a maximum height of $y_{max} = 39.5m$ above the ground. When he falls back towards the ground, he lands on a stiff, but soft, pad with thickness $0.5m$.



a. What was the launch speed v_i of the stuntman?

At maximum height, $v_{fy} = 0$.

$$v_{fy}^2 = v_{iy}^2 + 2a_y\Delta y \rightarrow v_{fy} = \sqrt{2g\Delta y} = \sqrt{2 \times 9.8\tfrac{m}{s^2} \times (39.5m - 1.4m)} = 27.3\tfrac{m}{s}$$

b. What was the stuntman's time of flight from launch to landing? You may ignore the small horizontal displacement of the stuntman needed to make him land on the pad.

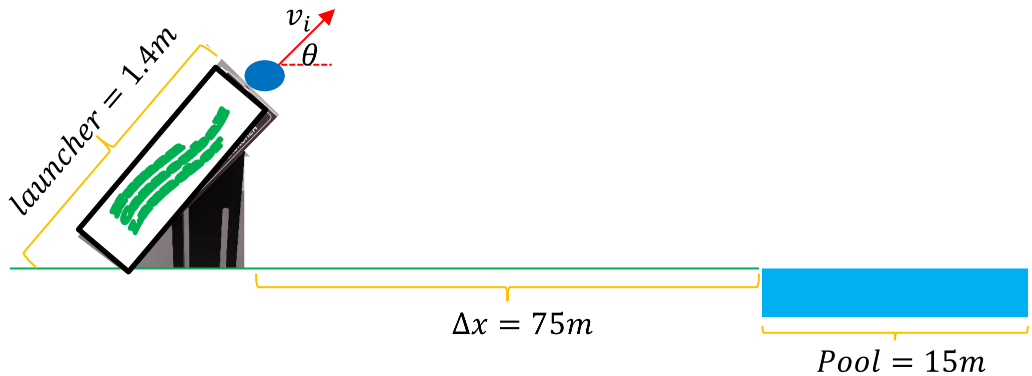
$$y_f = y_i + v_{iy}t + \tfrac{1}{2}a_y t^2$$

$$0.5m = 1.4m + 27.3\tfrac{m}{s}t - \tfrac{1}{2}\left(9.8\tfrac{m}{s^2}\right)t^2 \rightarrow 0 = 0.9 + 27.3t - 4.9t^2$$

$$\text{t} = \frac{-27.3 \pm \sqrt{(27.3)^2 - 4(0.9)(-4.9)}}{2(-4.9)} = \begin{cases} 5.6s \\ -0.03s \end{cases}$$

The time of flight is thus $5.6s$.

Unfortunately, the vertical launch was still not thrilling enough for the stuntman. Suppose he decides to launch himself from the backyard of his house into his neighbors backyard into their inground swimming pool located a horizontal distance $\Delta x = 75m$ of away from the launcher.



c. If the stuntman launches himself at the same speed v_i as in part a, but at an angle of $\theta = 42^0$above the horizontal, will the stuntman safely land in the swimming pool? If not, by what distance does he miss the pool? Assume the swimming pool is at ground level and is $15m$ long.

$$v_{ix} = v_i \cos\theta = 27.3\frac{m}{s}\cos 42 = 20.3\frac{m}{s} \quad \& \quad v_{iy} = v_i \sin\theta = 27.3\frac{m}{s}\sin 42 = 18.3\frac{m}{s}$$

$$y_f = y_i + v_{iy}t + \frac{1}{2}a_y t^2$$

$$0m = 1.4m\sin 42 + 18.3\frac{m}{s}t - \frac{1}{2}\left(9.8\frac{m}{s^2}\right)t^2 \rightarrow 0 = 0.94 + 18.3t - 4.9t^2$$

$$\text{t} = \frac{-18.3 \pm \sqrt{(18.3)^2 - 4(0.94)(-4.9)}}{2(-4.9)} = \begin{cases} 3.8s \\ -0.04s \end{cases}$$

$$x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2 = v_{ix}t = 20.3\frac{m}{s} \times 3.8s = 77.1m$$

Yes, the stuntman makes it safely.

d. Whether he makes it safely into the pool or not, what will be the magnitude of the stuntman's impact velocity?

$$v_{fx} = v_{ix} + a_x t = v_{ix} = v_i \cos\theta = 20.3\frac{m}{s}$$

$$v_{fy} = v_{iy} + a_y t = v_{iy} - gt = v_i \sin\theta - gt = 18.3\frac{m}{s} - \left(9.8\frac{m}{s^2} \times 3.8s\right) = -18.9\frac{m}{s}$$

$$v_f = \sqrt{v_{fx}^2 + v_{fy}^2} = \sqrt{\left(20.3\frac{m}{s}\right)^2 + \left(-18.9\frac{m}{s}\right)^2} = 27.7\frac{m}{s}$$

e. Whether he makes it safely into the pool or not, at what angle ϕ with respect to the horizontal will the stuntman's impact velocity make?

$$\phi = \tan^{-1}\left(\frac{v_{fy}}{v_{fx}}\right) = \tan^{-1}\left(\frac{-18.9\frac{m}{s}}{20.3\frac{m}{s}}\right) = -43^0$$

Physics 110 Formulas

Motion

$\Delta x = x_f - x_i$ $\quad v_{avg} = \frac{\Delta x}{\Delta t}$ $\quad a_{avg} = \frac{\Delta v}{\Delta t}$

Equations of Motion

displacement: $\begin{cases} x_f = x_i + v_{ix}t + \frac{1}{2}a_x t^2 \\ y_f = y_i + v_{iy}t + \frac{1}{2}a_y t^2 \end{cases}$

velocity: $\begin{cases} v_{fx} = v_{ix} + a_x t \\ v_{fy} = v_{iy} + a_y t \end{cases}$

time-independent: $\begin{cases} v_{fx}^2 = v_{ix}^2 + 2a_x \Delta x \\ v_{fy}^2 = v_{iy}^2 + 2a_y \Delta y \end{cases}$

Uniform Circular Motion

$F_r = ma_r = m\frac{v^2}{r}; \quad a_r = \frac{v^2}{r}$

$v = \frac{2\pi r}{T}$

$F_G = G\frac{m_1 m_2}{r^2}$

Geometry /Algebra

Circles	*Triangles*	*Spheres*
$C = 2\pi r$	$A = \frac{1}{2}bh$	$A = 4\pi r^2$
$A = \pi r^2$		$V = \frac{4}{3}\pi r^3$

Quadratic equation : $ax^2 + bx + c = 0$,

whose solutions are given by : $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Vectors

magnitude of a vector: $v = |\vec{v}| = \sqrt{v_x{}^2 + v^2{}_y}$

direction of a vector: $\phi = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

Useful Constants

$g = 9.8 \, m/s^2$ $\quad G = 6.67\times10^{-11} \, Nm^2/kg^2$

$N_A = 6.02\times10^{23} \, atoms/mole$ $\quad k_B = 1.38\times10^{-23} \, J/K$

$\sigma = 5.67\times10^{-8} \, W/m^2K^4$ $\quad v_{sound} = 343 \, m/s$

Linear Momentum/Forces

$\vec{p} = m\vec{v}$

$\vec{p}_f = \vec{p}_i + \vec{F}\Delta t$

$\vec{F} = m\vec{a}$

$\vec{F}_s = -k\vec{x}$

$F_f = \mu F_N$

Work/Energy

$K_t = \frac{1}{2}mv^2$

$K_r = \frac{1}{2}I\omega^2$

$U_g = mgh$

$U_S = \frac{1}{2}kx^2$

$W_T = FdCos\theta = \Delta E_T$

$W_R = \tau\theta = \Delta E_R$

$W_{net} = W_R + W_T = \Delta E_R + \Delta E_T$

$\Delta E_R + \Delta E_T + \Delta U_g + \Delta U_S = 0$

$\Delta E_R + \Delta E_T + \Delta U_g + \Delta U_S = -\Delta E_{diss}$

Heat

$T_C = \frac{5}{9}[T_F - 32]$

$T_F = \frac{9}{5}T_C + 32$

$L_{new} = L_{old}(1 + \alpha\Delta T)$

$A_{new} = A_{old}(1 + 2\alpha\Delta T)$

$V_{new} = V_{old}(1 + \beta\Delta T) : \beta = 3\alpha$

$PV = Nk_B T$

$\frac{3}{2}k_B T = \frac{1}{2}mv^2$

$\Delta Q = mc\Delta T$

$P_C = \frac{\Delta Q}{\Delta t} = \frac{kA}{L}\Delta T$

$P_R = \frac{\Delta Q}{\Delta T} = \varepsilon\sigma A\Delta T^4$

$\Delta U = \Delta Q - \Delta W$

Rotational Motion

$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$

$\omega_f = \omega_i + \alpha t$

$\omega^2{}_f = \omega^2{}_i + 2\alpha\Delta\theta$

$\tau = I\alpha = rF$

$L = I\omega$

$L_f = L_i + \tau\Delta t$

$\Delta s = r\Delta\theta : \; v = r\omega : \; a_t = r\alpha$

$a_r = r\omega^2$

Sound

$v = f\lambda = (331 + 0.6T)\frac{m}{s}$

$\beta = 10\log\frac{I}{I_0}; \quad I_o = 1\times10^{-12} \frac{W}{m^2}$

$f_n = nf_1 = n\frac{v}{2L}; \; f_n = nf_1 = n\frac{v}{4L}$

Fluids

$\rho = \frac{M}{V}$

$P = \frac{F}{A}$

$P_d = P_0 + \rho gd$

$F_B = \rho gV$

$A_1 v_1 = A_2 v_2$

$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$

$P_1 + \frac{1}{2}\rho v^2{}_1 + \rho gh_1 = P_2 + \frac{1}{2}\rho v^2{}_2 + \rho gh_2$

Simple Harmonic Motion/Waves

$\omega = 2\pi f = \frac{2\pi}{T}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{l}{g}}$

$v = \pm\sqrt{\frac{k}{m}}A\left(1 - \frac{x^2}{A^2}\right)^{\frac{1}{2}}$

$x(t) = A\sin\left(\frac{2\pi t}{T}\right)$

$v(t) = A\sqrt{\frac{k}{m}}\cos\left(\frac{2\pi t}{T}\right)$

$a(t) = -A\frac{k}{m}\sin\left(\frac{2\pi t}{T}\right)$

$v = f\lambda = \sqrt{\frac{F_T}{\mu}}$

$f_n = nf_1 = n\frac{v}{2L}$

$I = 2\pi^2 f^2 \rho v A^2$