Name____

Physics 110 Quiz #2, September 23, 2016

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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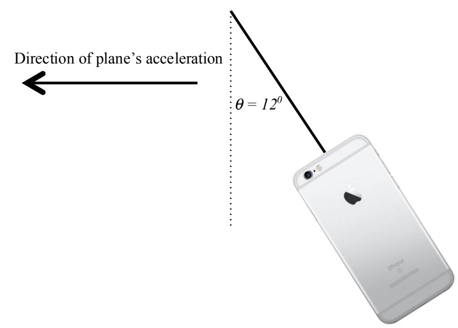
1. It's several years in the future and the new iPhone 8 has just been revealed. The phone is being touted as being indestructible and able to withstand anything you can do to it, including submersion in any liquid and drops. Suppose that you want to test the integrity of the iPhone 8 you decide to drop the phone from high in the air and see if it survives the impact with the ground. To do this you ask your friend who is a pilot to take you on your quest and you hop into the passenger seat of the plane (a Cessna 182) that is sitting at rest at the end of the runway. You decide to suspend your phone vertically from the headphone chord (they brought back the headphone jack on the iPhone 8) and as the plane accelerates down the runway the chord and iPhone swings through a 12^0 angle (measured with respect to the vertical) as shown below. If the mass of the iPhone 8 is $0.192kg$, what is the magnitude of the acceleration of the plane down the runway?



$$\sum F_x : F_T \sin\theta = ma_x$$

$$\sum F_y : F_T \cos\theta - F_w = ma_y = 0 \rightarrow F_T = \frac{mg}{\cos\theta}$$

$$\therefore a = \frac{F_T \sin\theta}{m} = g\tan\theta = 9.8\tfrac{m}{s^2}\tan 12 = 2.1\tfrac{m}{s^2}$$

2. Suppose that you need a takeoff speed of $90knots(\sim 104mph \sim 46.3\tfrac{m}{s})$, how far down the runway do you go before you become airborne? Take the initial position of your airplane to be at the origin.

$$v_{fx}^2 = v_{ix}^2 + 2a\Delta x$$

$$v_{fx}^2 = 2a\Delta x$$

$$\therefore \Delta x = \frac{v_{fx}^2}{2a} = \frac{\left(46.3\tfrac{m}{s}\right)^2}{2\times 2.1\tfrac{m}{s^2}} = 510m$$

3. After becoming airborne the plane climbs to a height of $5000\,ft\,(\sim 1524m)$ and levels off. You decide to conduct your experiment and hold the phone out of the window of the airplane and release the phone. What will be the magnitude of the impact velocity, just before the phone strikes the ground? Assume that your Cessna 182 is at its cruising speed of $135\,knots\,(\sim 156\,mph \sim 69.5\,\tfrac{m}{s})$. Ignore the affects of air resistance in this problem.

$$v_{fx} = v_{ix} + a_x t = v_{ix} = 69.5\,\tfrac{m}{s}$$
$$y_f = y_i + v_{iy} t + \tfrac{1}{2} a_y t^2 = -\tfrac{1}{2} g t^2$$
$$\rightarrow t = \sqrt{-\frac{2y_f}{g}} = \sqrt{\frac{2 \times 1524m}{9.8\,\tfrac{m}{s^2}}} = 17.6s$$
$$v_{fy} = v_{iy} + a_y t = -gt = -9.8\,\tfrac{m}{s^2} \times 17.6s = -172.8\,\tfrac{m}{s}$$
$$\therefore v_f = \sqrt{v_{fx}^2 + v_{fx}^2} = \sqrt{\left(69.5\,\tfrac{m}{s}\right)^2 + \left(-172.8\,\tfrac{m}{s}\right)^2} = 186.3\,\tfrac{m}{s}$$

Note: This assumes that the object accelerates for the entire trip to the ground. In fact it would have reached a much lower terminal velocity due to air resistance and would have fallen at this lower speed. But here I didn't have to worry about air resistance.

4. From the time that the phone is released until it strikes the ground below, how far horizontally has the phone traveled?

$$x_f = x_i + v_{ix} t + \tfrac{1}{2} a_x t^2 = v_{ix} t = 69.5\,\tfrac{m}{s} \times 17.6s = 1223m$$

5. To see if the iPhone 8 has survived the crash, you land immediately after landing go retrieve your phone. When you finally locate the phone, you notice that it has come to rest in a $2\,inch\,(\sim 0.05m)$ hole deep. What was the magnitude of average force exerted on the phone by the ground and was your phone damaged? To tell the extent of the damage, the iPhone 6 plus can withstand a force of about $90\,lbs\,(\sim 360N)$ before it breaks. Assuming this holds true for your iPhone 8, what shape was your iPhone 8 in?

$$v_{fx}^2 = v_{ix}^2 + 2a\Delta x = v_{ix}^2 + 2\left(\frac{F}{m}\right)\Delta x$$
$$\left(0\,\tfrac{m}{s}\right)^2 = \left(-186.3\,\tfrac{m}{s}\right)^2 + 2\left(\frac{F}{0.192kg}\right) \times (0.05m)$$
$$\therefore F = 6.66 \times 10^4 N \sim 16{,}700 lbs$$

So, I bet my phone did not survive the impact.

Useful formulas:

Motion in the r = x, y or z-directions

$$r_f = r_0 + v_{0r}t + \tfrac{1}{2}a_r t^2$$

$$v_{fr} = v_{0r} + a_r t$$

$$v_{fr}^{\ 2} = v_{0r}^{\ 2} + 2a_r\Delta r$$

Uniform Circular Motion

$$a_r = \frac{v^2}{r}$$

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

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

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

Geometry /Algebra

Circles — $C = 2\pi r$, $A = \pi r^2$

Triangles — $A = \tfrac{1}{2}bh$

Spheres — $A = 4\pi r^2$, $V = \tfrac{4}{3}\pi r^3$

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

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

Vectors

$$magnitude\ of\ a\,vector = \sqrt{v_x^{\ 2} + v_y^{\ 2}}$$

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

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

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

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

$$U_g = mgh$$

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

$$W_T = FdCos\theta = \Delta E_T$$

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

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

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

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

Heat

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

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

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

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

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

$$PV = Nk_BT$$

$$\tfrac{3}{2}k_BT = \tfrac{1}{2}mv^2$$

$$\Delta Q = mc\Delta T$$

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

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

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

Rotational Motion

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

$$\omega_f = \omega_i + \alpha t$$

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

$$\tau = I\alpha = rF$$

$$L = I\omega$$

$$L_f = L_i + \tau\Delta t$$

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

$$a_r = r\omega^2$$

Fluids

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

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

$$P_d = P_0 + \rho gd$$

$$F_B = \rho gV$$

$$A_1v_1 = A_2v_2$$

$$\rho_1A_1v_1 = \rho_2A_2v_2$$

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

Simple Harmonic Motion/Waves

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

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

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

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

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

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

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

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

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

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

Sound

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

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

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