Name____

Physics 120 Quiz #1, January 14, 2022

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. Suppose that you are driving down a road at $60mph\ (\sim 26.8\,\frac{m}{s})$. Exactly $300m$ ahead of you, there is a sign that says the speed limit in town is $30mph\ (\sim 13.4\,\frac{m}{s})$. You put on your brakes and decelerate at a rate of $5\frac{mph}{s}\ (\sim 2.2\,\frac{m}{s^2})$. Unfortunately, a cop sees you, pulls you over and says that when you crossed into the $30mph$ zone, you were speeding and gives you a ticket. You of course think that you were not speeding. When you go to court, you argue your case before the judge. To prove that you were not speeding, you use the information above and calculate for the judge how far you it would have taken you to reach $30mph$ from a starting speed of $60mph$. What is that distance?

$$v_{fx}^2 = v_{ix}^2 + 2a_x\Delta x$$
$$\left(13.4\,\tfrac{m}{s}\right)^2 = \left(26.8\,\tfrac{m}{s}\right)^2 - 2\times 2.2\,\tfrac{m}{s^2}\Delta x$$
$$\Delta x = 122.4m$$

2. Another way you could have proven to the judge that you were not speeding is to calculate your speed if you were to travel the full $300m$. What would your speed have been after this distance and what would this imply about you speeding?

$$v_{fx}^2 = v_{ix}^2 + 2a_x\Delta x = \left(26.8\,\tfrac{m}{s}\right)^2 - 2\times 2.2\,\tfrac{m}{s^2}\times 300m = -601.8\,\tfrac{m^2}{s^2}$$
$$v_f = \text{not defined}$$

This result means that (keeping this deceleration) you would have stopped well before $300m$.

3. A rock is dropped from rest from the edge of a cliff of unknown height. The rock hits the water below the cliff $6.2s$ after it was released. What is the height of the cliff?

$y_f = y_i + v_{iy} + \frac{1}{2}a_y t^2 = -\frac{1}{2} \times 9.8\frac{m}{s^2}(6.2s)^2 = -188.4m$ or $188.4m$ below where the rock was dropped.

4. Suppose now that another rock was thrown from the same cliff but this time with an unknown initial vertical velocity. The rock is observed to hit the water $4.5s$ after it was thrown. What are the magnitude and direction of the initial velocity that the stone was thrown from the cliff with?

$$y_f = y_i + v_{iy}t + \frac{1}{2}a_y t^2$$
$$-188.4m = v_{iy}(4.5s) - \frac{1}{2} \times 9.8\frac{m}{s^2}(4.5s)^2 = -188.4m$$
$$v_{iy} = -19.9\frac{m}{s}$$

The rock was thrown in the vertically downward direction (the negative sign) with a magnitude of $19.9\frac{m}{s}$.

5. For the case in part 4, what is the impact velocity (magnitude and direction) of the rock just before it struck the water?

$$v_{fy} = v_{iy} + a_y t = -19.9\frac{m}{s} - 9.8\frac{m}{s^2} \times 4.5s = -64\frac{m}{s}$$

Physics 120 Formula Sheet

General Definitions of Motion

$\Delta\vec{r} = \langle \Delta x, \Delta y, \Delta z \rangle = \langle x_f - x_i, y_f - y, z_f - z_i \rangle$

$\vec{v} = \frac{\Delta\vec{r}}{\Delta t} = \langle \frac{\Delta x}{\Delta t}, \frac{\Delta y}{\Delta t}, \frac{\Delta z}{\Delta t} \rangle$

$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \langle \frac{\Delta v_x}{\Delta t}, \frac{\Delta v_y}{\Delta t}, \frac{\Delta v_z}{\Delta t} \rangle$

$d\vec{r} = \langle dx, dy, dz \rangle$

$$\vec{v} = \langle v_x, v_y, v_z \rangle = \frac{d\vec{r}}{dt} = \langle \frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt} \rangle$$

$$\vec{a} = \langle a_x, a_y, a_z \rangle = \frac{d\vec{v}}{dt} = \langle \frac{dv_x}{dt}, \frac{dv_y}{dt}, \frac{dv_z}{dt} \rangle$$

Geometry

$C = 2\pi r \;\; A_{circle} = \pi r^2; \;\; A_{rect} = LW$

$A_{triangle} = \frac{1}{2}bh; \;\; A_{sphere} = 4\pi r^2$

$V_{sphere} = \frac{4}{3}\pi r^3; \;\; V_{cyl} = \pi r^2 h; \;\; V_{cone} = \frac{1}{3}\pi r^2 h$

Motion with constant acceleration

$\vec{r}_f = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2 \rightarrow \langle x_f, y, z_f \rangle = \langle x_i + v_{ix}t + \frac{1}{2}a_x t^2, y_i + v_{iy}t + \frac{1}{2}a_y t^2, z + v_{iz}t + \frac{1}{2}a_z t^2 \rangle$

$\vec{v}_f = \vec{v}_i + \vec{a}t \rightarrow \langle v_{fx}, v_{fy}, v_{fz} \rangle = \langle v_{ix} + a_x t, v_{iy} + a_y t, v_{iz} + a_z t \rangle$

Forces/Momentum

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

$\vec{F}_{net} = \frac{d\vec{p}}{dt} = m\vec{a}$

$\vec{p}_f - \vec{p}_i = \int d\vec{p} = \int \vec{F}_{net} dt$

$$\vec{J} = \int \vec{F}_{net} dt$$

$$\vec{F}_{net} = \vec{F}_{\parallel} + \vec{F}_{\perp} = \frac{d\vec{p}}{dt}\hat{p} + \vec{p}\frac{d\hat{p}}{dt} = m\vec{a}_{\parallel} + m\vec{a}_{\perp}$$

$$|\vec{F}_{\perp}| = m|\vec{a}_{\perp}| = m\frac{v^2}{r}$$

$$\vec{F}_G = G\frac{M_1 M_2}{r_{12}^2}\hat{r}_{12} \rightarrow |\vec{F}_G| = G\frac{M_1 M_2}{r_{12}^2}$$

$$\vec{F}_G = m\vec{g}; \quad \vec{g} = G\frac{M_{cb}}{(R_{cb} + h)}\hat{r}$$

$|\vec{F}_{fr}| = \mu|\vec{F}_N|$

$\vec{F}_s = -k\Delta\vec{r}$

Constants

$g = 9.8\frac{m}{s^2}; \;\; G = 6.67 \times 10^{-11}\frac{Nm^2}{kg^2}$

$v_{sound} = 343\frac{m}{s}; \;\; v_{light} = c = 3 \times 10^8 \frac{m}{s}$

$N_A = 6.02 \times 10^{23}$

Vectors

$\vec{C} = \vec{A} + \vec{B} \rightarrow \langle C_x, C_y, C_z \rangle = \langle A_x + B_x, A_y + B_y, A_z + B_z \rangle + \langle C_x, C_y, C_z \rangle; \quad \overline{|C|} = \sqrt{C_x^2 + C_y^2 + C_z^2}$

$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}|\cos\theta = A_x B_x + A_y B_y + A_z B_z$

$\vec{A} \times \vec{B} = |\vec{A}||\vec{B}|\sin\theta = \langle a_y b_z - b_y a_z, a_z b_x - b_z a_x, a_x b_y - b_x a_y \rangle$

Work and Energy

$$W_T = \int dW_T = \int \vec{F} \cdot d\vec{r} = \Delta K_T = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 = \frac{p_f^2}{2m} - \frac{p_i^2}{2m}$$

$$W_R = \int dW_R = \int \vec{\tau} \cdot d\vec{\theta} = \Delta K_R = \tfrac{1}{2}I\omega_f^2 - \tfrac{1}{2}I\omega_i^2 = \frac{L_f^2}{2I} - \frac{L_i^2}{2I}$$

$$W_{net} = W_T + W_R = \Delta E_{sys} = \begin{cases} 0 \\ W_{fr} \end{cases}$$

$$W_{net} = -\sum \Delta U = \Delta K_T + \Delta K_R$$

$$U_g = mgy$$

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

Rotational Motion

$$s = r\theta \rightarrow ds = rd\theta$$

$$\frac{ds}{dt} = r\frac{d\theta}{dt} \rightarrow v = r\omega; \quad \omega = \frac{d\theta}{dt}$$

$$a = \frac{dv}{dt} = r\frac{d\omega}{dt} = r\alpha; \quad \alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

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

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

$$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$$

Rotational Forces/Momentum

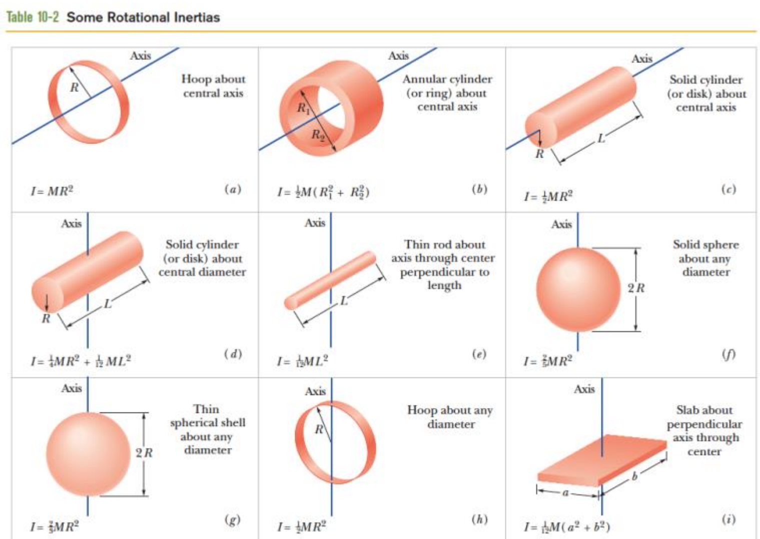
$$\vec{\tau} = \vec{r} \times \vec{F} = \frac{d\vec{L}}{dt} = I\vec{\alpha}$$

$$|\vec{\tau}| = rF\sin\theta = r_\perp F = rF_\perp$$

$$\vec{L} = I\vec{\omega}$$

$$I = \int r^2 dm$$

$$\vec{L}_f = \vec{L}_i + \int \vec{\tau}_{net} dt$$



Some moments of inertia from Halliday, Resnick, & Walker, 10th edition.