Name\_

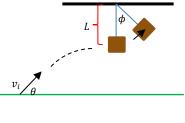
Physics 110 Quiz #6, May 12, 2022

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.

1. A dart of mass m = 0.2kg is launched from the ground at an angle  $\theta = 38^{\circ}$  measured with respect to the ground at a speed of  $v_i = 10\frac{m}{s}$ . When the dart reaches its highest point above the ground it strikes a soft wooden block of mass M = 1.3kg initially at rest. How high above the ground was the wooden block placed?

$$\begin{split} \Delta E &= \Delta K + \Delta U_g + \Delta U_s = 0\\ 0 &= \left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2\right) + \left(mgy_f - mgy_i\right)\\ 0 &= \frac{1}{2}m(v_i\cos\theta)^2 - \frac{1}{2}mv_i^2 + mgh\\ h &= \frac{v_i^2(1 - \cos^2\theta)}{2g} = \frac{\left(10\frac{m}{s}\right)^2(1 - \cos^23\theta)}{2 \times 9.8\frac{m}{s^2}} = 1.93m \end{split}$$



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2. Immediately after the dart strikes the wooden block it becomes stuck in the block. With what speed does the dart and block move after the collision?

$$p_{ix} = p_{fx} \to mv_{ix} = (m+M)V \to V = \left(\frac{m}{m+M}\right)v_{ix} = \left(\frac{0.2kg}{0.2kg+1.3kg}\right)10\frac{m}{s}\cos 38$$
$$V = 1.1\frac{m}{s}$$

3. Through what angle  $\phi$  measured with respect to the vertical do the dart and block swing through if the rope has a length of L = 1.0m.

$$\begin{aligned} \Delta E &= \Delta K + \Delta U_g + \Delta U_S = 0\\ 0 &= \left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2\right) + \left(mgy_f - mgy_i\right) = -\frac{1}{2}mv_i^2 + mgL(1 - \cos\phi)\\ \cos\phi &= 1 - \frac{v_i^2}{2gL} = 1 - \frac{\left(1.1\frac{m}{s}\right)^2}{2 \times 9.8\frac{m}{s^2} \times 1m} = 0.9437 \rightarrow \phi = 19.3^0 \end{aligned}$$

4. What fraction of the initial energy in the dart is lost in the collision with the wooden block?

$$f = \frac{\Delta K}{K_i} = \frac{\frac{1}{2}(m+M)V^2 - \frac{1}{2}mv_i^2}{\frac{1}{2}mv_i^2} = \left(\frac{m+M}{m}\right)\frac{V^2}{v_i^2} - 1 = \left(\frac{0.2kg + 1.3kg}{0.2kg}\right)\left(\frac{1.1\frac{m}{s}}{10\frac{m}{s}\cos 38}\right)^2 - 1$$
$$f = -0.85$$

5. Suppose that instead of the soft wooden block, a metal block of the same mass (M = 1.3kg) is suspended from the rope at rest. The same dart (m = 0.2kg) is launched at the same velocity as in part 1 and in this case the dart bounces off the metal block with a velocity  $v_{fx} = -\frac{3}{4}v_{ix}$ , where  $v_{ix}$  is the impact velocity of the dart with the metal block. Through what angle  $\phi$  measured with respect to the vertical, did the metal block swing?

$$p_{ix} = p_{fx} \to mv_{ix,m} = mv_{fx,m} + Mv_{fx,M} = -\frac{3}{4}mv_{ix,m} + Mv_{fx,M} \to v_{fx,M} = \frac{7}{4} \left(\frac{m}{M}\right) v_{ix,m}$$
$$v_{fx,M} = \frac{7}{4} \left(\frac{m}{M}\right) v_{ix,m} = \frac{7 \times 0.2kg}{4 \times 1.3kg} \times 10\frac{m}{s} \cos 38 = 2.12\frac{m}{s}$$

$$\Delta E = \Delta K + \Delta U_g + \Delta U_s = 0$$
  

$$0 = \left(\frac{1}{2}Mv_f^2 - \frac{1}{2}Mv_i^2\right) + \left(Mgy_f - Mgy_i\right) = -\frac{1}{2}Mv_i^2 + MgL(1 - \cos\phi)$$
  

$$\cos\phi = 1 - \frac{v_i^2}{2gL} = 1 - \frac{\left(2.12\frac{m}{s}\right)^2}{2 \times 9.8\frac{m}{s^2} \times 1m} = 0.7704 \rightarrow \phi = 39.6^0$$

Vectors  $v = \sqrt{v_x^2 + v_y^2}$  $\phi = \tan^{-1} \left( \frac{v_y}{v_x} \right)$ 

### **Motion Definitions**

Displacement:  $\Delta x = x_f - x_i$ Average velocity:  $v_{avg} = \frac{\Delta x}{\Delta t}$ Average acceleration:  $a_{avg} = \frac{\Delta v}{\Delta t}$ 

### **Equations of Motion**

displacement:  $\begin{cases}
x_f = x_i + v_{ix}t + \frac{1}{2}a_xt^2 \\
y_f = y_i + v_{iy}t + \frac{1}{2}a_yt^2 \\
velocity: \begin{cases}
v_{fx} = v_{ix} + a_xt \\
v_{fy} = v_{iy} + a_yt \\
time-independent: \begin{cases}
v_{fx}^2 = v_{ix}^2 + 2a_x\Delta x \\
v_{fy}^2 = v_{iy}^2 + 2a_y\Delta y
\end{cases}$ 

#### **Rotational Motion Definitions**

Angular displacement:  $\Delta s = r\Delta\theta$ Angular velocity:  $\omega = \frac{\Delta\theta}{\Delta t} \rightarrow v = r\omega$ Angular acceleration:  $\alpha = \frac{\Delta\omega}{\Delta t} \rightarrow \begin{cases} a_t = r\alpha \\ a_c = r\omega^2 \end{cases}$ 

### **Rotational Equations of Motion**

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

Momentum & Force  

$$\vec{p} = m\vec{v} \rightarrow p_x = mv_x; \ p_y = mv_y$$
  
 $\Delta \vec{p} = \vec{F} \Delta t \rightarrow \vec{p}_f = \vec{p}_i + \vec{F} \Delta t$   
 $\vec{F} = \frac{d\vec{p}}{dt} = m\vec{a} \rightarrow F_x = ma_x; \ F_y = ma_y$   
 $F_{fr} = \mu F_N$   
 $F_w = mg$   
 $F_s = -kx$   
 $F_G = G \frac{M_1 M_2}{r^2}$   
 $F_c = ma_c = m \frac{v^2}{R}$ 

### Work & Energy

$$\begin{cases} W_T = \int \vec{F} \cdot d\vec{r} = F dr \cos \theta = \Delta K_T \\ W_R = \int \vec{\tau} \cdot d\vec{\theta} = \tau d\theta = \Delta K_R \end{cases}$$
$$W_{net} = W_T + W_R = \Delta K_T + \Delta K_R = -\Delta U$$

$$K_{T} = \frac{1}{2}mv^{2}$$

$$K_{R} = \frac{1}{2}I\omega^{2}$$

$$U_{g} = mgy$$

$$U_{s} = \frac{1}{2}kx^{2}$$

$$\Delta E = \Delta E_{R} + \Delta E_{T}$$

$$\Delta E = \Delta K_{R} + \Delta K_{T} + \Delta U_{g} + \Delta U_{s} = \begin{cases} 0\\ W_{fr} \end{cases}$$

Rotational Momentum & Force  $\vec{\tau} = \vec{r} \times \vec{F}; \ \tau = r_{\perp}F = rF_{\perp} = rF\sin\theta$   $\tau = \frac{\Delta L}{\Delta t} = I\alpha$   $L = I\omega$  $\Delta \vec{L} = \vec{\tau}\Delta t \rightarrow \vec{L}_{f} = \vec{L}_{i} + \vec{\tau}\Delta t$ 

Fluids  

$$\rho = \frac{m}{v}$$

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

$$P_{y} = P_{air} + \rho gy$$

$$F_{B} = \rho gV$$

$$\rho_{1}A_{1}v_{1} = \rho_{2}A_{2}v_{2}; \text{ compressible}$$

$$A_{1}v_{1} = A_{2}v_{2}; \text{ incompressible}$$

$$P_{1} + \frac{1}{2}\rho v_{1}^{2} + \rho gy_{1} = P_{2} + \frac{1}{2}\rho v_{2}^{2} + \rho gy_{2}$$

Simple Harmonic Motion

$$\omega = 2\pi f = \frac{2\pi}{T}$$
$$T_s = 2\pi \sqrt{\frac{m}{k}}; \quad \omega = \sqrt{\frac{k}{m}}$$
$$T_p = 2\pi \sqrt{\frac{l}{g}}; \quad \omega = \sqrt{\frac{g}{l}}$$

## Geometry/Algebra

 $A = \pi r^2 \qquad C = 2\pi r = \pi D$ Circles:  $A = 4\pi r^2 \qquad V = \frac{4}{3}\pi r^3$ 

Spheres:

 $A = \frac{1}{2}bh$ 

Triangles:

Quadratics:

### Common Metric Prefixes

 $nano = 1 \times 10^{-9}$  $micro = 1 \times 10^{-6}$  $milli = 1 \times 10^{-3}$  $centi = 1 \times 10^{-2}$  $kilo = 1 \times 10^3$  $mega = 1 \times 10^6$ 

### Sound

$$\begin{split} v_s &= f\lambda = (331 + 0.6T) \frac{m}{s} \\ \beta &= 10 \log \frac{l}{l_o} \\ f_n &= nf_1 = n \frac{v}{2L}; n = 1,2,3, \dots \text{ open pipes} \\ f_n &= nf_1 = n \frac{v}{4L}; n = 1,3,5, \dots \text{ closed pipes} \end{split}$$

Waves

$$v = f\lambda = \sqrt{\frac{F_T}{\mu}}$$
  
$$f_n = nf_1 = n\frac{v}{2L}; n = 1,2,3,...$$
  
$$I = 2\pi^2 f^2 \rho v A^2$$

### Equations of Motion for SHM

$$x(t) = \begin{cases} x_{max} \sin\left(\frac{2\pi}{T}t\right) \\ x_{max} \cos\left(\frac{2\pi}{T}t\right) \end{cases}$$

gebra  

$$v(t) = \begin{cases} v_{max} \cos\left(\frac{2\pi}{T}t\right) \\ -v_{max} \sin\left(\frac{2\pi}{T}t\right) \\ -v_{max} \sin\left(\frac{2\pi}{T}t\right) \end{cases}$$

$$A = 4\pi r^{2} \qquad V = \frac{4}{3}\pi r^{3} \qquad a(t) = \begin{cases} -a_{max} \sin\left(\frac{2\pi}{T}t\right) \\ -a_{max} \cos\left(\frac{2\pi}{T}t\right) \\ -a_{max} \cos\left(\frac{2\pi}{T}t\right) \end{cases}$$

$$A = \frac{1}{2}bh \qquad v = \pm v_{max} \sqrt{1 - \left(\frac{x}{x_{max}}\right)^{2}}$$

$$ax^{2} + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^{2} - 4ac}}{2a} \qquad v = \pm \omega x_{max} \sqrt{1 - \left(\frac{x}{x_{max}}\right)^{2}}$$

# **Periodic Table of the Elements**

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https://www.wuwm.com/post/periodic-table-elements-turns-150#stream/0