Name________________________________________

Physics 110 Quiz #4, October 14, 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. A block of mass $M = 0.999kg$ is connected to a spring with stiffness $k = 140\,\frac{N}{m}$ and sits motionless on a horizontal surface. A bullet of mass $m = 0.001kg$ is fired horizontally into the block and the block and bullet compress the spring by an amount $x = 0.050m$. There is friction between the block and the surface with coefficient of kinetic friction $\mu_k = 0.50$. Using energy methods, what is the speed of the bullet/block system immediately after the collision?

$$\Delta K + \Delta U_g + \Delta U_s = \Delta E_{system} = -W_{fr}$$

$$\left(\tfrac{1}{2}m_{total}v_f^2 - \tfrac{1}{2}m_{total}v_i^2\right) + 0 + \left(\tfrac{1}{2}kx_f^2 - \tfrac{1}{2}kx_i^2\right) = -\mu_k m_{total} g d$$

$$-\tfrac{1}{2}m_{total}V^2 + \tfrac{1}{2}kx_f^2 = -\mu_k m_{total} g d$$

$$V = \sqrt{\frac{kx_f^2 + 2\mu_k m_{total} g d}{m_{total}}} = \sqrt{\frac{140\,\frac{N}{m}(0.05m)^2 + \left(2\times 0.5\times 1kg\times 9.8\,\frac{m}{s^2}\times 0.05m\right)}{1.0kg}}$$

$$V = 0.92\,{}^{m}\!/\!{}_{s}$$

2. What was the initial velocity of the bullet before it struck the block?

$$p_{i,x} = p_{f,x}$$

$$mv_i = (m+M)V$$

$$v_i = \left(\frac{m+M}{m}\right)V = \left(\frac{1.0kg}{0.001kg}\right)\times 0.92\,\frac{m}{s} = 920\,\frac{m}{s}$$

3. What fraction of the bullet's initial kinetic energy is dissipated as heat (due to damaging the block, increasing the temperature of the block) in the collision between the bullet and block?

$$\%K_{lost} = \left(\frac{K_i - K_f}{K_i}\right) \times 100\% = \left(1 - \frac{K_f}{K_i}\right) \times 100\%$$

$$\%K_{lost} = \left(1 - \frac{\frac{1}{2}(m+M)V^2}{\frac{1}{2}mv^2}\right) \times 100\% = \left(1 - \frac{\frac{1}{2}(m+M)\left(\frac{mv}{m+M}\right)^2}{\frac{1}{2}mv^2}\right) \times 100\%$$

$$\%K_{lost} = \left(1 - \frac{m}{m+M}\right) \times 100\% = \left(1 - \frac{0.001kg}{1.00kg}\right) \times 100\% = 99.9\%$$

4. Suppose that the block of mass $M$ connected to the spring were instead at rest initially on a frictionless surface. In this case when the bullet is fired into the block the amount bullet's initial kinetic energy is dissipated as heat in the collision is

a. greater than the case when the block was on the surface with friction.
b. less than the case when the block was on the surface with friction.
c. equal to the case when the block was on the surface with friction.
d. unable to be determined with the information given.

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

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

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

### 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

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

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

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