KEY

PHYS 1211 Fall 2021 Test 3
November 16, 2021

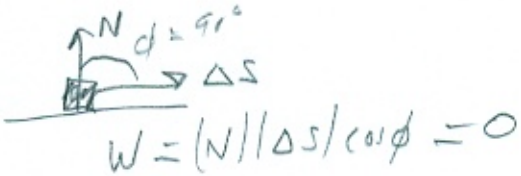
Name _____ **Student ID** _____ **Score** _____

Note: This test consists of one set of conceptual questions, five problems, and a bonus problem. For the problems, you *must show all* of your work, calculations, and reasoning clearly to receive credit. Be sure to include units in your solutions where appropriate. An equation sheet is provided on the last page.

Problem 1. Conceptual questions. State whether the following statements are *True* or *False*. (10 points total, no calculations required)

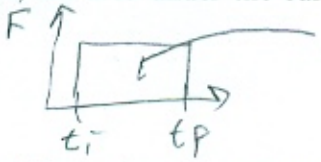
(a) The normal force does no work.

True



(b) For a plot of force versus time, the area under the curve between initial time t_i and final time t_f is the work.

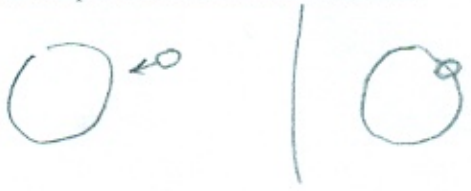
False



$F\Delta t$ = Impulse

(c) An asteriod crashing into the Arizona desert is an example of an inelastic collision.

True



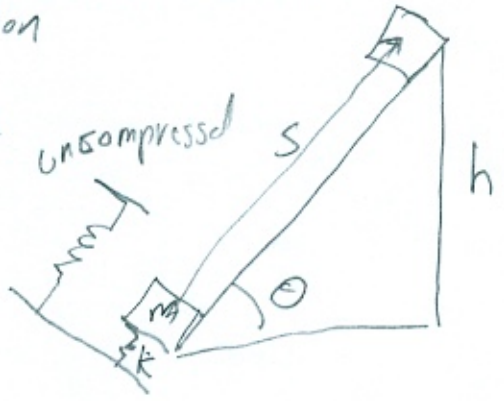
Problem 2. A 45 g bug is hovering in the air. A gust of wind exerts a force $\vec{F} = < 4.0, -6.0, 0.0 > \times 10^{-2}$ N on the bug. How much work is done by the wind as the bug undergoes a displacement of $\Delta\vec{r} = < 2.0, -2.0, 0.0 >$ m? (15 points total)

$$W = \vec{F} \cdot \Delta\vec{r} = F_x x + F_y y + F_z z$$
$$= (4 \times 10^{-2})(2) + (-6 \times 10^{-2})(-2) + (0)(0)$$
$$= 8 \times 10^{-2} + 12 \times 10^{-2} = \boxed{0.2\,\text{J}}$$

Problem 3. A 50 g ice cube is launched up a frictionless incline with a slope of 30° by a spring. If the spring is compressed 10 cm, how high up the slope does the ice cube travel from its starting point? The spring constant is 25 N/m. (15 points total)

No Friction. Use conservation of Energy

$$E = \frac{1}{2}mv^2 + mgy + \frac{1}{2}kx^2$$



$$E_i = \frac{1}{2}kx^2 \qquad v_i = 0, \; y_i = 0$$

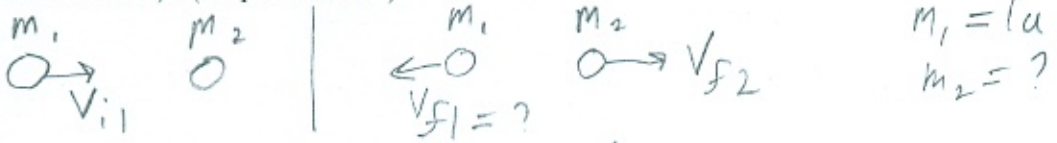
$$E_f = mgh \qquad y_f = h, \; v_f = 0, \; x_f = 0$$

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

$$h = \frac{kx^2}{2mg} = \frac{(25\,\text{N/m})(0.1\,\text{m})^2}{2(0.05\,\text{kg})(9.8\,\text{m/s}^2)} = \boxed{0.255\,\text{m}}$$

Problem 4. A proton (mass of 1 u, where u = atomic mass unit) is shot toward an unknown target nucleus which is at rest. The initial speed of the proton is 2.50×10^6 m/s. The target nucleus acquires a speed of 3.12×10^5 m/s. What is the mass of the target? (Bonus if you can guess the element). (15 points total)

V_{f2} V_{i1}



momentum and energy are conserved

$V_{f2} = \frac{2m_1}{m_1+m_2} V_{i1}$ solve for m_2

$(m_1+m_2)V_{f2} = 2m_1V_{i1}$

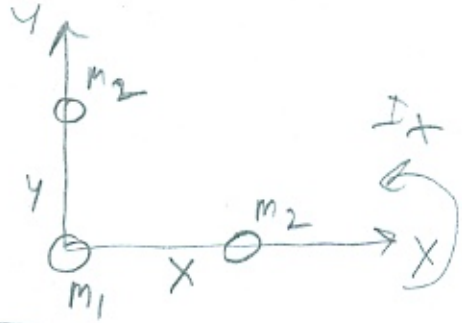
$m_1V_{f2} + m_2V_{f2} = 2m_1V_{i1}$

$m_2V_{f2} = 2m_1V_{i1} - m_1V_{f2}$

$m_2 = 2m_1\frac{V_{i1}}{V_{f2}} - m_1 = 2(1)\left(\frac{2.56\times10^6}{3.12\times10^5}\right) - 1$

$m_2 = 15.4u$ either ^{15}N or ^{15}O

Problem 5. Three masses in the $x-y$ are connected by massless-rods making a triangle. The masses are m_1 =300 g, m_2=200 g, and m_3 =100 g. Their positions are $\vec{r}_1 =< 0,0,0 >$, $\vec{r}_2 =< 0,10,0 >$ cm, and $\vec{r}_3 =< 10,0,0 >$ cm. Determine (a) the center of mass of the system and (b) the moment of inertia of the system for rotation about the x-axis. (15 points total)



a) $X_{cm} = \frac{m_1X_1 + m_2X_2 + m_3X_3}{m_1+m_2+m_2}$

$= \frac{m_1(0) + m_2(0) + 0.1kg(0.1m)}{.3+.2+.1}$

$= \frac{0.01}{0.6} = 1.67\times10^{-2}m = \boxed{1.67cm}$

b) $Y_{cm} = \frac{m_1Y_1 + m_2Y_2 + m_3Y_3}{m_1+m_2+m_2} = \frac{0 + (0.2kg)(0.1m)}{0.6kg}$

$= \boxed{3.33cm}$

c) $I_x = \sum m_i r_i^2 = m_2y^2$

$= (0.2kg)(0.1m)^2 = \boxed{2\times10^{-3}\ kgm^2}$

Problem 6. A 750 g disk and a 760 g ring, both 15 cm in diameter, are rolling along a horizontal surface at 1.5 m/s when they encounter a 15° slope. How far up the slope (the displacement) does each travel before rolling back down? (30 points total)

Use conservation of energy

$m = 0.75\,kg$

$R = 0.075\,m$

$V_i = 1.5\,m/s$

$\theta = 15^\circ$

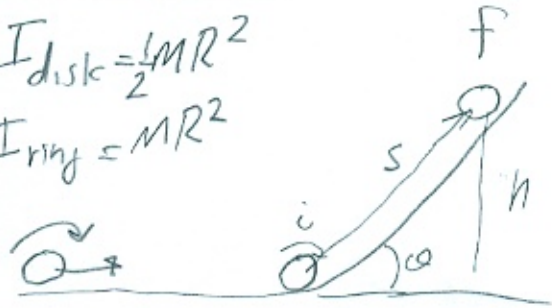
Find s?

$y_i = 0$

$V_f = 0$

$I_{disk} = \frac{1}{2}MR^2$

$I_{ring} = MR^2$



Total energy $E = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + mgy$

$E_i = E_f$

$E_i = \frac{1}{2}mV_i^2 + \frac{1}{2}I\omega^2$, $E_f = mgy_f = mgh$

$= \frac{1}{2}mV_i^2 + \frac{1}{2}cMR^2\left(\frac{V_i}{R}\right)^2$ | let $I = cMR^2$, $c = \frac{1}{2}$ or 1

$V_t = r\omega$

$= \frac{1}{2}mV_i^2 + \frac{1}{2}cmV_i^2$

$= \frac{1}{2}(1+c)mV_i^2 = mgh$

$\Rightarrow h = \frac{(1+c)V_i^2}{2g}$

geometry

$h = s\sin\alpha \Rightarrow s = \frac{h}{\sin\alpha}$

$s\sin\alpha = \frac{(1+c)V_i^2}{2g}$

$s = \frac{(1+c)V_i^2}{2g\sin\alpha}$

Ring $s = \frac{(1+1)V_i^2}{2g\sin\alpha} = \frac{V_i^2}{g\sin\alpha}$

$= \frac{(1.5)^2}{(9.8)\sin 15^\circ} = \boxed{0.887\,m}$

Disk $s = \frac{(1+\frac{1}{2})V_i^2}{2g\sin\alpha} = \frac{3V_i^2}{4g\sin\alpha} = \boxed{0.665\,m}$

m_2 T L

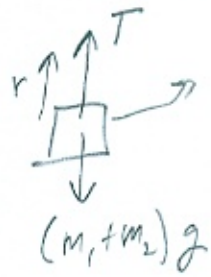
Bonus Problem. A 20 kg wood ball hangs from a 2.0-m-long wire. The maximum tension the wire can withstand without breaking is 400 N. A 1.0 kg projective traveling horizontally hits and embeds itself in the wood ball. What is the greatest speed this projectile can have without causing the wire to break? (5 points total)

m_1

- Use conservation of momentum before and after collision
- Newton 2nd Law for circular motion

$$m_1 V_1 = (m_1 + m_2) V_2$$

$$V_2 = \left(\frac{m_1}{m_1 + m_2}\right) V_1 \quad -(1)$$



$$+\uparrow \Sigma F_r = (m_1 + m_2) a_r$$

$$T - (m_1 + m_2) g = (m_1 + m_2) \frac{V_2^2}{L}$$

solve for V_2^2

$$V_2^2 = \frac{[T - (m_1 + m_2) g] L}{(m_1 + m_2)} \quad -(2)$$

substitute (1) into (2)

$$\frac{(m_1)^2}{(m_1 + m_2)^2} V_1^2 = \frac{[T - (m_1 + m_2) g] L}{(m_1 + m_2)}$$

or

$$V_1^2 = \frac{(m_1 + m_2)[T - (m_1 + m_2) g] L}{m_1^2}$$

or

$$V_1 = \frac{1}{m_1} \sqrt{(m_1 + m_2)[T - (m_1 + m_2) g] L}$$

$$= \frac{1}{1} \sqrt{(21)[400 - (21)(9.8)] 2}$$

$$\Rightarrow V_1 = \boxed{90.3 \text{ m/s}}$$