Name (please print): ______________________________________
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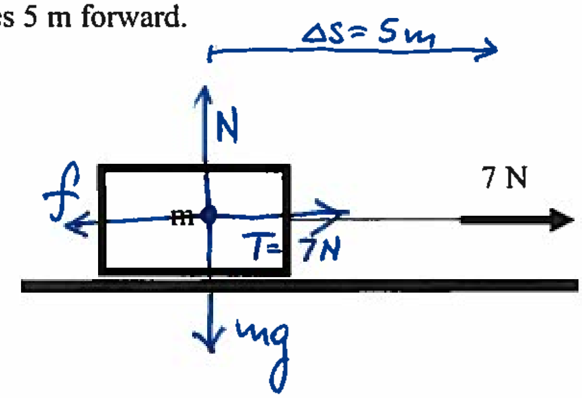
Section Number (e.g. M003) ________ SUID ________________

Physics 211, Fall 2019 Exam 3

Document your work or earn no credit. *Use the back of each sheet if you run out of space. Cross out any parts that correspond to given up thoughts.* ***For numerical answers give at least 2 significant digits and specify units.*** *Assume g=10 m/s² throughout this exam.* ***See the last page for the table with moments of inertia.***

1. [20pts total] A crate of mass m=3 kg is being pulled on leveled floor with a force of 7 Newtons using a cord inclined horizontally (see picture below). The coefficient of kinetic friction between the crate and the floor is μ_k=0.2. The crate moves 5 m forward.



(a) [6pts] Calculate the work done by the frictional force.

$$W_f = \vec{f}\cdot\vec{\Delta s} = -f\Delta s$$

Newton's 2nd Law in vertical direction:

$$m\underset{0}{a_y} = N - mg \rightarrow N = mg$$

$$f = \mu N = \mu mg$$

$$W_f = -\mu mg\Delta s = -30\ J$$

(b) [2pts] Calculate the work done by the gravitational force (i.e. by weight).

$$W_{mg} = m\vec{g}\cdot\vec{\Delta s} = mg\Delta s\underset{0}{\cos 90^\circ} = 0$$

(c) [2pts] Calculate the work done by the tension force of the cord.

$$W_T = \vec{T}\cdot\vec{\Delta s} = T\cdot\Delta s = 7\cdot 5 = 35\ J$$

(d) [2pts] Calculate the work done by the normal force from the floor.

$$W_N = \vec{N}\cdot\vec{\Delta s} = 0$$

(e) [3pts] Calculate the net work done on the block.

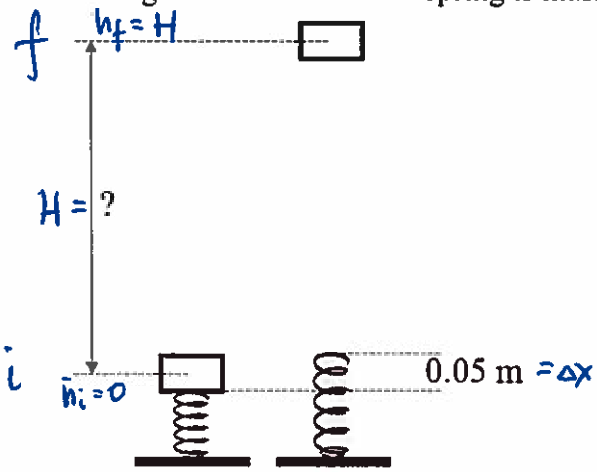
$$W_{net} = W_f + W_{mg} + W_T + W_N = -30 + 35 = 5\ J$$

(f) [5pts] Assuming the block started from rest, **use work-kinetic energy relation** to calculate its final velocity.

$$W_{net} = \Delta K = K_f - \underset{0}{K_i} = \frac{1}{2}mv_f^2$$

$$v_f = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{2\cdot 5}{3}} = 1.82\ \frac{m}{s}$$

2. [20pts total] A 0.35kg block is resting on a vertical spring compressed by 0.05m relatively to its natural length. The spring constant is equal to 1500 N/m. The spring is then allowed to relax, thus the block is shot upwards. How high does the block rise above its initial position? Neglect the air drag and assume that the spring is massless.



$$E_i = E_f$$

$$K_i + U_i = K_f + U_f$$

$$K_i = 0, \quad U_i = U_{spring} = \frac{1}{2}k\Delta x^2, \quad K_f = 0, \quad U_f = U_{gravit.} = mgH$$

$$\frac{1}{2}k\Delta x^2 = mgH$$

$$H = \frac{\frac{1}{2}k\Delta x^2}{mg} = \frac{\frac{1}{2}\,1500 \cdot 0.05^2}{0.35 \cdot 10} = 0.54 \text{ m}$$

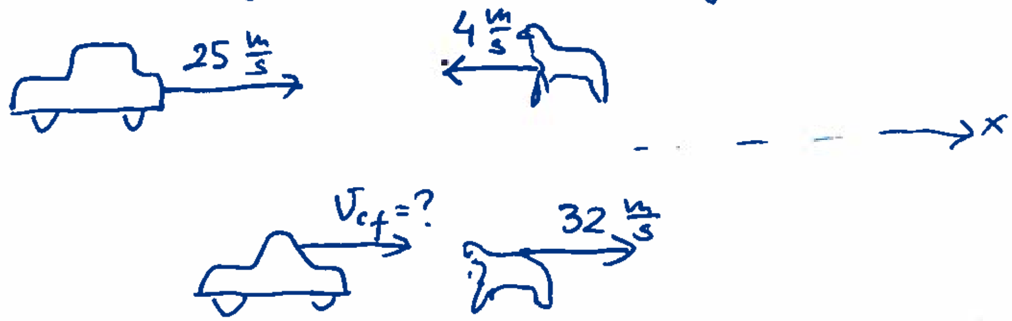
3. [20pts total] A moose running at a speed of 4 m/s, runs head on into a car. The car is going 25 m/s (about 55 mph) immediately before the collision. The mass of the moose is 600 kg. The mass of the car is 1100 kg.

(a)[10pts] The moose bounces off the car with a speed of 32 m/s immediately after the collision. What is the speed of the car in m/s immediately after the collision?

$m_c = 1100 \text{ kg}$ $\qquad$ $m_m = 600 \text{ kg}$

i

f



$$\vec{P}_{tot\,i} = \vec{P}_{tot\,f}$$

$$\underset{25}{m_c v_{cix}} + \underset{-4}{m_m v_{mix}} = \underset{v_{cf} = ?}{m_c v_{cfx}} + \underset{32}{m_m v_{mfx}}$$

$$v_{cf} = \frac{1100 \cdot 25 + 600(-4) - 600 \cdot 32}{1100} = 5.4 \ \frac{m}{s}$$

(b)[10pts] (A different scenario than in point (a)). The moose falls into the car through the front window and gets stuck in the car. What is the speed of the car immediately after the collision?

i $\qquad$ same as above

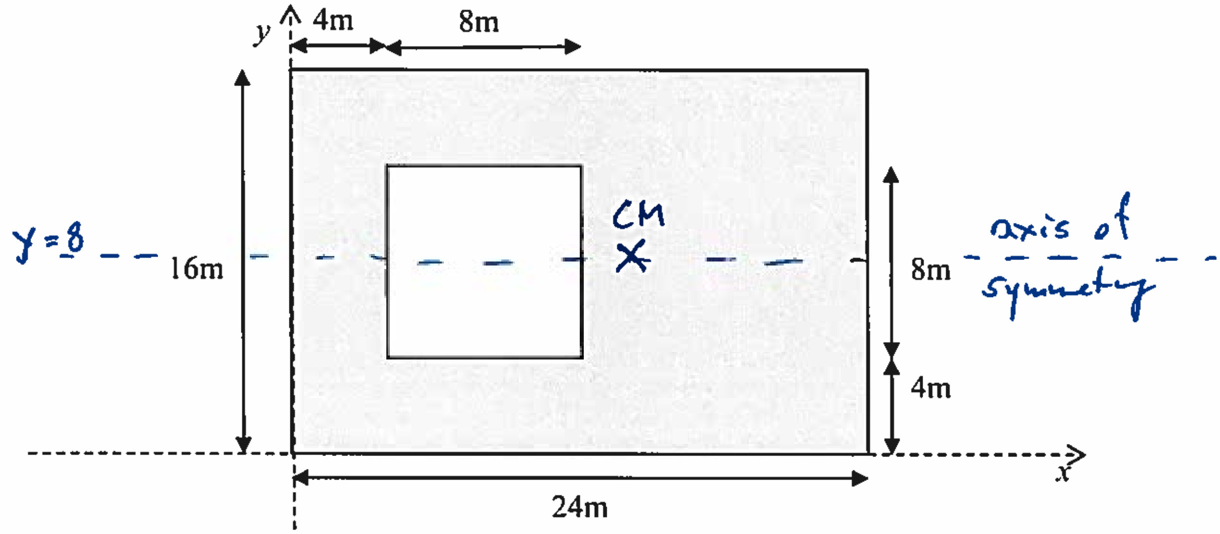
f

$(v_{cf} = v_{mf})$

$$m_c v_{cix} + m_m v_{mix} = (m_c + m_m) v_{cf}$$

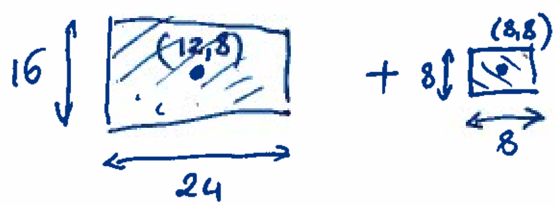
$$v_{cf} = \frac{1100 \cdot 25 + 600(-4)}{1100 + 600} = 14.7 \ \frac{m}{s}$$

4. [20pts] Find the center-of-mass of the uniform plate shown below – express your result as x and y coordinates of the center-of-mass location in the coordinate system shown below. Also mark its position on the drawing and label it "CM".



$Y_{CM} = 8\text{ m}$ from symmetry

fastest way to find X_{cm} is a trick with negative mass:



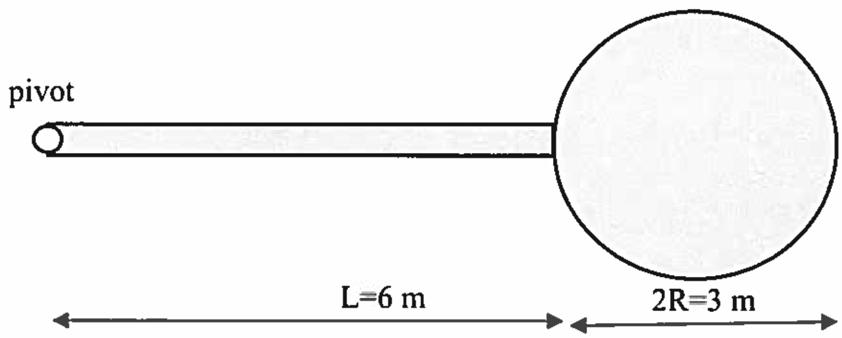
$m_1 = 16 \cdot 24$
$= 384$

$m_2 = -8 \cdot 8$
$= -64$

$$X_{CM} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} = \frac{384 \cdot 12 + (-64)\,8}{384 + (-64)}$$

$$= 12.8\text{ m}$$

5. [20pts] Find the moment of inertia of a solid disk of mass M_d=7 kg attached to a slender rod of mass M_r=5 kg about the axis of rotation going through the far end of the rod and perpendicular to the disk (the pivot point is shown below). The dimensions are given below.



$$I = I_{disk} + I_{rod}$$

$$I_{disk} = \underbrace{I_{disk\ cM}}_{= \frac{1}{2} M_d R^2} + M_d (L+R)^2$$

$$I_{rod} = \underbrace{I_{rod\ cM}}_{= \frac{1}{12} M_r L^2} + M_r \left(\frac{L}{2}\right)^2$$

$$= \frac{1}{3} M_r L^2$$

(OK to get this from the Table)

$$I = 461.6 \ kg \cdot m^2$$

Table 9.2 Moments of Inertia of Various Bodies