Name (please print): _____
Last *First*

Section Number (e.g. M013) _____ SUID _____

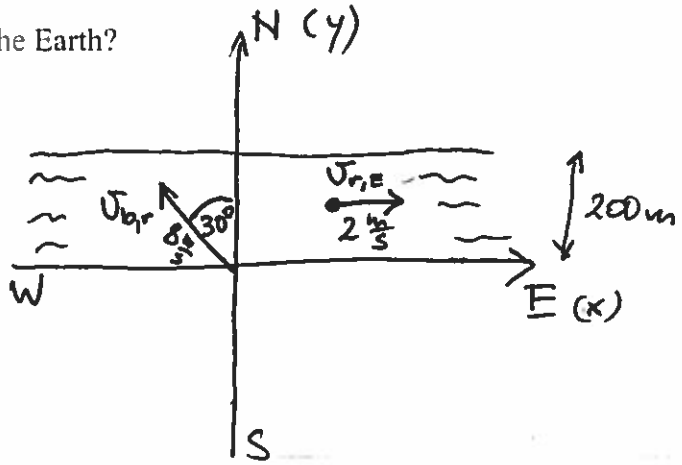
Physics 211, Fall 2019 Exam 2

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 $g=10\ m/s^2$ throughout the entire exam.
$(\sin 30^0 = 0.500, \cos 30^0 = 0.866)$

1. [20pts total] A 200-m-wide river flows due east at a uniform speed of 2 m/s. A boat with a speed of 8 m/s relative to the water leaves a south bank pointed in direction of 30° west of north.

   a) [14pts] What is the speed of the boat relative to the Earth?



$$\vec{v}_{b,E} = \vec{v}_{b,r} + \vec{v}_{r,E}$$

$$= (-8\sin 30^\circ, 8\cos 30^\circ) + (2,0)$$
$$= (2 - 8\sin 30^\circ, 8\cos 30^\circ)$$
$$= (-2, 6.93)$$

$$v_{b,E} = \sqrt{(-2)^2 + 6.93^2} = 7.21\ \frac{m}{s}$$

   b) [3pts] How long does the boat take to cross the river?

$$\Delta t = \frac{\Delta y}{v_{b,E\,y}} = \frac{200}{6.93} = 28.9\ s$$

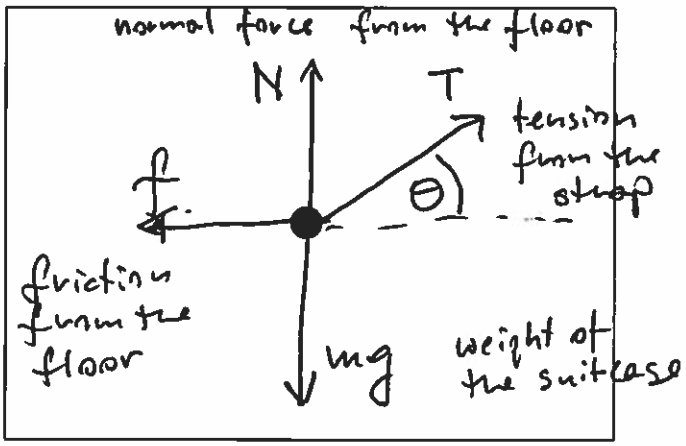
   c) [3pts] Where does it land along the river relative to its starting point (specify distance and say whether upstream or downstream)?

$$\Delta x = v_{b,E\,x} \cdot \Delta t = -2 \cdot 28.9 = -57.7\ m$$

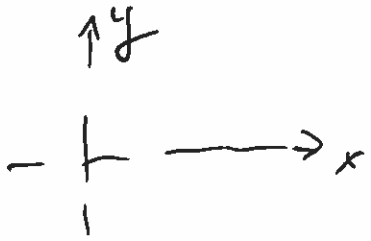
upstream

2. [20pts total] A women at an airport is towing her 20 kg suitcase at constant speed by pulling on a strap at an angle $\theta = 30°$. The coefficient of kinetic friction between the suitcase and the floor is $\mu = 0.3$

a) [8pts] Draw a free-body diagram for the suitcase. Describe forces you draw.



b) [12pts] What is the tension in the strap?



Unknown f, N, T

$$\begin{cases} ma_x = T\cos\theta - f \\ \quad \| \\ \quad 0 \\ ma_y = N + T\sin\theta - mg \\ \quad \| \\ \quad 0 \\ f = \mu N \end{cases}$$

$N = mg - T\sin\theta$

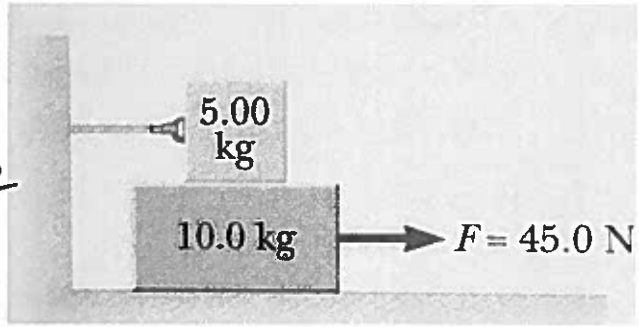
$f = \mu(mg - T\sin\theta)$

$0 = T\cos\theta - \mu(mg - T\sin\theta)$

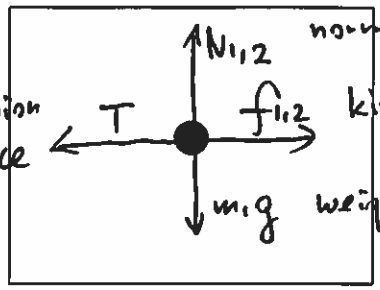
$\mu mg = T(\cos\theta + \mu\sin\theta)$

$$\boxed{T = \frac{\mu}{\cos\theta + \mu\sin\theta} mg} = \frac{0.3}{0.866 + 0.3 \cdot 0.5} 20 \cdot 10 = 59 \text{ N}$$

3. [25pts total] A m_1=5 kg block is placed on top of m_2=10 kg block as shown below. A horizontal force of F=45 N is applied to the 10 kg block, and the 5 kg block is tied to the wall. The coefficient of kinetic friction between all moving parts is μ =0.2.



a) [4pts] Draw a free-body diagram for the upper block. Describe forces you draw.



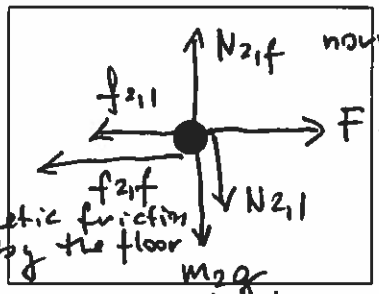
normal force on 1 by 2

tension force

kinetic friction on 1 by 2

weight

b) [6pts] Draw a free body diagram for the lower block. Describe forces you draw.



normal force on 2 by the floor

applied force on 2

kinetic friction on 2 by the floor

weight

$f_{2,1} = f_{1,2}$ } Newton's 3rd Law
$N_{2,1} = N_{1,2}$

c) [5pts] What is the tension in the string?

unknown $f_{1,2}, a_{1,2}, T$

$$m_1 a_{1x} = f_{1,2} - T$$
$$\| \; 0$$
$$m_1 a_{1y} = N_{1,2} - m_1 g$$
$$f_{1,2} = \mu N_{1,2}$$

$$T = f_{1,2} = \mu N_{1,2} = \mu m_1 g$$
$$= 0.2 \cdot 5 \cdot 10 = 10 \text{ N}$$

d) [10pts] What is the acceleration of the lower block?

unknown $f_{2,1}$ $f_{2,f}$ N_{2f} $N_{2,1}$ a_{2x}

$$m_2 a_{2x} = F - f_{2,1} - f_{2,f}$$
$$m_2 a_{2y} = N_{2,f} - N_{2,1} - m_2 g$$
$$\| \; 0$$
$$f_{2,1} = \mu N_{2,1}$$
$$f_{2,f} = \mu N_{2,f}$$
$$N_{2,1} = N_{1,2} = m_1 g$$

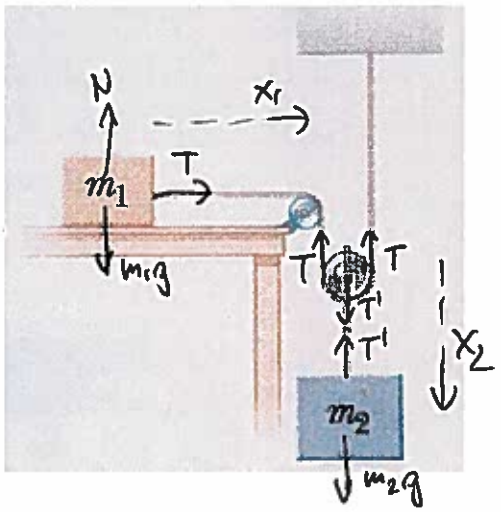
$$N_{2,f} = N_{2,1} + m_2 g = (m_1 + m_2) g$$

$$f_{2,f} = \mu (m_1 + m_2) g$$

$$m_2 a_x = F - \mu (m_1 + m_2 + m_1) g$$
$$= F - \mu (2m_1 + m_2) g$$

$$a_{2x} = \frac{F}{m_2} - \mu \frac{2m_1 + m_2}{m_2} g =$$
$$= \frac{45}{10} - 0.2 \frac{2 \cdot 5 + 10}{10} 10 = 0.5 \frac{m}{s^2}$$

4. [20pts total] For the system shown below, the pulleys and the cord are light and the surface of the table is frictionless. The cord does not stretch. m_1=3 kg, m_2=9 kg



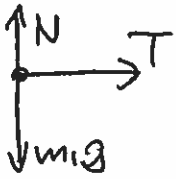
a) [2pts] If block m_1 slides to the right by $\Delta x_1 = 0.1m$, by how much will the block m_2 descent?

$$\Delta x_2 = \frac{1}{2}\Delta x_1 = 0.05\,m$$

b) [18pts] What is the tension in the cord?

viewed as 2-part system

m_1:



m_2 + pulley:

unknown a_1, a_2, T

$$\begin{cases} m_1 a_1 = T \\ m_2 a_2 = m_2 g - 2T \\ a_2 = \frac{1}{2} a_1 \quad \text{(see a)} \end{cases}$$

$$\rightarrow a_1 = \frac{T}{m_1}$$

$$m_2 \frac{1}{2}\frac{T}{m_1} = m_2 g - 2T$$

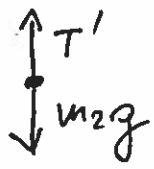
$$T\left(\frac{m_2}{2m_1} + 2\right) = m_2 g$$

$$\boxed{T = \frac{m_2}{\frac{m_2}{2m_1} + 2} g} = \frac{g}{\frac{g}{2 \cdot 3} + 2} 10 = 25.7\,N$$

viewed as 3-part system

m_1 : see above

m_2:



moveable pulley:

unknown a_1, a_2, T, T'

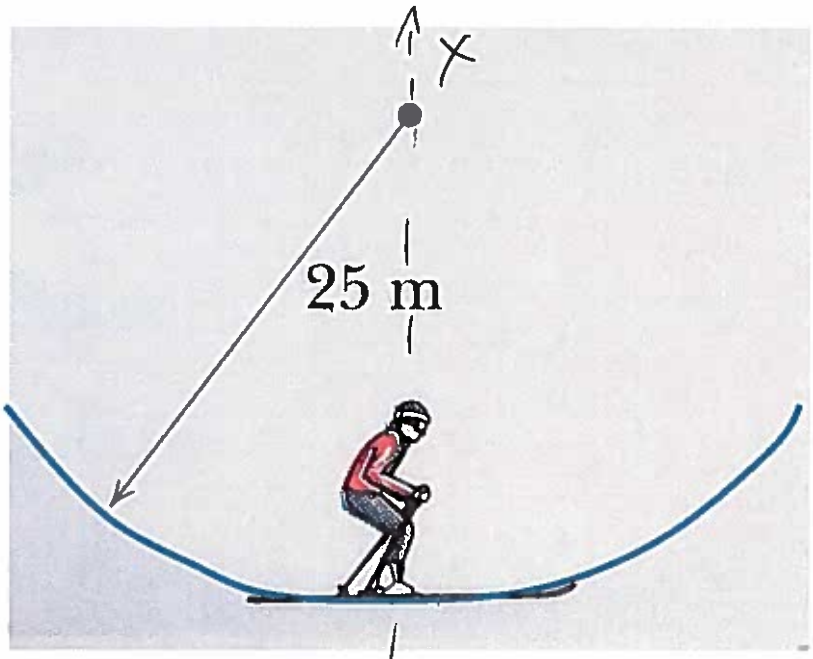
$$\begin{cases} m_1 a_1 = T \\ m_2 a_2 = m_2 g - T' \\ 0 = 2T - T' \quad \text{(pulley)} \\ a_2 = \frac{1}{2} a_1 \end{cases}$$

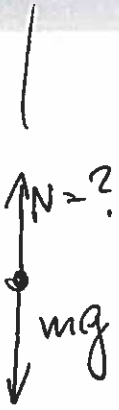
same as above

if solved for T'

$$T' = 2T = 51.4\,N$$

5. [15pts] A skier with a mass of 80 kg is at the bottom of circular bowl with a radius of 25 m and has a speed of 5 m/s. What is the normal force on the skier from the ground?





$$\begin{cases} ma_x = N - mg \\ a_x = \dfrac{v^2}{R} \end{cases}$$

$$N = m(a_x + g) = m\left(\frac{v^2}{R} + g\right)$$

$$= 80\left(\frac{5^2}{25} + 10\right) = 80 \cdot 11 = 880\ N$$