# PHY 211 – Exam 2 (Version 1)

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**SUID:** ______________

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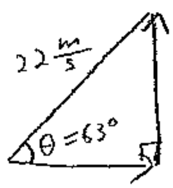
**It is very important that you print your name at the top of the exam page. Please do it before you read any questions!**

*Document your work. Use the back of each sheet if you run out of space.*

**1.[25 pts total]** Mike throws a ball upward and toward the east at a $63^0$ angle with the level ground and a speed of 22 m/s. Nancy drives east past Mike at 30 m/s at the instant he releases the ball.

**a.** [6 pts] What are the x and y components of the initial velocity of the ball in Mike's reference frame?




$$V_{ix} = V_i \cos\theta = 22\frac{m}{s}\cos 63° = \boxed{9.99\frac{m}{s}}$$

$$V_{iy} = V_i \sin\theta = 22\frac{m}{s}\sin 63° = \boxed{19.6\frac{m}{s}}$$

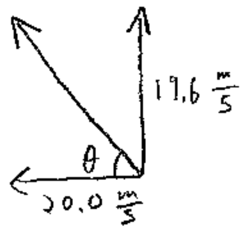
**b.** [3 pts] Is the ball heading east or west in Nancy's reference frame?

In Nancy's reference frame,

$$V_{ix} = 9.99\frac{m}{s} - 30\frac{m}{s} = -20.0\frac{m}{s}$$

so the ball is heading west.

**c.** [8 pts] What is the ball's initial speed in Nancy's reference frame?

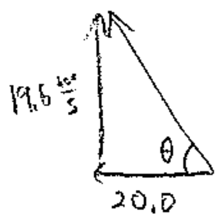



$$V_{iN} = \sqrt{V_{ixN}^2 + V_{iyN}^2}$$

$$= \sqrt{20.0^2 + 19.6^2} = \boxed{28.0 \frac{m}{s}}$$

Y-component is the same in both frames.

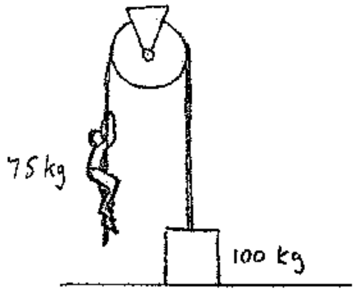
**d.** [8 pts] What is the ball's initial angle in Nancy's reference frame?



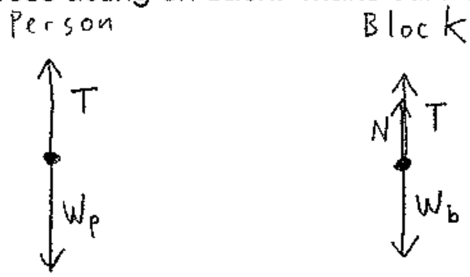

$$\tan\theta = \frac{V_{iyN}}{V_{ixN}} = \frac{19.6}{20.0}$$

$\Rightarrow$ $\boxed{\theta = 44.4^\circ \text{ above the horizontal, heading west}}$

**2. [25 pts total]** The following diagram shows a 75 kg person holding onto a rope running through a pulley with a 100 kg block attached to it. Assume that the string and pulley are massless and that there is no friction in the pulley. The system is at rest.




**a.** [5 pts] Draw the free-body diagrams for the person and for the block, labeling all of the forces acting on each. Make sure to label which free-body diagram is which.




$$W_p = m_p g$$
$$W_b = m_b g$$

**b.** [10 pts] What is the tension in the rope?

$\Sigma \vec{F} = m\vec{a}$ $\Rightarrow$ $T - W_p = 0 \Rightarrow T - m_p g = 0 \Rightarrow T = m_p g$

$\Sigma \vec{F} = 0$ $\Rightarrow T = 75\text{ kg} \cdot 9.8\frac{\text{m}}{\text{s}^2} = \boxed{735\text{ N}}$

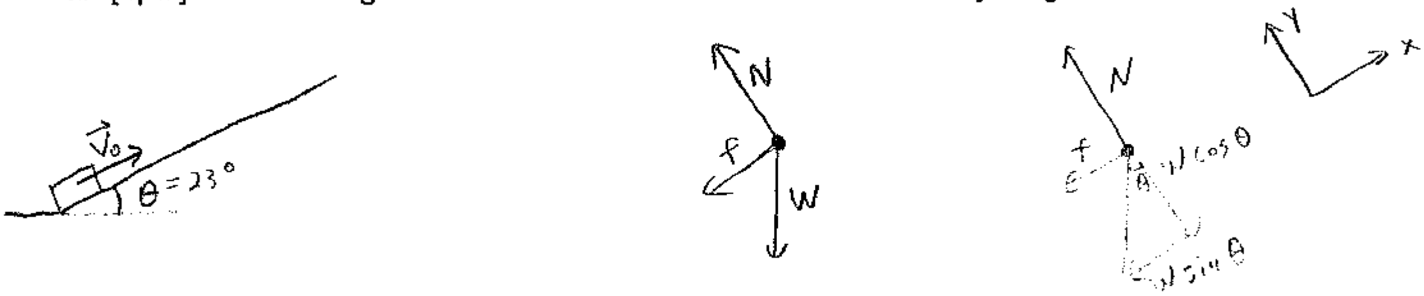
**c.** [10 pts] The block rests on an industrial-size scale. What is the reading of the scale (in Newtons)?

$$T + N - W_b = 0$$
$$N = W_b - T = m_b g - T = 100\text{ kg} \times 9.8\frac{\text{m}}{\text{s}^2} - 735\text{ N}$$
$$= 245\text{ N}$$

The normal force on the block is equal to the normal force of the block on the scale, so the scale reads $\boxed{N = 245\text{ N}}$

**3. [25 pts total]** A 0.050 kg wooden block at the bottom of a wooden ramp is given an initial speed up the ramp of 3.0 m/s. The ramp is inclined at 23$^0$ above level ground. The coefficient of kinetic friction of wood on wood is 0.20 and the coefficient of static friction of wood on wood is 0.50.

a. [4pts] Draw a diagram of the situation and draw the free body diagram for the block.




b. [9pts] How far up the ramp is the block when its speed slows to zero?

$$\sum \vec{F} = m\vec{a} \Rightarrow \sum F_x = ma_x , \quad \sum F_y = ma_y , \quad f = \mu_K N, W = mg$$

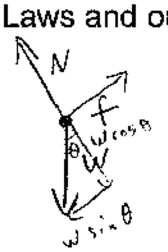
$$N - W\cos\theta = 0 , \quad -f - W\sin\theta = ma$$

$$N = mg\cos\theta \Rightarrow f = \mu_K mg\cos\theta$$

$$\Rightarrow -\mu_K \cancel{m} g\cos\theta - \cancel{m}g\sin\theta = \cancel{m}a$$

$$a = -0.20 \times 9.8\cos 23° - 9.8\sin 23° = -5.63\,\frac{m}{s^2}$$

c. [8pts] What is the maximum angle to which the ramp can be raised before the block placed at rest on the ramp will start to slide down? Justify your answer from Newton's Laws and our model of friction.




$$N - W\cos\theta = 0$$

$$f - W\sin\theta = 0$$

$f = \mu_S N$ when the angle is just small enough that the block doesn't slip.

$$W = mg \Rightarrow N = mg\cos\theta$$

$$\mu_s N - mg\sin\theta = 0 \Rightarrow \mu_s \cancel{mg}\cos\theta - \cancel{mg}\sin\theta = 0$$

$$\Rightarrow \mu_s = \frac{\sin\theta}{\cos\theta} = \tan\theta \Rightarrow \theta = \tan^{-1}\mu_s$$

$$\theta = \tan^{-1}(0.50) = \boxed{26.6°}$$

d. [4pts] When the block's speed slows to zero in the above example does it start to slide back down, or does it stay where it is? Explain.

When the block comes to rest, static friction is the relevant force. The block stays if the angle is less than or equal to 26.6°. Since the actual angle is 23°, the block stays where it is when it comes to rest.

3.b.) cont.)

$V_0 = 3.0\,\frac{m}{s}$, $V_f = 0$, $a = -5.63\,\frac{m}{s^2}$

$$V_f^2 = V_0^2 + 2aX \qquad X = \frac{V_f^2 - V_0^2}{2a}$$

$$\Rightarrow X = \frac{0 - 3.0^2}{-2 \times 5.63} = \boxed{0.799\ m}$$

**4. [25 pts total]** A computer hard disk 8.0 cm in diameter is initially at rest. A small dot is painted on the edge of the disk. The disk accelerates at 600 rad/s$^2$ for ½ s, then coasts at a steady angular velocity for another ½ s.

a. [6 pts] What is the speed of the dot after ½ s?

$r = 4.0\,cm = 0.040\,m \qquad \alpha = 600\,\frac{rad}{s^2},\; t = 0.5\,s,\; \omega_i = 0$

$\omega_1 = \omega_0 + \alpha t \Rightarrow \omega_1 = \alpha t = 600\,\frac{rad}{s^2} \times 0.5\,s = 300\,\frac{rad}{s}$

$V = \omega_1 r = 300\,\frac{rad}{s} \times 0.040\,m = \boxed{12.0\,\frac{m}{s}}$

b. [6 pts] Through how many revolutions has the dot turned after ½ s?

$\theta_1 - \theta_0 = \cancel{\omega_0 t} + \frac{1}{2}\alpha t^2 = \frac{1}{2} \times 600 \times 0.5^2 = 75\,rad$

$= 75\,rad \,\frac{1\,rev}{2\pi\,rad} = \boxed{11.9\,rev}$

c. [6 pts] What is the speed of the dot after 1 s?

$\omega_1 = 300\,\frac{rad}{s}, \quad \alpha = 0$

$\boxed{V = 12.0\,\frac{m}{s}}$, same as part a, because the speed doesn't change.

d. [7 pts] Through how many revolutions has it turned after 1 s?

$\theta_2 = \theta_1 + \omega_1 t + \cancel{\frac{1}{2}\alpha t^2}$

$= 75\,rad + 300\,\frac{rad}{s} \times 0.5\,s = 225\,rad$

$\Rightarrow 225\,rad\,\frac{1\,rev}{2\pi\,rad} = \boxed{35.8\,rev}$

# Formula Sheet for Physics 211

$$\vec{v} = \frac{d\vec{x}}{dt}; \quad \vec{a} = \frac{d\vec{v}}{dt}$$

$$\Delta x = x(t_2) - x(t_1) \ = \text{ signed area under the v(t) curve from t1 to t2} = \int_{t_1}^{t_2} v(t)dt$$

$$\Delta v = v(t_2) - v(t_1) \ = \text{ signed area under the a(t) curve from t1 to t2} = \int_{t_1}^{t_2} a(t)dt$$

$$v_x = v_{0x} + a_x t; \quad x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2; \quad v_x^2 = v_{0x}^2 + 2a_x \Delta x$$

$$\theta = \frac{s}{r} : \theta \text{ in radians}; \quad \omega = \frac{d\theta}{dt} \quad \alpha = \frac{d\omega}{dt}$$

$$a_c = a_{rad} = \frac{v^2}{r}; \quad T = \frac{2\pi r}{v}$$

$$v = \omega r : \omega \text{ in radians per unit time}; \quad a_{tan} = \alpha r : \alpha \text{ in radians per unit time squared}$$

$$\omega = \omega_0 + \alpha t; \quad \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2; \quad \omega^2 = \omega_0^2 + 2\alpha\Delta\theta$$

$$\vec{v} = v_x\hat{i} + v_y\hat{j}; \quad v_x = |v|\cos(\theta); \quad v_y = |v|\sin(\theta)$$

$$v = |\vec{v}| = \sqrt{v_x^2 + v_y^2}; \quad \theta = \tan^{-1}(v_y/v_x)$$

$$\vec{v}_{CB} = \vec{v}_{CA} + \vec{v}_{AB}$$

$$g = 9.8 m/s^2$$

$$\vec{F}_{net} = \sum_i \vec{F}_i = m\vec{a}; \quad \vec{F}_{AB} = -\vec{F}_{BA}$$

$$|\vec{F}_{fk}| = \mu_k N; \quad |\vec{F}_{fs}| \le \mu_s N$$

$$|F_{net,radial}| = \frac{mv^2}{R}$$