Practice Problems for 2nd Midterm for Calculus-Based Physics-1: Mechanics (PHYS150-01)

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1 Vectors and Newton's Laws

For each of the exercises below, $\vec{a} = 3\hat{i} + 4\hat{j}$, and $\vec{b} = 6\hat{i} + 8\hat{j}$.

1. Calculate the magnitude of $\vec{a}$: $|\vec{a}| = \sqrt{3^2 + 4^2} = 5$.
2. Calculate the magnitude of $\vec{b}$: $|\vec{b}| = \sqrt{4^2 + 8^2} = 10$.
3. Calculate the dot product $\vec{a} \cdot \vec{b}$: $3 * 6 + 4 * 8 = 50$ (Notice the dot product gives a number).
4. Using $\vec{a} \cdot \vec{b} = |\vec{a}||\vec{b}| \cos\theta$, get the angle θ between the vectors: $\vec{a} \cdot \vec{b}/(|\vec{a}||\vec{b}|) = \cos\theta = 50/(5 * 10) = 1$. So $\cos\theta = 1$, therefore $\theta = 0$.

2 Restoring Forces and Young's Modulus

1. The Young's Modulus of a material, Y, is given in the following form:

$$\frac{x}{L} = \frac{p}{Y} \tag{1}$$

The *pressure* p is the applied force divided by the area being pressed or pulled $p = F/A$. The displacement x is the amount of length change, and L is the original length of the object. If a 100 N force is applied to an object with cross-sectional area 1.0 cm^2, with original length 5 cm, and the length changes by 1 mm, what is the Young's Modulus?

Solve it algebraically before plugging in numbers:
$Y = (F/A)(L/x)$.
But we need the area in m^2: 1 cm^2 $= 10^{-4}$ m^2. So we have
$Y = (100/10^{-4})(5cm/1mm) = 10^2 10^6 50 = 5 \times 10^9$ Pascals

3 Frictional Forces

1. We did a lab to measure μ_{k}, the coefficient of static friction. Show that the free-body diagram yields the following equation $\mu_{\mathrm{k}} = \frac{m_{\mathrm{P}}}{m_{\mathrm{B}}} < 1$:

The pulley transmits the gravitational force (which points down) into tension which pulls the block sideways. The tension is therefore $m_{\mathrm{P}}g$, where m_{P} is the mass on the pulley. The frictional force is $\mu_{\mathrm{B}}N$, where N is the normal force. The normal force is $m_{\mathrm{B}}g$, where m_{B} is the mass of the block. If these forces are in balance, we have $\mu_{\mathrm{B}}m_{\mathrm{B}}g = m_{\mathrm{P}}g$ so $\mu = \frac{m_{\mathrm{P}}}{m_{\mathrm{B}}}$. The mass on the pulley was always smaller because the block mass included the wood and weights added to it.