# Class Five: General Physics 3114
# Kigali Institute of Science and Technology

Professor David Feldman. 3 January 2012

**Outline for Today:**

1. Friction Forces
2. Hooke's Law and Springs
3. Simple Harmonic Motion and Waves
4. Rotational Kinematics

Last class was about dynamics—explaining motion using Newton's laws. Today, we continue with some additional topics in dynamics and kinematics. Next week: **Midterm Exam:** 10 January 2012.

**Friction Forces:** Friction is a force between two objects. It acts parallel to surfaces. Acts to prevent one surface from sliding across the other. Different surfaces behave differently. This is measured by the *coefficient of friction.*

**Kinetic Friction.** Friction between two objects that are moving relative to each other. Ex. I drag a table across the floor and friction exerts a force in the direction opposite to the motion.

$$F_{\text{kinetic}} = \mu_k F_N \tag{1}$$

where $F_N$ is the normal force. Ex: a 10kg block is pushed across a horizontal surface at a constant speed. The coefficient of friction is $\mu_k = 0.4$. What is the force pulling the block?

**Static Friction.** Force between two objects when the "stick together." E.g., I push on board but it doesn't move.

$$F_{\text{static}} = \mu_s F_N \ . \tag{2}$$

Here $F_{\text{static}}$ is the maximum value that the friction force can exert. The friction force "adjusts" depending on how hard the object is being pushed. Eventually, though, the friction force can get no larger and the object will start to slip. Ex. A 10 kg box sits at rest on the floor. The coefficient of static friction is $\mu_s = 0.6$. What is the hardest you can push on it without it moving?

**Springs and Hooke's Law:** Springs (and many other things) have the property that the force they exert is proportional to the amount they are stretched or compressed.

$$F\text{spring} = -k_s x \ , \tag{3}$$

where $k_s$ is the spring constant. It is different for different springs. And $x$ is the displacement from equilibrium. Hooke's law is an approximation. It works very well for many materials, but it is not a fundamental law of nature the way that Newton's laws are. You will investigate Hooke's Law in the lab.

Example: A 10 kg object is hung from a spring. The spring is stretched by 10 cm. What is the spring constant for the spring? The 10 kg object is removed and a different object is now attached to the same spring. The spring's displacement is now 12 cm. What is the new object's mass?

**Simple Harmonic Motion:** See the separate handout for more details. An object on the end of a spring will undergo simple harmonic motion—it oscillates at a single frequency. A nice way to see this is using Newton's second law and a bit of calculus. Ignoring friction, we have $F_{\text{net}} = -kx$. We also know that $F_{\text{net}} = ma$ by Newton's second law. The acceleration is just the second derivative of the position $x$. Combining all this we have:

$$m\frac{d^2x}{dt^2} = -kx \quad \Rightarrow \quad \frac{d^2x}{dt^2} = -\sqrt{\frac{k}{m}}x = -\omega^2 x \ . \tag{4}$$

This equation has solutions $x(t) = A\sin(\omega t)$: A sine save with angular frequency $\omega$.

**Waves:** See the handout on wave motion. Key terms: frequency, angular frequency, hertz, period, wavelength.

**Rotational Kinematics:** See the handout on "Angular Motion in a Plane." I think the key thing is to think of $\theta = s/r$ as being the *definition* of an angle.