Exam 1 information

- Exam 1 will be held **Tonight at 7:30 pm in HECC 207.**
- The exam is designed to take one hour and you will be given 75 minutes to complete your work. **The Exam will cover material in chapters 1-4.**
- **Some practice exam problems are available on the class web site.**
- **You will not need** a scantron. The exam book and formula sheet will be provided to you.
- **You will need your TAMU ID** and remember your section number and lecturers name.
- You will be allowed to use a calculator (simple), but if you have a programmable calculator, you must have cleared its memory **BEFORE** coming to the exam.
- Cell phones should be turned off and stored for the exam period. **Any use of cell phones during the exam is prohibited and if used will be considered an Honor Code violation.**
Chapter 5

Applying Newton’s Laws
Learning Goals

- How to use Newton’s Laws to solve problems involving forces that act on a body in equilibrium.
- How to use Newton’s 2\textsuperscript{nd} Law to solve problems involving the forces that act on an accelerating body.
- The nature of the different types of frictional forces: Static, Kinetic, Rolling, and Fluid Resistance, and how to solve problems that involve these forces.
- How to solve problems involving forces that act on a body moving along a circular path.
- The key properties of the four fundamental forces of nature.
Be careful when drawing your free body diagrams. MP is looking for you to draw these vectors in the correct angular configuration.
Newton’s Laws for Particles in Equilibrium

\[
\sum \vec{F}_{Net} = 0 \quad \text{then} \quad \vec{a}_{object} = 0
\]

using components

\[
\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0
\]
Problem-Solving Strategy 5.1  Newton’s First Law: Equilibrium of a Particle

IDENTIFY the relevant concepts: You must use Newton’s first law for any problem that involves forces acting on a body in equilibrium—that is, either at rest or moving with constant velocity. For example, a car is in equilibrium when it’s parked, but also when it’s traveling down a straight road at a steady speed.

If the problem involves more than one body and the bodies interact with each other, you’ll also need to use Newton’s third law. This law allows you to relate the force that one body exerts on a second body to the force that the second body exerts on the first one.

Identify the target variable(s). Common target variables in equilibrium problems include the magnitude and direction (angle) of one of the forces, or the components of a force.

SET UP the problem using the following steps:

1. Draw a very simple sketch of the physical situation, showing dimensions and angles. You don’t have to be an artist!
2. Draw a free-body diagram for each body that is in equilibrium. For the present, we consider the body as a particle, so you can represent it as a large dot. In your free-body diagram, do not include the other bodies that interact with it, such as a surface it may be resting on or a rope pulling on it.
3. Ask yourself what is interacting with the body by touching it or in any other way. On your free-body diagram, draw a force vector for each interaction. Label each force with a symbol for the magnitude of the force. If you know the angle at which a force is directed, draw the angle accurately and label it. Include the body’s weight, unless the body has negligible mass. If the mass is given, use \( w = mg \) to find the weight. A surface in contact with the body exerts a normal force perpendicular to the surface and possibly a friction force parallel to the surface. A rope or chain exerts a pull (never a push) in a direction along its length.
4. Do not show in the free-body diagram any forces exerted by the body on any other body. The sums in Eqs. (5.1) and (5.2) include only forces that act on the body. For each force on the body, ask yourself “What other body causes that force?” If you can’t answer that question, you may be imagining a force that isn’t there.

5. Choose a set of coordinate axes and include them in your free-body diagram. (If there is more than one body in the problem, choose axes for each body separately.) Label the positive direction for each axis. If a body rests or slides on a plane surface, it usually simplifies things to choose axes that are parallel and perpendicular to this surface, even when the plane is tilted.

EXECUTE the solution as follows:

1. Find the components of each force along each of the body’s coordinate axes. Draw a wiggly line through each force vector that has been replaced by its components, so you don’t count it twice. The magnitude of a force is always positive, but its components may be positive or negative.
2. Set the sum of all \( x \)-components of force equal to zero. In a separate equation, set the sum of all \( y \)-components equal to zero. (Never add \( x \)- and \( y \)-components in a single equation.)
3. If there are two or more bodies, repeat all of the above steps for each body. If the bodies interact with each other, use Newton’s third law to relate the forces they exert on each other.
4. Make sure that you have as many independent equations as the number of unknown quantities. Then solve these equations to obtain the target variables.

EVALUATE your answer: Look at your results and ask whether they make sense. When the result is a symbolic expression or formula, check to see that your formula works for any special cases (particular values or extreme cases for the various quantities) for which you can guess what the results ought to be.
Using Free Body Diagrams
Figure 5.1

(a) The situation

(b) Free-body diagram for gymnast

(c) Free-body diagram for rope

Gymnast hanging from the ceiling using a massless rope.
(a) Engine, chains, and ring

(b) Free-body diagram for engine

(c) Free-body diagram for ring O
Pulleys and Massless Ropes

For a massless rope passing over a frictionless pulley, all that happens is for the tension in the rope to change direction. The value of the tension remains the same.
Using Newton’s 2nd Law when there is acceleration

\[ \sum \vec{F}_{Net} = m\vec{a}_{sys} \]

using components

\[ \sum F_x = ma_{x-system} \quad \text{and} \quad \sum F_y = ma_{y-system} \]
A toboggan loaded with students with a total weight, \( w \), slides down a snow covered hill. What is its acceleration?
The friction and normal forces are really components of a single contact force.

On a microscopic level, even smooth surfaces are rough; they tend to catch and cling.
Figure 5.19

(a) No applied force, box at rest. No friction: $f_s = 0$

(b) Weak applied force, box remains at rest. Static friction: $f_s < \mu_s n$

(c) Stronger applied force, box just about to slide. Static friction: $f_s = \mu_s n$

(d) Box sliding at constant speed. Kinetic friction: $f_k = \mu_k n$

(e) Box at rest; static friction equals applied force. Box moving; kinetic friction is essentially constant.
Static and Kinetic Friction

Magnitude of Static Friction \( f_{\text{static}} \leq \mu_{\text{static}} n \)

Magnitude of Kinetic Friction \( f_{\text{kinetic}} = \mu_{\text{kinetic}} n \)

where \( n \) is the magnitude of the "normal force" between the two objects

Note: Static friction can have a value up to the maximum allowable and then the object begins to move. As mentioned in the pre-lectures, it provides just enough force to have the system remain fixed. Kinetic friction will always have a value of \( \mu_k n \).
Components of a Contact Force

- Frictional Force: $F_{\text{Ramp, Box}} = F_{\text{Ramp, Box}}$  
- Normal Force: $F_{\text{Ramp, Box}} \perp \equiv N$

Kinetic Friction: $f_k = \mu_k N$

Static Friction: $f_s \leq \mu_s N$