engr14 – intro to solid mechanics

**tue/thu, 11:30-1:20pm, 550-200**

### Syllabus

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Topic</th>
<th>Reading</th>
<th>HW due</th>
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<tr>
<td>W01</td>
<td>Force Week</td>
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<td>Ch 1-2</td>
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<tr>
<td>Tue</td>
<td>01/05</td>
<td>What's statics?</td>
<td>1.1-1.5</td>
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<tr>
<td>Thu</td>
<td>01/06</td>
<td>What's a force?</td>
<td>2.1-2.9</td>
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<td>W02</td>
<td>Particle Week</td>
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<td>Ch 3</td>
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<tr>
<td>Tue</td>
<td>01/12</td>
<td>What's a free body diagram at a particle?</td>
<td>3.1-3.2</td>
<td>HW1</td>
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<tr>
<td>Thu</td>
<td>01/14</td>
<td>What's force equilibrium at a particle?</td>
<td>3.3-3.4</td>
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<tr>
<td>W03</td>
<td>Moment Week</td>
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<td>Ch 4</td>
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<tr>
<td>Tue</td>
<td>01/19</td>
<td>What's a moment?</td>
<td>4.1-4.4</td>
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<tr>
<td>Thu</td>
<td>01/21</td>
<td>What's a couple? What's distributed loading?</td>
<td>4.5-4.7</td>
<td>HW2</td>
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<tr>
<td>W04</td>
<td>Practice Week</td>
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<td>Ch 1-4</td>
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<tr>
<td>Tue</td>
<td>01/26</td>
<td>Problems, problems, problems...</td>
<td>1.1-4.7</td>
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<tr>
<td>Thu</td>
<td>01/28</td>
<td><strong>Midterm 1</strong>, in class, closed book, 1 cheat sheet</td>
<td>1.1-4.7</td>
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<tr>
<td>W05</td>
<td>2d Equilibrium Week</td>
<td></td>
<td>Ch 5</td>
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<tr>
<td>Tue</td>
<td>02/02</td>
<td>What's a free body diagram of a 2d system?</td>
<td>5.1-5.2</td>
<td></td>
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<tr>
<td>Thu</td>
<td>02/04</td>
<td>What's force and moment equilibrium in 2d?</td>
<td>5.3-5.4</td>
<td>HW3</td>
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</tbody>
</table>

### Textbook / e-textbook

- Russell C. Hibbeler: Statics.
- Prentice Hall, 14th edition
- Engineering mechanics: statics
- Statics study pack for engineering mechanics
Homework I - Chapters 1 and 2

due Thursday, 01/14/16, 11:30am, 550-200

For late homework, you are responsible to arrange drop off with the teaching team. Once you have used up your three late days, you will no longer receive points for your homework. Here are our current office hours and contact information.

<table>
<thead>
<tr>
<th>When</th>
<th>When</th>
<th>Where</th>
<th>Jean-claude</th>
<th><a href="mailto:jceagle@stanford.edu">jceagle@stanford.edu</a></th>
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</thead>
<tbody>
<tr>
<td>Mon</td>
<td>05:00 - 07:00pm</td>
<td>520-155</td>
<td>Jenky</td>
<td><a href="mailto:jenky61@stanford.edu">jenky61@stanford.edu</a></td>
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<tr>
<td>Tue</td>
<td>05:00 - 07:00pm</td>
<td>520-155</td>
<td>Josh</td>
<td><a href="mailto:joshuasiegel@stanford.edu">joshuasiegel@stanford.edu</a></td>
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<tr>
<td>Wed</td>
<td>11:00 - 01:00pm</td>
<td>520-155</td>
<td>Kayla</td>
<td><a href="mailto:kepowers@stanford.edu">kepowers@stanford.edu</a></td>
</tr>
<tr>
<td>Wed</td>
<td>05:00 - 07:00pm</td>
<td>520-155</td>
<td>Ellen</td>
<td><a href="mailto:ekuhl@stanford.edu">ekuhl@stanford.edu</a></td>
</tr>
</tbody>
</table>

For this homework, you need to be familiar with chapters 1 and 2 of your book! You may skip pages 23-32.
basic quantities

- **length.** meter [m]
- **time.** second [s]
- **mass.** gram [g]
- **force.** newton [N]

idealizations

**particle.** A particle has a finite mass but a size that can be neglected. For example, the size of the earth is insignificant compared to the size of the orbit; therefore the earth can be modeled as a particle when studying planet motion.

**rigid body.** A rigid body is a combination of a large number of particles with all particles remaining at a fixed distance from one another.

**concentrated force.** A concentrated force is a representation of loading as a single point force. This is justified if the load is applied to an area which is small compared to the overall size of the body.

1.2 fundamental concepts

**newton’s three laws of motion**

- **first law**
  equilibrium
  if \( \sum F = 0 \) then \( \mathbf{v} = \text{const.} \)

- **second law**
  accelerated motion
  \( \mathbf{F} = m \cdot \mathbf{a} \)

- **third law**
  actio = reactio
  \( \mathbf{F}_{AB} = - \mathbf{F}_{BA} \)

weight

**SI system**

\[ W = m \cdot g \]

- \( W \) ... weight (derived quantity)
- \( m \) ... mass (basic quantity)
- \( g \) ... acceleration due to gravity
  \( g = 9.81 \text{ m/s}^2 \)

**FPS system**

\[ m = \frac{W}{g} \]

- \( m \) ... mass (derived quantity)
- \( W \) ... weight (basic quantity)
- \( g \) ... acceleration due to gravity
  \( g = 32.2 \text{ ft/s}^2 \)
1.3 units of measurement

**SI system**
- basic units: meters [m], seconds [s], kilogram [kg]
- derived unit: Newton [N = kg · m/s²]

**FPS system**
- basic units: feet [ft], seconds [s], pounds [lb]
- derived unit: slug [slug = lb · s²/ft]

2. force vectors

- to show how to add forces and resolve forces into components using the parallelogram law
- to express force in Cartesian coordinate system and explain how to determine a vector's magnitude and direction
- to introduce the dot product in order to determine the angle between two vectors or the projection of one vector onto another

2.2 vector operations

**vector addition and subtraction**

- vector addition: \( R = A + B = B + A \)

- vector subtraction: \( R = A - B = -B + A \)

2.3 vector addition and forces

**I. find the resultant force**

\[ F_R = F_1 + F_2 \]

- parallelogram vs triangle
II. Find the components of a force

- Parallelogram vs triangle

2.3 Vector Addition and Forces

IIa. Find the resultant of several forces

F_R = F_u + F_v

2.3 Vector Addition and Forces

2.4 Addition of Forces (2d)

Force addition in Cartesian coordinates

- We can easily add and subtract forces using a Cartesian coordinate system

\[
\begin{align*}
F &= \begin{bmatrix} F_x \\ F_y \end{bmatrix} \\
F = |F| \cos \theta \\
F_y = |F| \sin \theta \\
F_R &= \begin{bmatrix} F_{Rx} \\ F_{Ry} \end{bmatrix} \\
F_{Rx} &= \sum F_x \\
F_{Ry} &= \sum F_y
\end{align*}
\]

- We can determine the magnitude of a force using the Pythagoras

\[
F_R = \sqrt{ [F_{Rx}^2 + F_{Ry}^2] }
\]

- We can determine the direction of a force using trigonometry

\[
\theta = \tan^{-1} \left( \frac{F_{Ry}}{F_{Rx}} \right)
\]

Example 2.5

- Determine F_{1x} and F_{1y}

- Determine F_{2x} and F_{2y}

- Determine F_{Rx} and F_{Ry}

2.4 Addition of Forces (2d)
example 2.5

- determine $F_{1x}$ and $F_{1y}$
  
  $F_{1x} = -200 \cdot \sin 30^\circ \text{N} = -100\text{N}$
  
  $F_{1y} = +200 \cdot \cos 30^\circ \text{N} = +173\text{N}$

- determine $F_{2x}$ and $F_{2y}$
  
  $F_{2x} = +260 \cdot \frac{12}{13} \text{N} = +240\text{N}$
  
  $F_{2y} = -260 \cdot \frac{5}{13} \text{N} = -100\text{N}$

- determine $F_{Rx}$ and $F_{Ry}$
  
  $F_{Rx} = -100\text{N} + 240\text{N} = +140\text{N}$
  
  $F_{Ry} = +173\text{N} - 100\text{N} = +73\text{N}$
  
  $F_R = \sqrt{[140^2 + 73^2]} \text{N} = 157.9\text{N}$

problems 1 (2-34/35) & 2 (2-36/37)

Problem 1

- determine $F_{1x}$ and $F_{1y}$
  
  $F_{1x} = +400 \cdot \sin 30^\circ \text{N} = +200\text{N}$
  
  $F_{1y} = +400 \cdot \cos 30^\circ \text{N} = +346.4\text{N}$

- determine $F_{2x}$ and $F_{2y}$
  
  $F_{2x} = +250 \cdot \cos 45^\circ \text{N} = +176.8\text{N}$
  
  $F_{2y} = -250 \cdot \sin 45^\circ \text{N} = -176.8\text{N}$

- determine $F_{Rx}$ and $F_{Ry}$
  
  $F_{Rx} = +200.0\text{N} +176.8\text{N} = +376.8\text{N}$
  
  $F_{Ry} = +346.4\text{N} - 176.8\text{N} = +169.6\text{N}$
  
  $F_R = \sqrt{[376.8^2 + 169.6^2]} \text{N} = 413\text{N}$

Problem 2

- determine $F_{Rx}$ and $F_{Ry}$
  
  $F_{Rx} = +200.0\text{N} +176.8\text{N} = +376.8\text{N}$
  
  $F_{Ry} = +346.4\text{N} - 176.8\text{N} = +169.6\text{N}$
  
  $F_R = \sqrt{[376.8^2 + 169.6^2]} \text{N} = 413\text{N}$

- determine $\theta$
  
  $\theta = \tan^{-1} \left[ \frac{F_{Ry}}{F_{Rx}} \right]$
  
  $= \tan^{-1} \left[ \frac{169.6}{376.8} \right] = 24.2^\circ$
**Problem 2 (2-36/2-37)**

**Rectangular Components:** By referring to Fig. a, the x and y components of $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$ can be written as

\[
\begin{align*}
(F_1)_x &= 900 \text{ N} \\
(F_2)_x &= 750 \cos 45^\circ = 530.33 \text{ N} \\
(F_3)_x &= 650 \left(\frac{4}{5}\right) = 520 \text{ N} \\
(F_1)_y &= 0 \\
(F_2)_y &= 750 \sin 45^\circ = 530.33 \text{ N} \\
(F_3)_y &= 650 \left(\frac{3}{5}\right) = 390 \text{ N}
\end{align*}
\]

**Resultant Force:** Summing the force components algebraically along the x and y axes, we have

\[
\begin{align*}
\downarrow \Sigma (F_R)_x &= \Sigma F_x; \quad (F_R)_x = 900 + 530.33 + 520 = 1950.33 \text{ N} \rightarrow \\
\uparrow \Sigma (F_R)_y &= \Sigma F_y; \quad (F_R)_y = 530.33 - 390 = 140.33 \text{ N} \uparrow
\end{align*}
\]

The magnitude of the resultant force $\mathbf{F}_R$ is

\[
F_R = \sqrt{(F_R)_x^2 + (F_R)_y^2} = \sqrt{1950.33^2 + 140.33^2} = 1955 \text{ N} = 1.96 \text{ kN} \text{ Ans.}
\]

The direction angle $\theta$ of $\mathbf{F}_R$, measured clockwise from the positive x axis, is

\[
\theta = \tan^{-1}\left(\frac{(F_R)_y}{(F_R)_x}\right) = \tan^{-1}\left(\frac{140.33}{1950.33}\right) = 4.12^\circ \text{ Ans.}
\]