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

**sylabus**

**engr14 – intro to solid mechanics**

<table>
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<th>Topic</th>
<th>Reading</th>
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<td>W01</td>
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<td>Force Week</td>
<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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<td>Thu</td>
<td>01/07</td>
<td>What’s a force?</td>
<td>2.1-2.9</td>
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<td>W02</td>
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<td>Particle Week</td>
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<td>Tue</td>
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<td>What’s a free body diagram at a particle?</td>
<td>3.1-3.2</td>
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<td>Thu</td>
<td>01/14</td>
<td>What’s force equilibrium at a particle?</td>
<td>3.3-3.4</td>
<td>HW1</td>
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<td>W03</td>
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<td>Moment Week</td>
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<td>01/18</td>
<td>What’s a moment?</td>
<td>4.1-4.4</td>
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<td>01/21</td>
<td>What’s a couple? What’s distributed loading?</td>
<td>4.5-4.7</td>
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<td>W04</td>
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<td>Practice Week</td>
<td>Ch 1-4</td>
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<tr>
<td>Tue</td>
<td>01/26</td>
<td>Problems, problems, problems...</td>
<td>1.1-1.7</td>
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<tr>
<td>Thu</td>
<td>01/28</td>
<td>Midterm 1, in class, closed book, 1 cheat sheet</td>
<td>1.1-1.7</td>
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<tr>
<td>W05</td>
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<td>2d Equilibrium Week</td>
<td>Ch 5</td>
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<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>
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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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</table>

**Homework II - Chapters 3 and 4**

due Thursday, 01/21/16, 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:jangles@stanford.edu">jangles@stanford.edu</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon</td>
<td>05:00 - 07:00pm</td>
<td>520-155</td>
<td>Jenny</td>
<td><a href="mailto:jeanny61@stanford.edu">jeanny61@stanford.edu</a></td>
</tr>
<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>
</tr>
<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>Walter</td>
<td><a href="mailto:wgoodwin@stanford.edu">wgoodwin@stanford.edu</a></td>
</tr>
</tbody>
</table>

For this homework, you need to be familiar with chapters 3 and 4 of your book! All solutions for problems 1 - 4 must include a free body diagram!
3. equilibrium of a particle

- to introduce the concept of the free-body diagram for a particle
- to show how to solve particle equilibrium problems using the equations of equilibrium
- when cables are used for hoisting loads, the must be selected so that they do not fail. Today, we will show how to calculate cable forces for such cases

newton’s three laws of motion

- first law of motion
  - equilibrium
  - if \( \sum \mathbf{F} = 0 \) then \( \mathbf{v} = \text{const.} \)
- second law of motion
  - accelerated motion
  - \( \mathbf{F} = m \cdot \mathbf{a} \)
- third law of motion
  - actio = reactio
  - \( \mathbf{F}_{AB} = - \mathbf{F}_{BA} \)

procedure for drawing a FBD

I. isolate the particle of interest - easy ;-) here shown for particle A
II. show all forces - tricky!
  3 cables, 3 tension forces assume directions
III. label each force - easy ;-)
conceptual problem 3-1

show that the longer the cables, the less the forces in each cable.

for longer cables, the angle $\theta$ becomes smaller, $\cos \theta$ becomes bigger, and $F_{AB}$ and $F_{AC}$ become smaller.

3.3 coplanar force systems

4. force system resultants

today’s objectives

• to discuss the concept of a moment of a force
• to calculate the moment of a force in 2d and 3d using the scalar formulation
• to discuss the cross product as a tool to calculate moments
• to calculate the moment of a force in 2d and 3d using the vector formulation

concept quiz

1. a force of magnitude $F$ can be applied in four different 2-d configurations (P,Q,R,S). select the cases resulting in the maximum and minimum torque values on the nut. (max, min).

A) (Q, P) B) (R, S)
C) (P, R) D) (Q, S)

2. if $M = r \times F$, then what is the value of $M \cdot r$?

A) 0 B) 1
C) $r^2 F$ D) none of the above.

4.1 moment - scalar formulation

engineering intuition

$M_0 = F \cdot d$  

[M] = N·m = lb·ft

$O$ ... fixed point  
$F$ ... force  
$d$ ... moment arm

largest moment  smaller moment  no moment
**example 4.1**

determine the moment $M_0$ of the force $F$ about point $O$

For each case illustrated in Fig. 4–4, determine the moment of the force about point $O$.

**SOLUTION (SCALAR ANALYSIS)**

The line of action of each force is extended as a dashed line in order to establish the moment arm $d$. Also illustrated is the tendency of rotation of the member as caused by the force. Furthermore, the orbit of the force about $O$ is shown as a colored curl. Thus,

- Fig. 4–4a $M_0 = (100 \text{ N})(2 \text{ m}) = 200 \text{ N} \cdot \text{m}$ *Ans.*
- Fig. 4–4b $M_0 = (50 \text{ N})(0.75 \text{ m}) = 37.5 \text{ N} \cdot \text{m}$ *Ans.*
- Fig. 4–4c $M_0 = (40 \text{ lb})(4 \text{ ft} + 2 \cos 30^\circ \text{ ft}) = 229 \text{ lb} \cdot \text{ft}$ *Ans.*

**example 4.2**

Determine the resultant moment of the four forces acting on the rod shown in Fig. 4–5 about point $O$.

**SOLUTION**

Assuming that positive moments act in the +$k$ direction, i.e., counterclockwise, we have

$$
\zeta + (M_k)_0 = \Sigma Fd;
$$

- $(M_k)_0 = -50 \text{ N}(2 \text{ m}) + 60 \text{ N}(0) + 20 \text{ N}(3 \sin 30^\circ \text{ m})$
- $-40 \text{ N}(4 \text{ m} + 3 \cos 30^\circ \text{ m})$
- $(M_k)_0 = -334 \text{ N} \cdot \text{m} + 334 \text{ N} \cdot \text{m}$ *Ans.*

For this calculation, note how the moment-arm distances for the 20-N and 40-N forces are established from the extended (dashed) lines of action of each of these forces.
**right-handed system**

\[ C = A \times B = A \cdot B \cdot \sin \theta \ u_C \]

- \( C \) is a vector
- \( C \) is orthogonal to \( A \) and \( B \)
- \( C \) is the area enclosed by \( A \) and \( B \), i.e., \( A \cdot B \cdot \sin \theta \)

\[ C = A \times B = \det \begin{bmatrix} A_x & B_x & x \\ A_y & B_y & y \\ A_z & B_z & z \end{bmatrix} \]

\[ C = \begin{bmatrix} A_y B_z - A_z B_y \\ A_z B_x - A_x B_z \\ A_x B_y - A_y B_x \end{bmatrix} \]

**4.2 cross product**

**right-handed system**

\[ M_O = r \times F = r \cdot F \cdot \sin \theta \ u_M \]

- \( M_O \) is a vector
- \( M_O \) is orthogonal to \( r \) and \( F \)
- \( M_O \) is the area enclosed by \( r \) and \( F \), i.e., \( r \cdot F \cdot \sin \theta \)

\[ M_O = r \times F = \det \begin{bmatrix} r_x & F_x & x \\ r_y & F_y & y \\ r_z & F_z & z \end{bmatrix} \]

\[ M_O = \begin{bmatrix} r_y F_z - r_z F_y \\ r_z F_x - r_x F_z \\ r_x F_y - r_y F_x \end{bmatrix} \]

**4.3 moment - vector formulation**

**example 4.5**

Determine the moment \( \vec{M}_0 \) of the force \( F \) about point \( O \)

Use two different approaches and compare the results!

**4.4 principle of moments**

**example 4.5**

Determine the moment \( \vec{M}_0 \) of the force \( F \) about point \( O \)

**SOLUTION**

The moment arm \( d \) in Fig. 4.18a can be found from trigonometry.

\[ d = (3 \text{ m}) \sin 75^\circ = 2.898 \text{ m} \]

Thus,

\[ M_{O} = Fd = (5 \text{ kN})(2.898 \text{ m}) = 14.5 \text{ kN} \cdot \text{m} \]

\( \text{Ans.} \)

Since the force tends to rotate or orbit clockwise about point \( O \), the moment is directed into the page.
**Example 4.5**

Determine the moment $M_O$ of the force $F$ about point $O$.

**Solution**

The $x$ and $y$ components of the force are indicated in Fig. 4-186. Considering counterclockwise moments as positive, and applying the principle of moments, we have:

$$
\zeta + M_O = -F_x d_y - F_y d_x
$$

$$
= -(5 \text{ kN} \cos 45^\circ \times 3 \text{ m}) - (5 \text{ kN} \sin 45^\circ \times 3 \text{ m})
$$

$$
= -14.5 \text{ kN} \cdot \text{m} = 14.5 \text{ kN} \cdot \text{m}
$$

**Example 4.6**

Force $F$ acts at the end of the angle bracket in Fig. 4-19a. Determine the moment of the force about point $O$.

**Solution (Scalar Analysis)**

The force is resolved into its $x$ and $y$ components, Fig. 4-19b, then

$$
\zeta + M_O = 400 \sin 30^\circ \text{ N}(0.2 \text{ m}) - 400 \cos 30^\circ \text{ N}(0.4 \text{ m})
$$

$$
= -98.6 \text{ N} \cdot \text{m} = 98.6 \text{ N} \cdot \text{m}
$$

**Solution (Vector Analysis)**

Using a Cartesian vector approach, the force and position vectors, Fig. 4-19c, are

$$
\mathbf{r} = (0.4 - 0.3) \text{ m}
$$

$$
\mathbf{F} = (400 \sin 30^\circ \hat{i} - 400 \cos 30^\circ \hat{j}) \text{ N}
$$

$$
= (200 \hat{i} - 346.4 \hat{j}) \text{ N}
$$