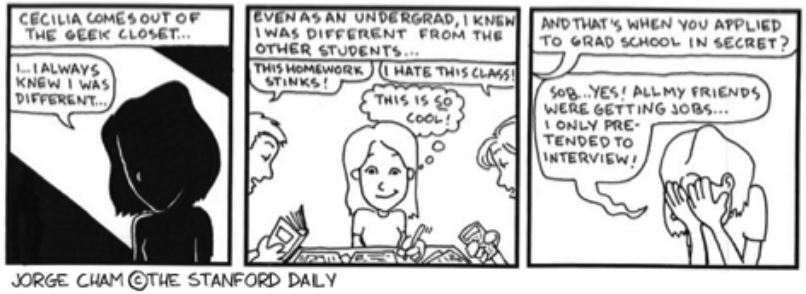
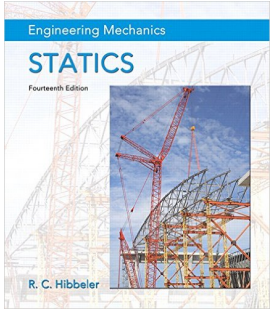
engr14 – intro to solid mechanics



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

engr14 – intro to solid mechanics

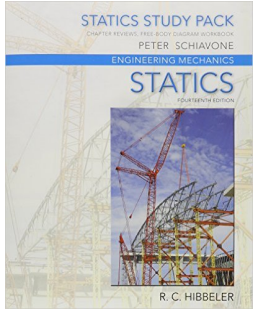


textbook / e-textbook

russell c. hibbeler
prentice hall, 14th edition

engineering mechanics
statics

statics study pack
for engineering mechanics



textbook. russell c hibbeler: statics.

engr14 – intro to solid mechanics

Day	Date	Topic	Reading	HW due
	W01	**Force Week**	**Ch 1-2**	
Tue	01/05	~~What's statics?~~	1.1-1.5	
Thu	01/07	What's a force?	2.1-2.9	
	W02	**Particle Week**	**Ch 3**	
Tue	01/12	What's a free body diagram at a particle?	3.1-3.2	
Thu	01/14	What's force equilibrium at a particle?	3.3-3.4	HW1
	W03	**Moment Week**	**Ch 4**	
Tue	01/19	What's a moment?	4.1-4.4	
Thu	01/21	What's a couple? What's distributed loading?	4.5-4.7	HW2
	W04	**Practice Week**	**Ch 1-4**	
Tue	01/26	Problems, problems, problems…	1.1-4.7	
Thu	01/28	**Midterm 1**, in class, closed book, 1 cheat sheet	1.1-4.7	
	W05	**2d Equilibrium Week**	**Ch 5**	
Tue	02/02	What's a free body diagram of a 2d system?	5.1-5.2	
Thu	02/04	What's force and moment equilibrium in 2d?	5.3-5.4	HW3

syllabus

engr14 – intro to solid mechanics

	W06	**3d Equilibrium Week**	**Ch 5**	
Tue	02/09	What's a free body diagram of a 3d system?	5.5	
Thu	02/11	What's force and moment equilibrium in 3d?	5.6-5.7	HW4
	W07	**Structures Week**	**Ch 6**	
Tue	02/16	What's a truss?	6.1-6.3	
Thu	02/18	What's a frame?	6.6	HW5
	W08	**Internal Force Week**	**Ch 7**	
Tue	02/23	What's a shear and moment diagram?	7.1-7.3	
Thu	02/25	**Midterm 2**, all day take home, Thu-Fri 2pm	5.1-6.6	
	W09	**Friction & Center Week**	**Ch 8-9**	
Tue	03/01	What's friction?	8.1-8.2	
Thu	03/03	What's the center?	9.1-9.2	
	W10	**That's it Week**	**Ch 1-9**	
Tue	03/08	The Last Lecture	1.1-9.2	
Thu	03/10	Problems, problems, problems…	1.1-9.2	
Wed	03/16	**Final**, in class, closed book, 1 cheat sheet	1.1-9.2	

syllabus

homework	20 %	five homework assignments, 4% each
exams	80 %	two midterms, one final, 30%, 25%, 25% each
final grade	≥ 90 A range	≥ 80 B range ≥ 70 C range < 70 lower

homework. homework sets will be announced in class and assigned via **coursework**. homework will be **graded for completeness, correctness, and clarity**. assignments must be **completed in pencil on engineering computation paper**. solutions must be legible and orderly, with complete and **properly labeled** free body diagrams. answers must be clearly **boxed**. the meaning of variables that you introduce must be clear. if the grader cannot **read and follow your work**, you will not get credit. you have **up to three late days** to use over the quarter. a late day is charged for any fraction of a day past the due date. once you have used your allocation of late days, further late submissions will be corrected, but will receive a score of zero. the final homework may not be submitted late.

Homework I - Chapters 1 and 2

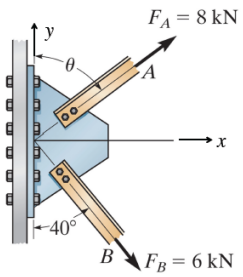
due Thursday, 01/14/16, 11:30am, 550-200

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.

When	When	Where	Jean-claude	jcangles@stanford.edu
Mon	05:00 - 07:00pm	520-155	Jeanny	jeanny61@stanford.edu
Tue	05:00 - 07:00pm	520-155	Josh	joshuasiegel@stanford.edu
Wed	11:00 - 01:00pm	520-155	Kayla	kepowers@stanford.edu
Wed	05:00 - 07:00pm	520-155	Ellen	ekuhl@stanford.edu

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

Problem 1 (Hibbeler 2-12)



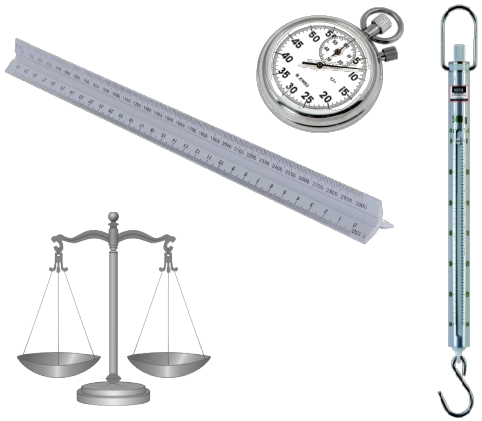
1.1 Determine the x and y components of the forces $\mathbf{F}_A$ and $\mathbf{F}_B$.

1.2 Determine the angle θ so that the resultant force of $\mathbf{F}_A$ and $\mathbf{F}_B$ is directed horizontally to the right, i.e., the y component of the resultant force is zero.

1.3 Determine the x component of the resultant force.

basic quantities

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

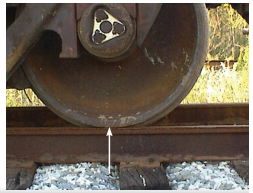


idealizations

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

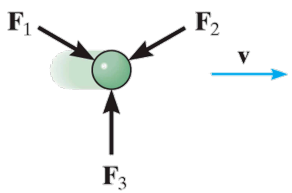
rigid body. a rigid body is a combination of a large number of particles with all particles remaining at a fixed distance from one another.

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.



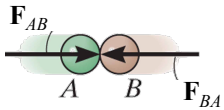
newton 's three laws of motion

- first law
  equilibrium
  if $\sum \boldsymbol{F} = \boldsymbol{0}$ then $\boldsymbol{v}$ = const.



- second law
  accelerated motion
  $\boldsymbol{F} = \boldsymbol{m} \cdot \boldsymbol{a}$

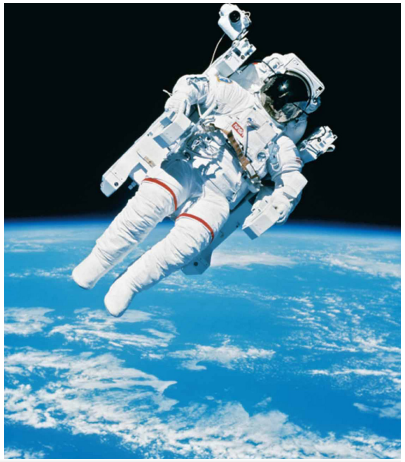
- third law
  actio = reactio
  $\boldsymbol{F}_{AB} = -\boldsymbol{F}_{BA}$



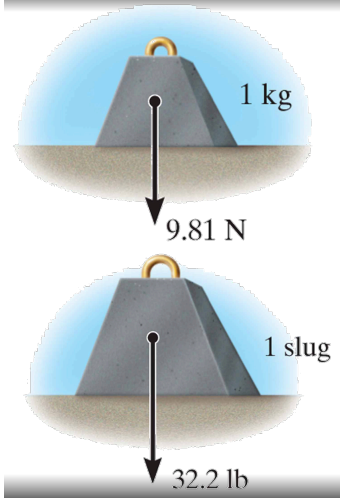
weight

SI system
$W = m \cdot g$
W ... weight (derived quantity)
m ... mass (basic quantity)
g ... acceleration due to gravity
$g = 9.81$ m/s^2

FPS system
$m = W / g$
m ... mass (derived quantity)
W ... weight (basic quantity)
g ... acceleration due to gravity
$g = 32.2$ ft/s^2



systems of units



SI system

basic units
- meters [m]
- seconds [s]
- kilogram [kg]

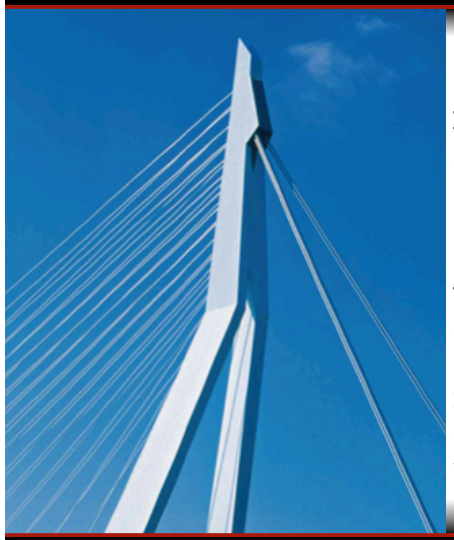
derived unit
- Newton [N = kg · m /s²]

FPS system

basic units
- feet [ft]
- seconds [s]
- pounds [lb]

derived unit
- slug [slug = lb · s²/ft]

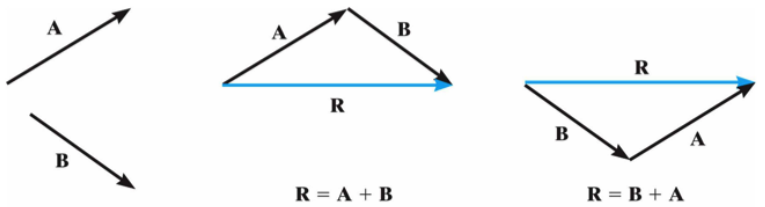
today's objectives



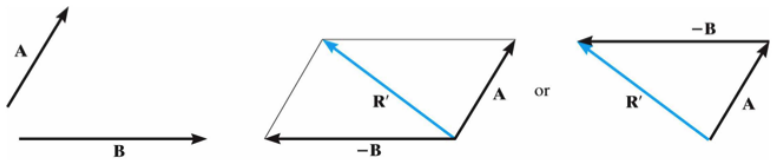
- to show how to **add forces** and **resolve forces into components** using the parallelogram law
- to express force in Cartesian coordinate system and explain how to determine a **vector's magnitude and direction**
- to introduce the dot product in order to **determine the angle** between two vectors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

vector addition and subtraction

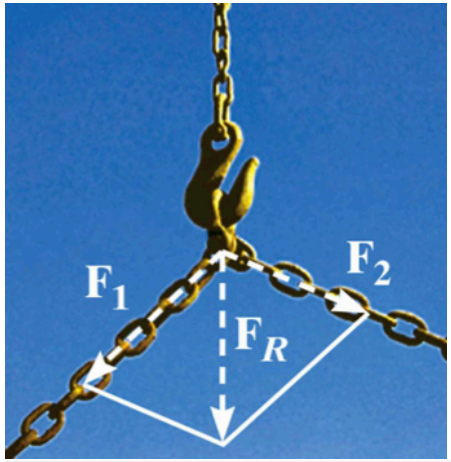
vector addition $R = A + B = B + A$

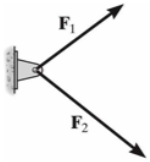


vector subtraction $R = A - B = -B + A$



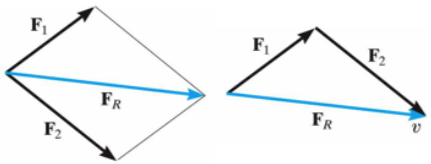
I. find the resultant force



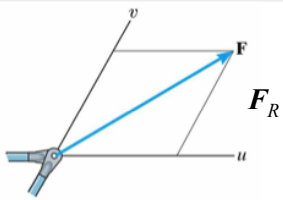


$F_R = F_1 + F_2$

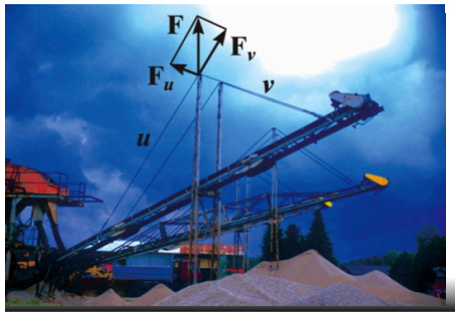
parallelogram vs triangle



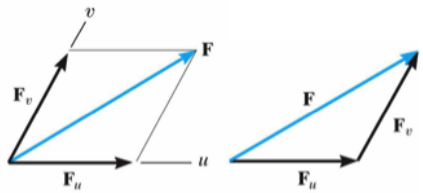
II. find the components of a force



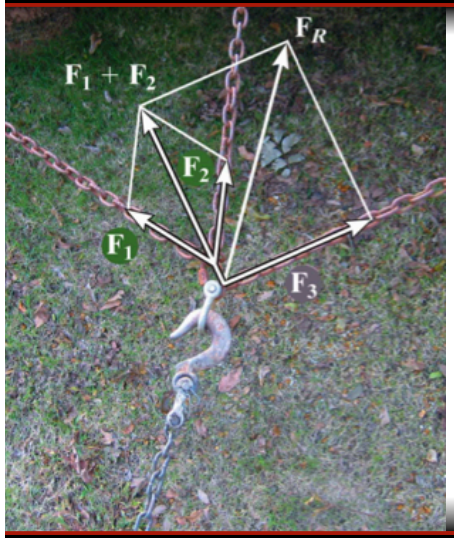
$$F_R = F_u + F_v$$



parallelogram vs triangle

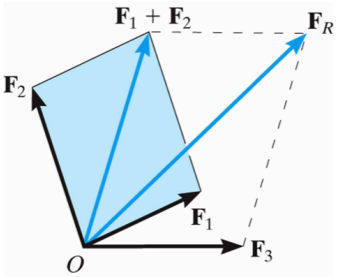


Ia. find the resultant of several forces



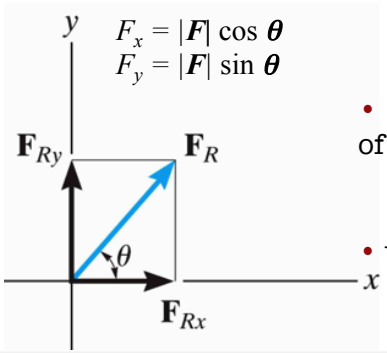
$$F_R = F_1 + F_2 + F_3$$

double parallelogram



force addition in cartesian coordinates

$$F = \begin{bmatrix} F_x \\ F_y \end{bmatrix}$$



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

$$F_R = \begin{bmatrix} F_{Rx} \\ F_{Ry} \end{bmatrix} \qquad F_{Rx} = \sum F_x \quad F_{Ry} = \sum F_y$$

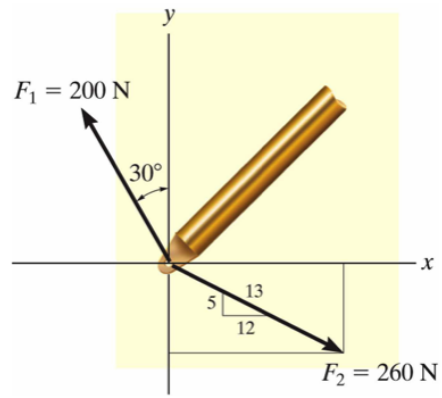
- we can determine the magnitude of a force using the Pythagoras

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

- we can determine the direction of a force using trigonometry

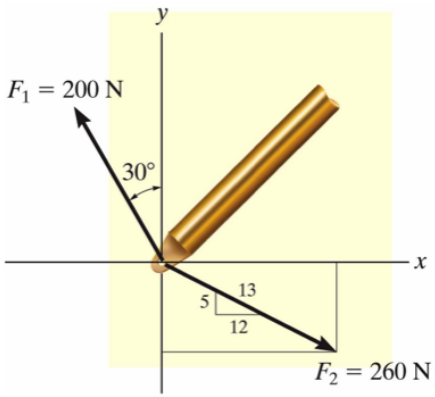
$$\theta = \tan^{-1}[F_{Ry} / F_{Rx}]$$

example 2.5



- determine F_{1x} and F_{1y}
- determine F_{2x} and F_{2y}
- determine F_{Rx} and F_{Ry}

example 2.5



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

F_{1x} = - 200 · sin 30° N = -100N
F_{1y} = +200 · cos 30° N = +173N

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

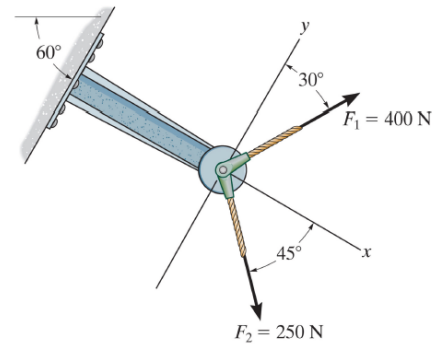
F_{2x} = + 260 ·12/13 N = +240N
F_{2y} = -260 · 5/13 N = - 100N

- determine F_{Rx} and F_{Ry}

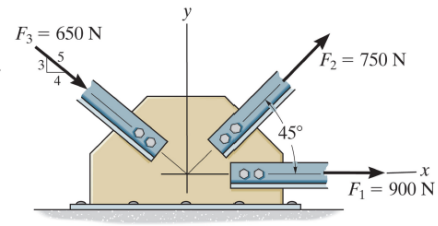
F_{Rx} = - 100N +240N = +140N
F_{Ry} = +173N -100N = +73N
$F_R = \sqrt{[140^2 + 73^2]}$N = 157.9N

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

Problem 1

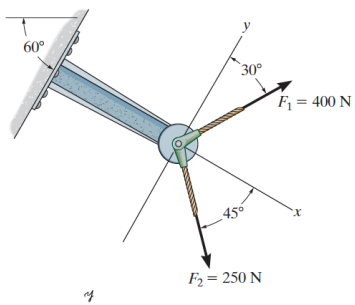


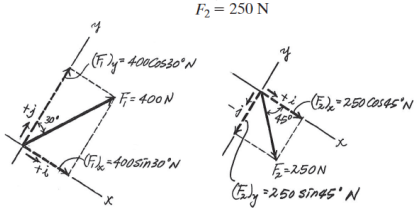
Problem 2



[1] resolve each force into its x- and y-components
[2] determine the x- and y-components of the resultant force
[3] determine magnitude and direction of resultant force

problem 1 (2-34/2-35)





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

F_{1x} = +400 · sin 30° N = +200N
F_{1y} = +400 · cos 30° N = +346.4N

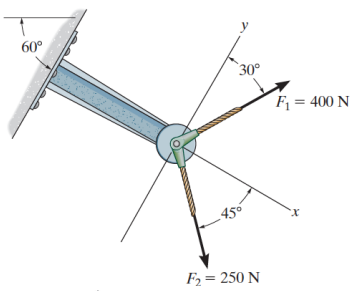
- determine F_{2x} and F_{2y}

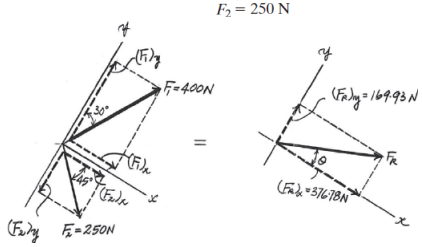
F_{2x} = +250 · cos 45°N = +176.8N
F_{2y} = - 250 · sin 45°N = - 176.8N

- determine F_{Rx} and F_{Ry}

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

problem 1 (2-34/2-35)





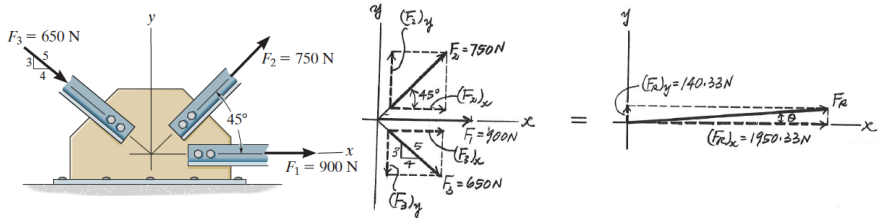
- determine F_{Rx} and F_{Ry}

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

- determine θ

$\theta = \tan^{-1}[F_{Ry} / F_{Rx}]$
$= \tan^{-1}[169.6/376.8] = 24.2°$

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

$$(F_1)_x = 900 \text{ N} \qquad (F_1)_y = 0$$

$$(F_2)_x = 750 \cos 45° = 530.33 \text{ N} \qquad (F_2)_y = 750 \sin 45° = 530.33 \text{ N}$$

$$(F_3)_x = 650\left(\frac{4}{5}\right) = 520 \text{ N} \qquad (F_3)_y = 650\left(\frac{3}{5}\right) = 390 \text{ N}$$

problem 2 (2-36/2-37)

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

$$\xrightarrow{+} \Sigma(F_R)_x = \Sigma F_x; \qquad (F_R)_x = 900 + 530.33 + 520 = 1950.33 \text{ N} \rightarrow$$

$$+\uparrow \Sigma(F_R)_y = \Sigma F_y; \qquad (F_R)_y = 530.33 - 390 = 140.33 \text{ N} \uparrow$$

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

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

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

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