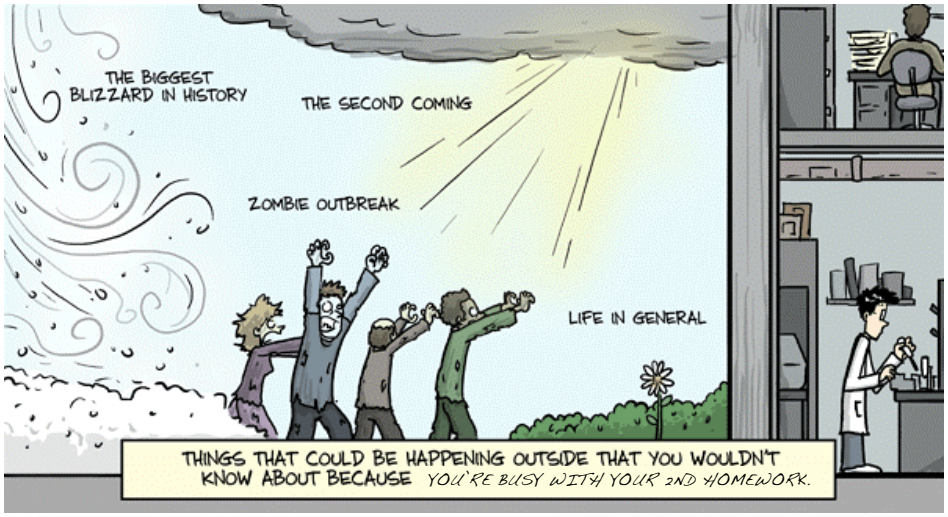
e14 - applied mechanics: statics



mon/wed/fri, 12:50-2:05pm, 370-370

e14 - applied mechanics: statics

day	date		topic	chapter
	w01		**force week**	**ch 1-2**
mon	mar	28	what's statics?	1.1-1.5
wed	mar	30	what's a 2d force?	2.1-2.4
fri	apr	01	what's a 3d force?	2.5-2.9
	w02		**particle week**	**ch 3**
mon	apr	04	what's a free body diagram at a point?	3.1-3.2
wed	apr	06	what's force equilibrium at a point?	3.3-3.4
fri	apr	08	~~problem session 1~~	
	w03		**moment week**	**ch 4**
mon	apr	11	~~what's a moment?~~	4.1-4.4
wed	apr	13	what's a couple? what's distributed loading?	4.5-4.7
fri	apr	15	problem session 2	
	w04		**practice week**	**ch 1-4**
mon	apr	18	problems, problem, problems ...	
wed	apr	20	midterm 1, all day take home, wed 12pm - thu 2pm	
fri	apr	22	recover-from-midterm friday / no problem session	
	w05		**2d equilibrium week**	**ch 5**
mon	apr	25	what's a free body diagram of a 2d system?	5.1-5.2
wed	apr	27	what force and moment equilibrium in 2d?	5.3-5.4
fri	apr	29	problem session 3	

second homework due

first midterm: takehome

syllabus

e14 - applied mechanics: statics

Homework II - Chapters 3 and 4

due Friday, 04/15/11, 12:50pm, 370-370

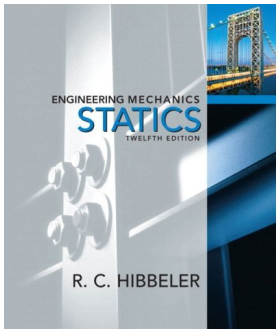
For late homework, you are responsible to arrange drop off with our grader Kaushik Mani, kmani@stanford.edu. Once you have used up your three late days, you will no longer receive points for your homework. Here are our office hours and emails.

when	when	where	who	email
Tuesdays	06:00 - 07:30pm	Durand 247	Charbel	ceid@stanford.edu
Wednesdays	02:30 - 04:00pm	Durand 217	Ellen	ekuhl@stanford.edu
Wednesdays	05:00 - 06:30pm	Durand 393	Chris	cploch@stanford.edu
Thursdays	10:00 - 11:30am	Durand 203	Joules	jmgould@stanford.edu
Thursdays	01:00 - 02:30pm	Durand 393	Estevan	estevanm@stanford.edu

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!

homework #02

e14 - applied mechanics: statics

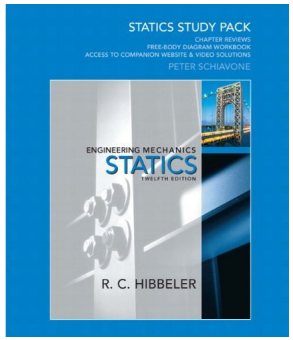


textbook.

russell c. hibbeler
prentice hall, 12th edition

engineering mechanics
statics

read chapters 3 and 4 for homework #2



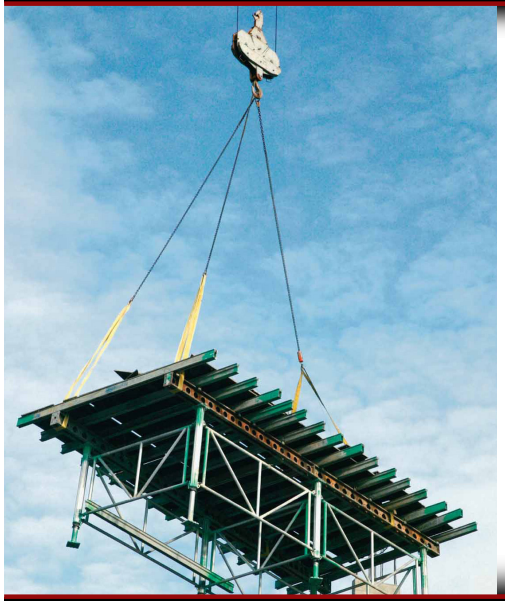
homework #02

design your own e14 t-shirt!

©julie mai

e14 t-shirt design context

what we've done so far...

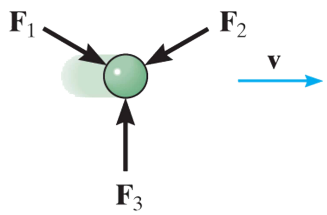


- to introduce the concept of the free-body diagram for a particle
- to show how to solve particle equilibrium problems using the equations of equilibrium
- when cables are used for hoisting loads, the must be selected so that they do not fail. today, we will show how to calculate cable forces for such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

3. equilibrium of a particle

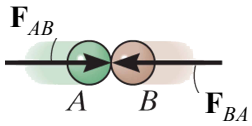
newton's three laws of motion

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



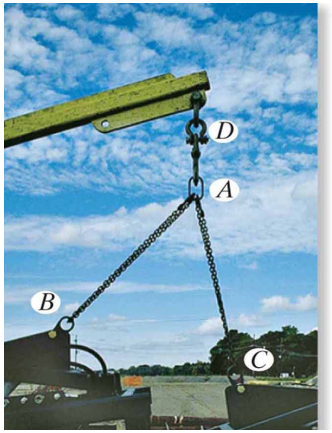
- second law
  accelerated motion
  $\boldsymbol{F} = m \cdot \boldsymbol{a}^{=0}$

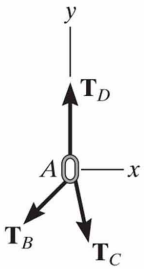
- third law
  actio = reactio
  $\boldsymbol{F}_{AB} = -\boldsymbol{F}_{BA}$



3.1 equilibrium condition of a particle

procedure for drawing a FBD





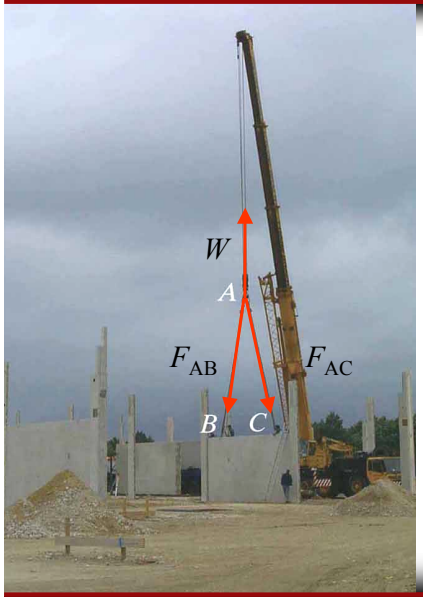
I. isolate the particle of interest - easy ;-)
here shown for particle A

II. show all forces - tricky!
3 cables, 3 tension forces
assume directions

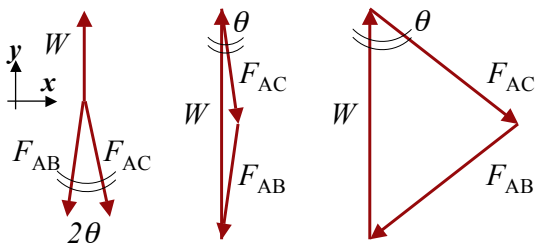
III. label each force - easy ;-)

3.2 free body diagram

conceptual problem 3-1



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



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

today's objectives

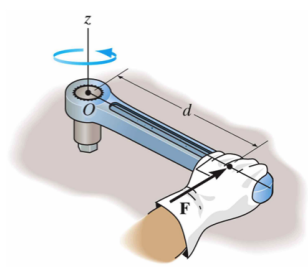
- to discuss the concept of a moment of a force
- to calculate the moment of a force in 2d and 3d using the scalar formulation
- to discuss the cross product as a tool to calculate moments
- to calculate the moment of a force in 2d and 3d using the vector formulation

engineering intuition

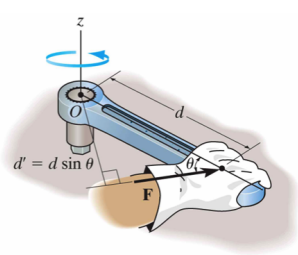
$M_0 = F \cdot d$ $\qquad$ $[M] = \text{N}\cdot\text{m} = \text{lb}\cdot\text{ft}$

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

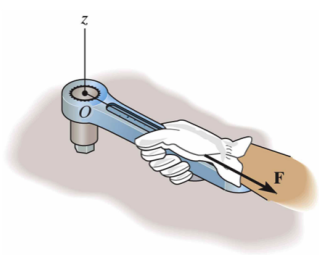
largest moment



smaller moment

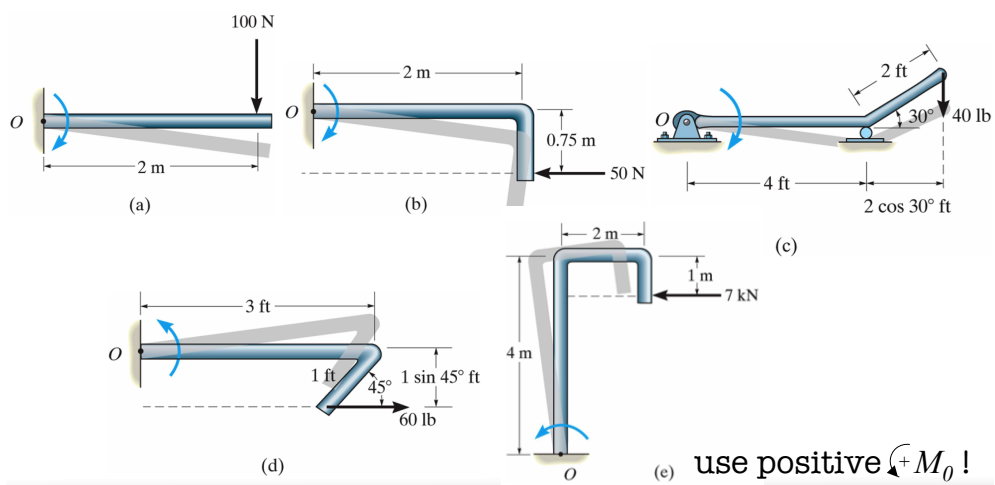


no moment



example 4.1

determine the moment M_0 of the force F about point O



use positive $\circlearrowleft + M_0$!

example 4.2

EXAMPLE 3.2

Determine the resultant moment of the four forces acting on the rod shown in Fig. 3–5 about point O.

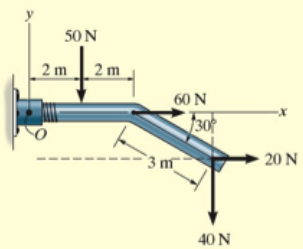


Fig. 3–5

SOLUTION

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

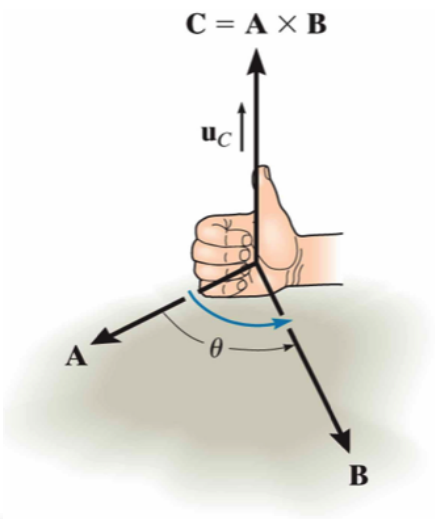
$$\circlearrowleft + M_{R_O} = \Sigma Fd;$$

$$M_{R_O} = -50\text{ N}(2\text{ m}) + 60\text{ N}(0) + 20\text{ N}(3\sin 30^\circ\text{ m}) - 40\text{ N}(4\text{ m} + 3\cos 30^\circ\text{ m})$$

$$M_{R_O} = -334\text{ N}\cdot\text{m} = 334\text{ N}\cdot\text{m}\circlearrowright \qquad \textit{Ans.}$$

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



$$\boldsymbol{C} = \boldsymbol{A} \times \boldsymbol{B} = A \cdot B \cdot \sin\theta \; \boldsymbol{u}_C$$

- $\boldsymbol{C}$ is a vector
- $\boldsymbol{C}$ is orthogonal to $\boldsymbol{A}$ and $\boldsymbol{B}$
- C is the area enclosed by $\boldsymbol{A}$ and $\boldsymbol{B}$, i.e., $A \cdot B \cdot \sin\theta$

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

$$\boldsymbol{C} = \begin{bmatrix} A_y B_z - A_z B_y \\ A_z B_x - A_x B_z \\ A_x B_y - A_y B_x \end{bmatrix} \circlearrowleft +$$

right-handed system

... if your thumb is the $\boldsymbol{x}$ axis...

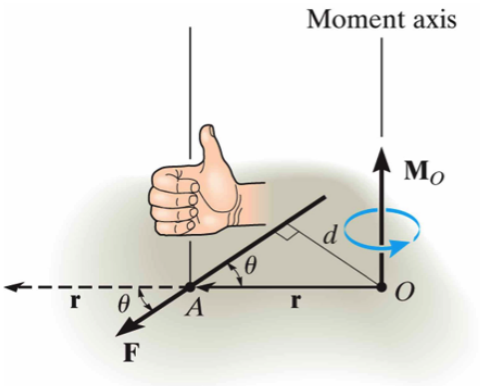
... and your middle finger is the $\boldsymbol{z}$ axis...

... then your index finger is...

right-handed system

... pointing right at your abs ...

right-handed system



$$\boldsymbol{M}_O = \boldsymbol{r} \times \boldsymbol{F} = r \cdot F \cdot \sin\theta \;\; \boldsymbol{u}_M$$

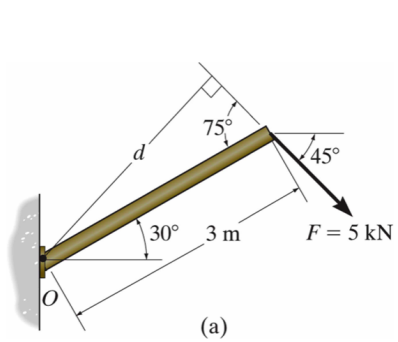
- $\boldsymbol{M}_O$ is a vector
- $\boldsymbol{M}_O$ is orthogonal to $\boldsymbol{r}$ and $\boldsymbol{F}$
- M_O is the area enclosed by $\boldsymbol{r}$ and $\boldsymbol{F}$, i.e., $r \cdot F \cdot \sin\theta$

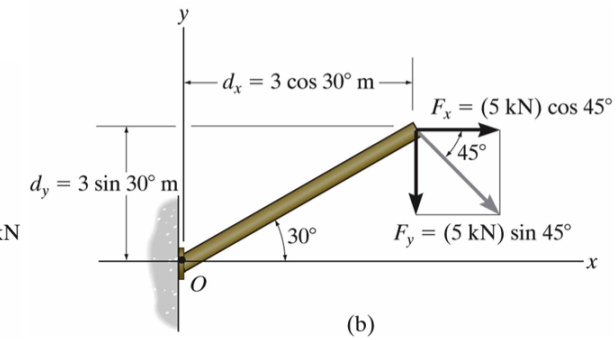
$$\circlearrowleft + \; \boldsymbol{M}_O = \boldsymbol{r} \times \boldsymbol{F} = \det \begin{bmatrix} r_x & F_x & \boldsymbol{x} \\ r_y & F_y & \boldsymbol{y} \\ r_z & F_z & \boldsymbol{z} \end{bmatrix}$$

$$\circlearrowleft + \; \boldsymbol{M}_O = \begin{bmatrix} r_y F_z - r_z F_y \\ r_z F_x - r_x F_z \\ r_x F_y - r_y F_x \end{bmatrix}$$

example 4.5

determine the moment $\circlearrowleft + M_0$ of the force F about point O

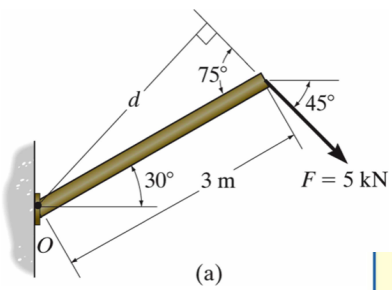




use two different approaches and compare the results!

example 4.5

determine the moment $\circlearrowleft + M_0$ of the force F about point O



SOLUTION I

The moment arm d in Fig. 3–18a can be found from trigonometry.

$$d = (3\text{ m})\sin 75° = 2.898\text{ m}$$

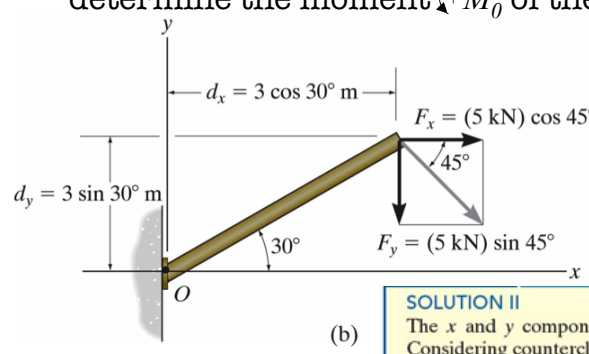
Thus,

$$M_O = Fd = (5\text{kN})(2.898\text{ m}) = 14.5\text{ kN}\cdot\text{m} \circlearrowright \qquad \textit{Ans.}$$

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 $\circlearrowleft + M_0$ of the force F about point O



SOLUTION II

The x and y components of the force are indicated in Fig. 3–18b. Considering counterclockwise moments as positive, and applying the principle of moments, we have

$$\circlearrowright + M_O = -F_x d_y - F_y d_x$$
$$= -(5\cos 45°\text{ kN})(3\sin 30°\text{ m}) - (5\sin 45°\text{ kN})(3\cos 30°\text{ m})$$
$$= -14.5\text{ kN}\cdot\text{m} = 14.5\text{ kN}\cdot\text{m} \circlearrowright \qquad \textit{Ans.}$$