FITTING A WHEELCHAIR, BIOMECHANICS, AND DESIGN

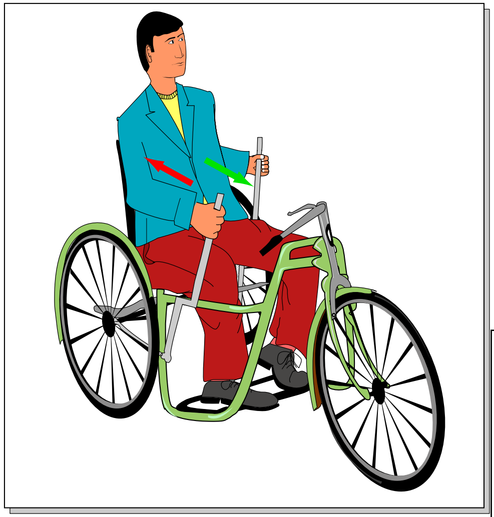

Figure by MIT OCW.

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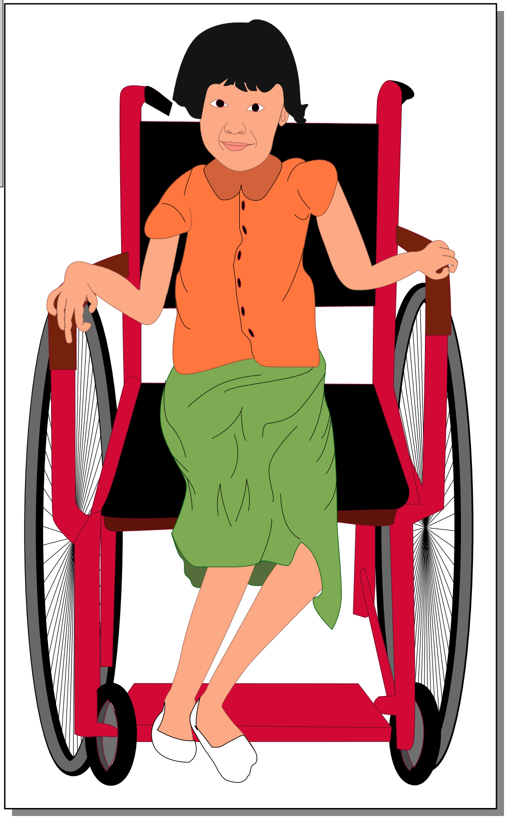
Source: http://doitfoundation.org/brasilito082305.htm



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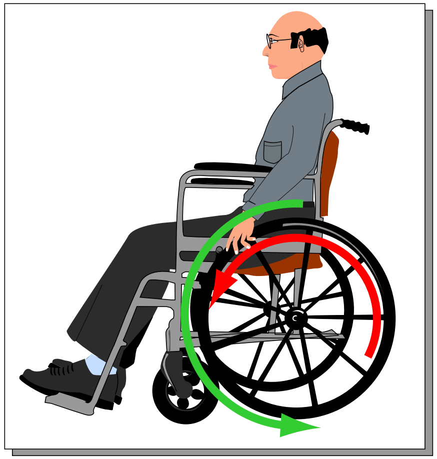


Figure by MIT OCW.

CORRECT FITTING OF A WHEELCHAIR
Complications from improper fitting

Sitting habits

- Able bodied person – long period of sitting usually 1-2 hours, shifting weight all the time
- Disabled person may sit for 3 to 10 hours per day without repositioning

Complications due to poor posture

- Contractions and deformities
- Tissue breakdown
- Reduced performance and tolerance
- Urinary and respiratory infection
- Fatigue and discomfort

Photo removed due to copyright restrictions.
Source: http://doitfoundation.org/brasilito082305.htm

CORRECT FITTING OF A WHEELCHAIR
Correct anatomical and wheelchair positions

- Want to distribute weight over butt and thighs
- Only want 1.25cm clearance between

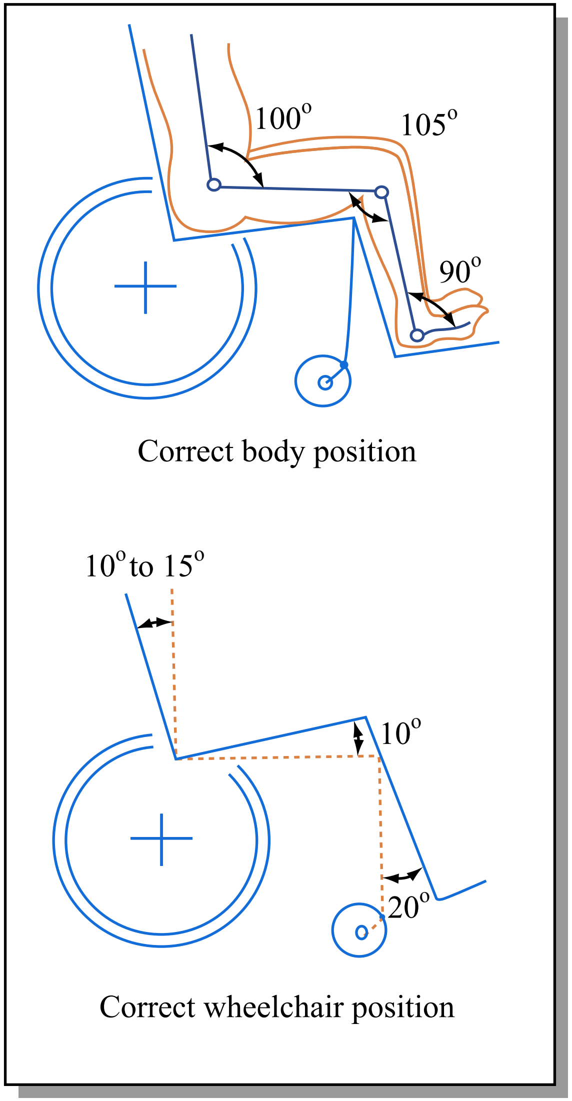


Figure by MIT OCW. After Mayall, 1995.

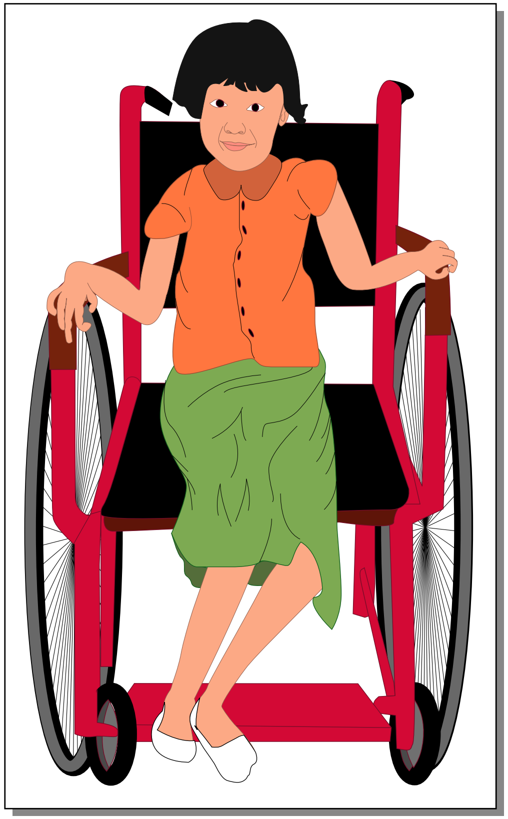


Figure by MIT OCW.

Wheelchair Foundation Chair
(www.kidswithnoborders.org)

CORRECT FITTING OF A WHEELCHAIR
Considerations during assessment

Considerations during prescription

- Diagnosis and prognosis
- Age
- Communication status
- Cognitive function
- Perceptual function
- Physical ability
- **Level of independence in activities during daily living**
- Transfer ability and modality
- Mobility (ambulation and wheelchair mobility)
- Body weight
- Sensory status
- Presence of edema
- Leisure interests
- **Transportation to and from home**
- **Roughness of usage**
- Time spent in wheelchair daily
- **Financial resources of patient**

List from (Mayall, 1995)

Wheelchair Foundation in Tanzania

Tanzania Big Game Safari:

•Largest donator in Tanzania, giving away nearly 7,000 chairs so far.

•Said Wheelchair Foundation will give a chair to anyone who seems to need one – a loose requirement that may include people who are crawling on the ground to people who may walk with a crutch.

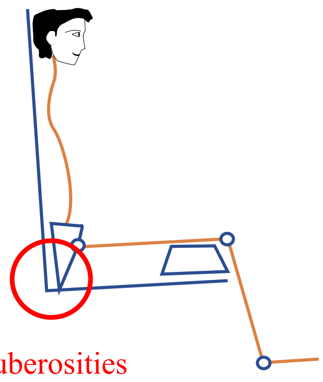
•Admitted they get so many chairs every year that after the first few hundred have been distributed, it is very difficult to find genuinely disabled people to whom they can give them.

Monduli Rehab Center:

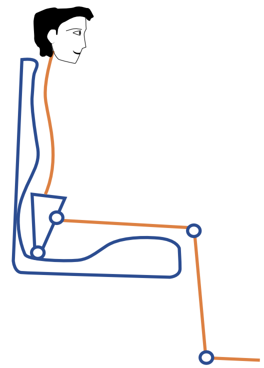
•Criticized the WC Foundation and said wheelchairs should not be given out like candy.

•Because the village terrain is so rough, people should be encouraged to walk with crutches or braces, and WCs should be a last resort.

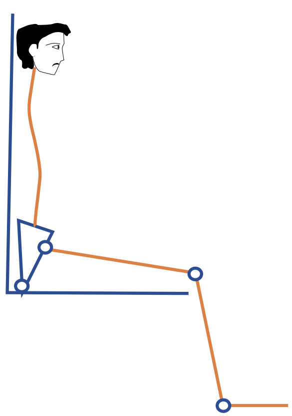
CORRECT FITTING OF A WHEELCHAIR
Cushioning and positioning



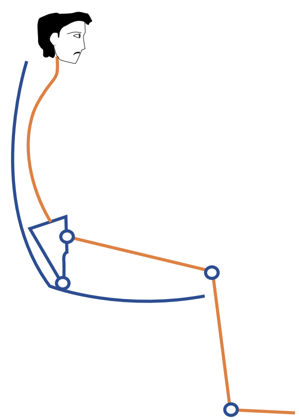
Pelvis positioning with a pre-ischial bar.



Pelvis positioning with contoured firm seat and back.



Pelvis positioning without a pre-ischial bar.



Pelvis positioning with a sling seat and back.

Figure by MIT OCW. After Mayall, 1995.

Pressure Sores

(Close eyes if squeamish)

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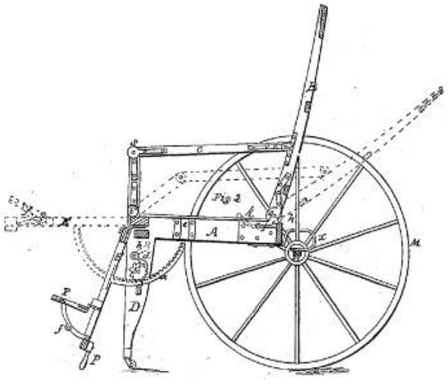
WHEELCHAIR PROPULSION



First US wheelchair patent
A.P. Blunt, et. all., 1869

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Example state-of-the-art
Quickie wheelchair, 2006

- Wheelchair propulsion 2-10% efficient (Woude et al, 1986, 1998)
- Optimal human chemical-mechanical whole body efficiency ~ 25% (Mark's STD Handbook, 1978)
  - Occurs at ½ max muscle force and ¼ max muscle speed
  - Optimal efficiency and max power output do not occur together → **Engage more muscles for more power**

Determine best system → Wheelchair propulsion project

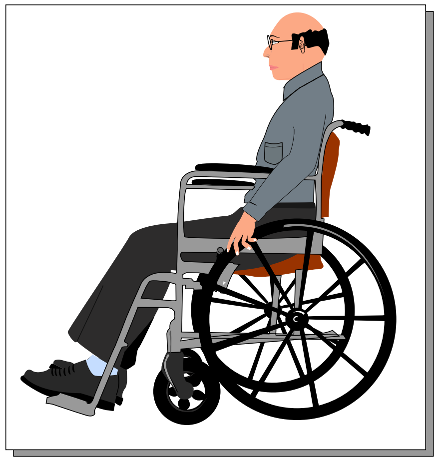
UROP: Mario Bollini

- Determine the upper body motion that yields highest sustainable power at highest efficiency to deterministically design a wheelchair drive system

WHEELCHAIR PROPULSION RESEARCH

Previous work: **Power output measured from different drive systems**

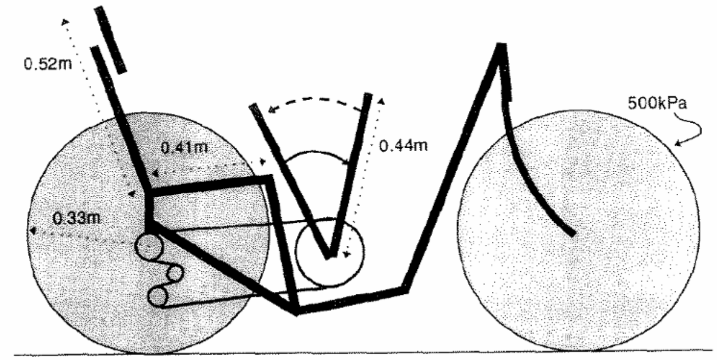
Figure by MIT OCW.



Conventional chair

$P_{out} = 26.5W$

(van der Linden, et al, 1996)



Lever-powered tricycle

$P_{out} = 39.3W$

(van der Woude, et al, 1997)

Motivation: **To deterministically design a drive system for long and short distance travel, the maximum available efficient power should dictate the design**

$$\eta P_{human} = \eta T_{human}\,\omega_{human} = P_{out} = F_{resist}V_{device} = F_{resist}R_{wheel}\,\omega_{wheel}$$

P_{human}: TBD

F_{resist}: **dictated by environment**

ω_{wheel}: **calculated**

$$\frac{\omega_{wheel}}{\omega_{human}} = Gear\ Ratio$$

$Gear\ Ratio$: **tune through design**

WHEELCHAIR PROPULSION RESEARCH

Upper body biomechanics data

Fifth-percentile arm strength (N) exerted by sitting men														
(1)	(2)		(3)		(4)		(5)		(6)		(7)			
Elbow flexion (deg)	Pull		Push		Up		Down		In		Out			
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right		
180	222	231	187	222	40	62	58	76	58	89	36	62		
150	187	249	133	187	67	80	80	89	67	89	36	67		
120	151	187	116	160	76	107	93	116	89	98	45	67		
90	142	165	98	160	76	89	93	116	71	80	45	71		
60	116	107	96	151	67	89	80	89	76	89	53	71		

Figure by MIT OCW.

(Shigley, Mischke, 1996)

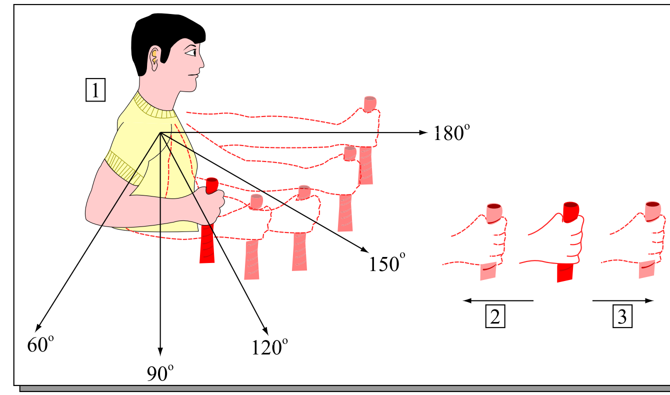
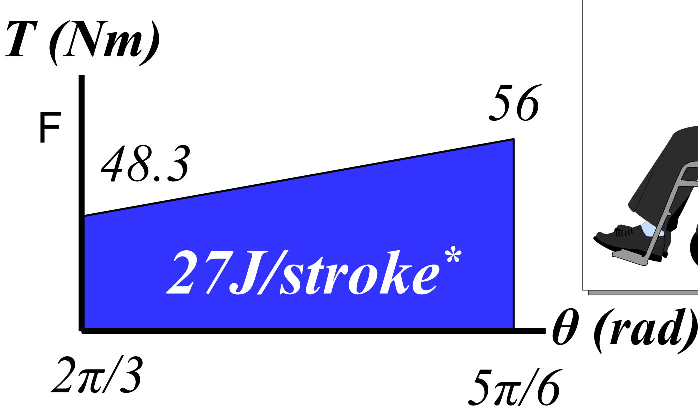
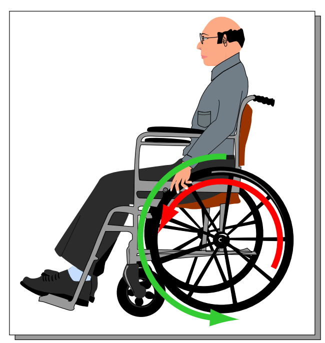


Figure by MIT OCW.

Single arm energy output





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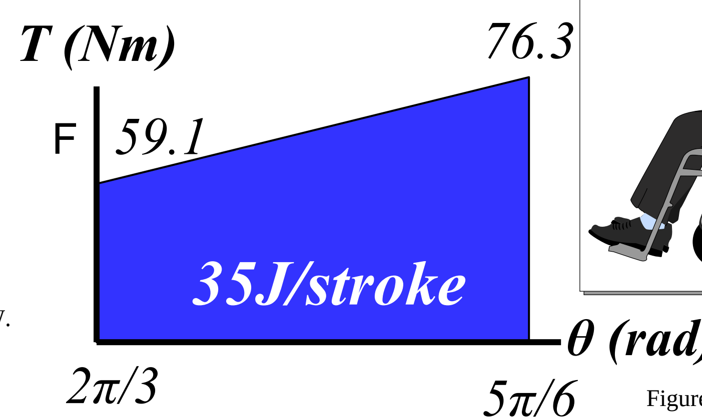


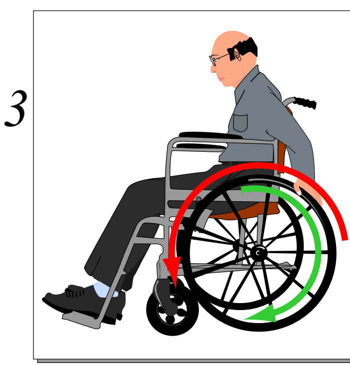


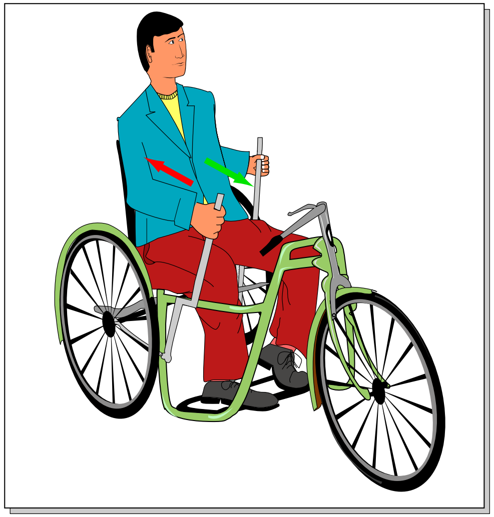
Figure by MIT OCW.

Conventional wheelchair propulsion

Opposed handrim-wheel rotation

*2% error from van der Linden, et al, 1996

Single arm energy output



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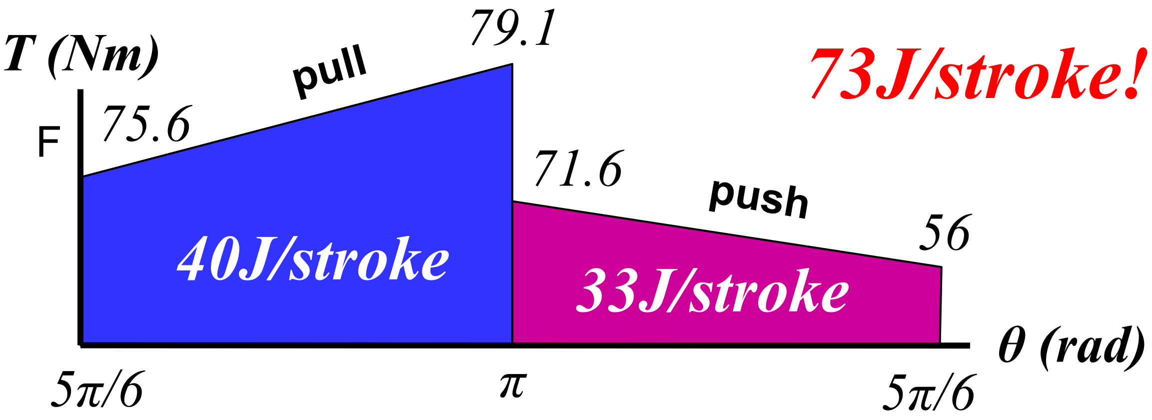


Rowing-motion propulsion

Additional questions

- What unidentified upper body motions can give high power output
- How different disabilities affect range of motion
- What type of resistance forces will be encountered depending on the environment

Safety factors

Uncertainties in strength

$\sigma_p = \sigma_y/n_s$

Where σ_p = permissible stress,
σ_y = yield strength,
n_s = strength factor of safety
(typically 1.2 to 1.4)

Uncertainties in Loading

$F_p = F_y/n_L$

Where F_p = permissible load,
F_y = max load,
n_L = strength factor of safety

$$n_{total} = n_s n_L$$

For machines that can cause injury or death, n_{total} is typically 4 to 10+

When choosing a safety factor, consider:

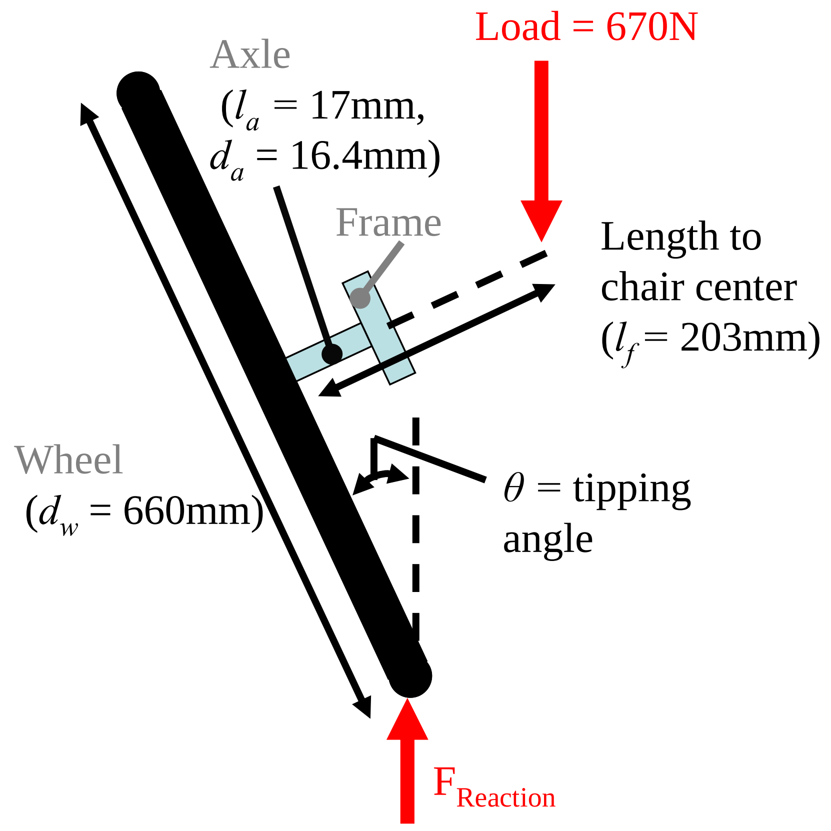
- Does the load come from human activity
- Does loading come from natural sources (terrain, etc)
- What are the consequences of failure?
- Is the loading due to a prelaod?
- Does the load come from a power source (ex. starting vs. steady torque)?
- Does the load come from driven machinery that can change its output?

Theory adapted from: Shigley, 1983, Wikipedia, 2007

EXAMPLE
Estimating loading factor in bicycles (drop case)

http://www.youtube.com/watch?v=cikuW8zZqZE&mode=related&search=

EXAMPLE
Estimating stress in wheelchair axle during tip-over



EXAMPLE
Stress in cantilevered Cannondale front shock

Photo removed due to copyright restrictions.

HOMEWORK

- Bring 5 questions for Abdullah next class
- Do calculations from class activity (email me results by next Thurs at 5pm)
- Reading from Positioning in a Wheelchair
- Have first group meeting, define Functional Requirements and project scope, and send to Mentors and Community Partners for Review
- Pick first presentation day (March 6th, 7-9pm???) will present strategies then

Break into teams of 4 to 5, get a mobility aid from 3-446, and go to tunnels in basement

Tasks:

- Measure the rolling resistance of your team's mobility aid and calculate the coefficient of rolling friction
- Measure your MAX mechanical power output on a flat surface for each person in the group (must travel at least 50 feet). Can use rolling start to negate transient effects.
- Estimate the angle of one of the tunnel ramps (you can do this mathematically and/or experimentally – don't just eyeball it)
- Measure each group member's mechanical power out while going up a ramp. (Note: one wheelchair team should go up backwards)

CLASS ACTIVITY
MIT tunnel map