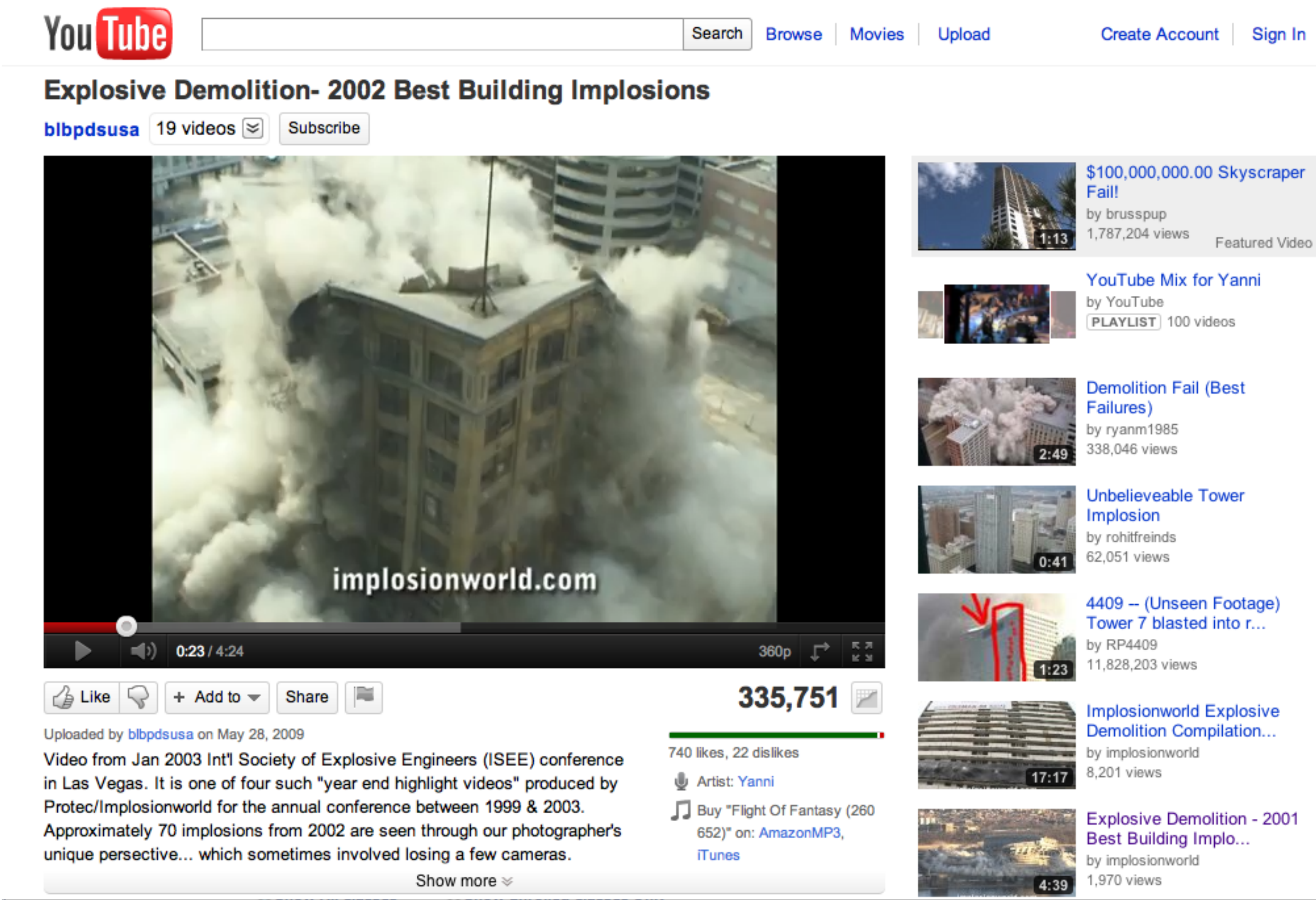
Lecture 16: Statics, Equilibrium, Strength of Materials and Structures. (See Giancoli Chapter 9)



What happened to those buildings?

A. They Exploded
B. They Imploded
C. They Fell Over

And Why? -be prepared to explain!

Statics and Equilibrium

- Conditions for Equilibrium
- Forces and Torques still exist when there is no motion! (Remember Newton's 1st Law)
- No net force or torque (The 2nd law)
- Stability of Structures (Newton's 3rd Law)
- Strength of Materials (Stress, Strain)
- Balance, strength and stability of the Human body

Strategy for Statics Problems

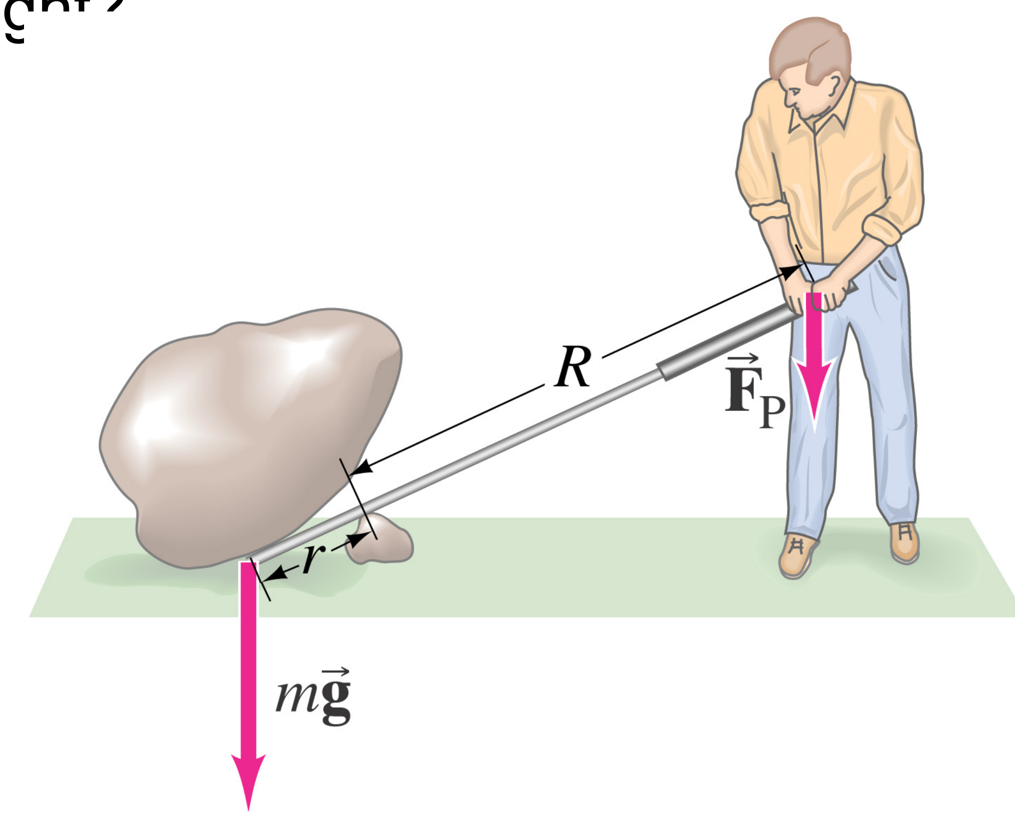
<u>Examples</u>

- Lever, used to lift a rock, jemmy a door, pull a nail.
- Pulley or “Block-and-Tackle”
- A large object that needs to stay balanced

- In All cases we can resolve:
  - Net Force Horizontally
  - Net Force Vertically
  - Net Torque about some axis that we select.

In this Lever problem, resolving Torques gives mgr = F_pR. Is some additional force acting to match the big rock's weight?

1. Yes, the ground pushing up on the large rock
2. Yes, vertical component of normal force on the small rock.
3. No, no additional force needed because the mechanical advantage is R/r, multiplying the force applied

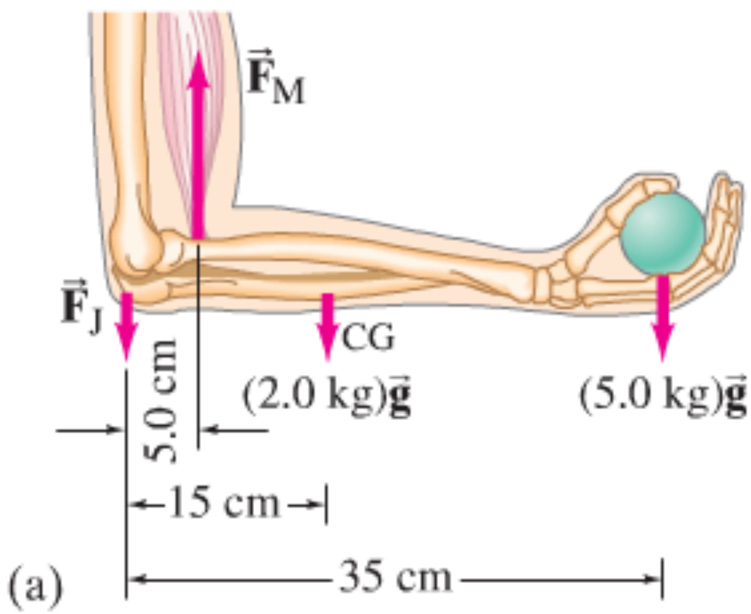


Balance and Stability

- Can a Person Easily Touch their Toes with their back to a Wall?

1. Yes
2. No
3. Depends on how flexible they are

Lifting a Weight



Resolve forces vertically:

$F_M = F_J + W_{ball} + W_{arm}$

Resolve Torques 'about' the elbow:

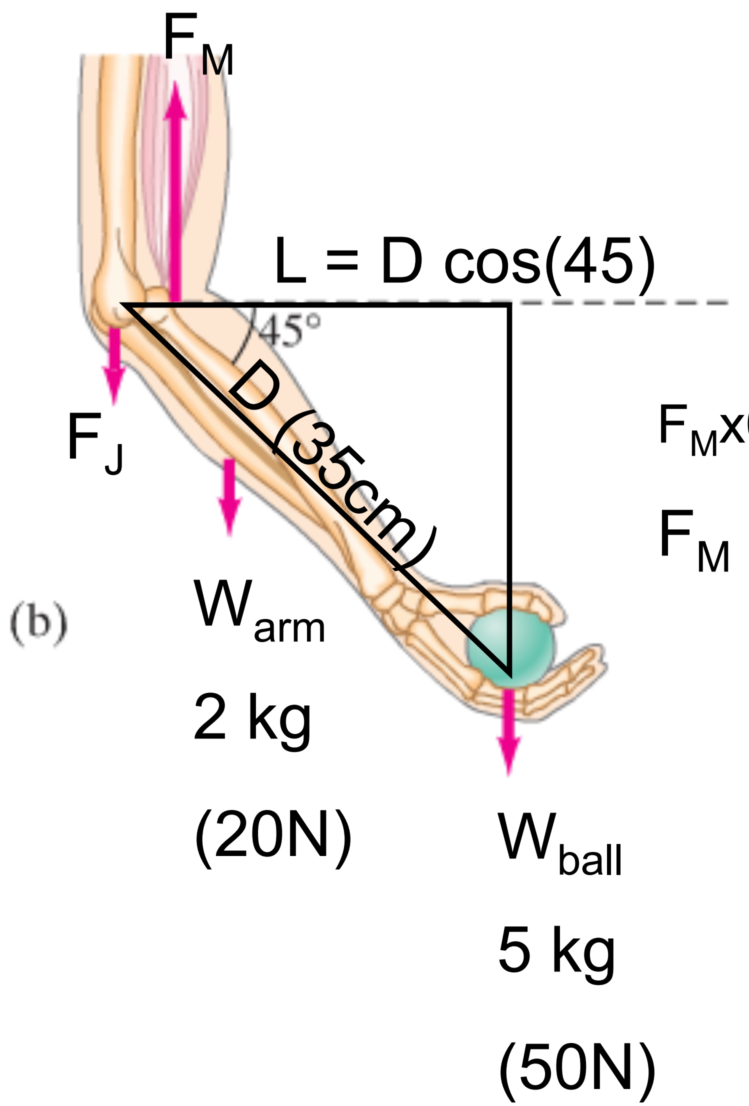
$F_M \times 5cm = W_a \times 15cm \times W_{ball} \times 35cm$

$F_M = 400$ N

What is F_J ?

Do you notice any Friction in your joints?
Synovial joints have μ_S=0.01, μ_K=0.003

Now Bend the Arm!



What is the force required of the Biceps Muscle now?

Again resolve the Torque:

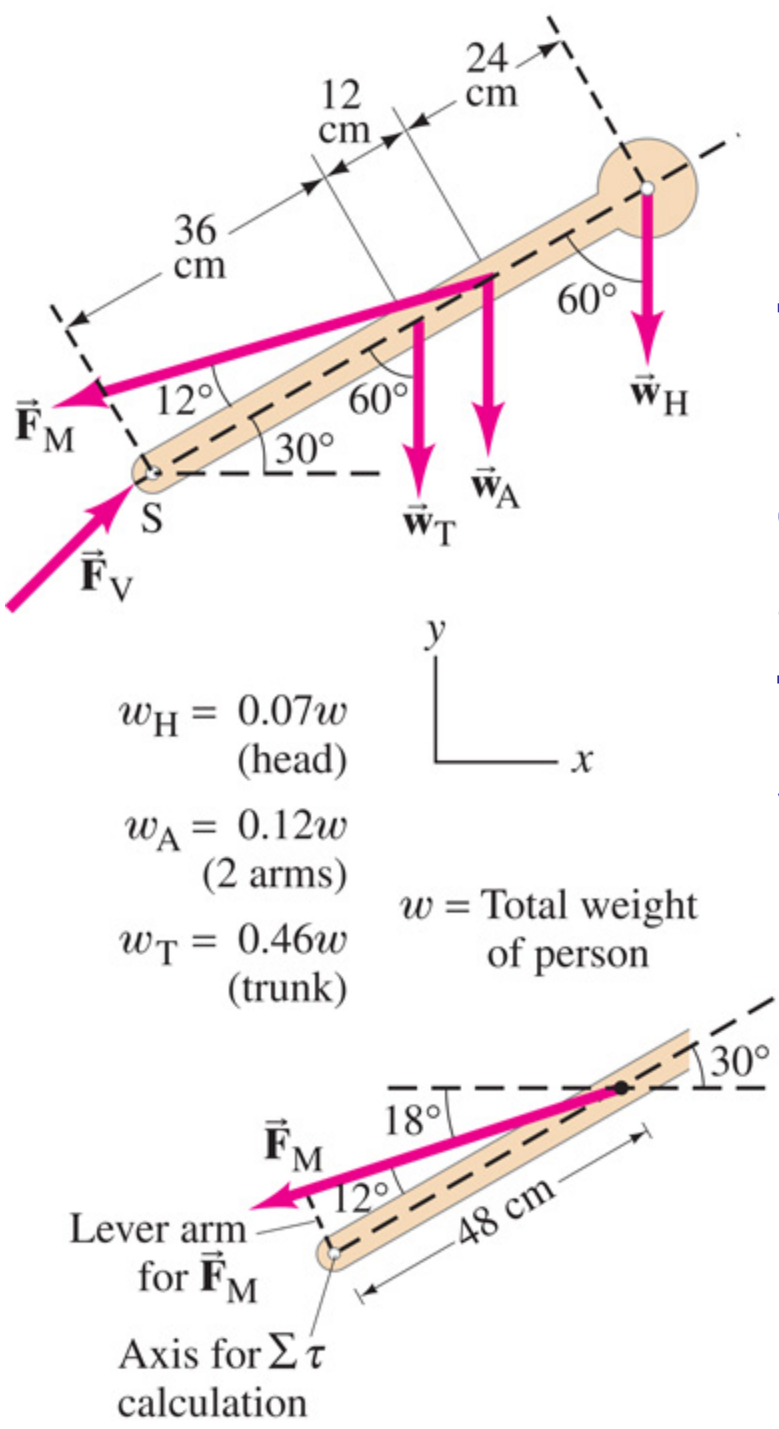
$F_M x0.05cos45 = 20x0.15cos45 + 50x0.35cos45$

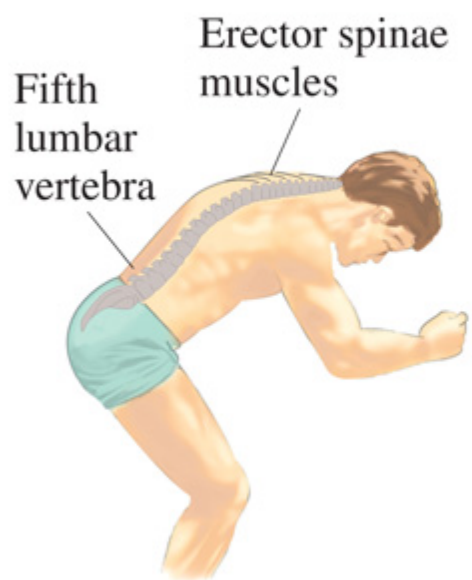
$F_M = 400$ N

So the angle makes no difference to the force required by the Bicep. Is this true for all other muscles involved?

The Human Spine

The angle at which this man's back is bent places an enormous force on the disks at the base of his spine, as the lever arm for F_M is so small.



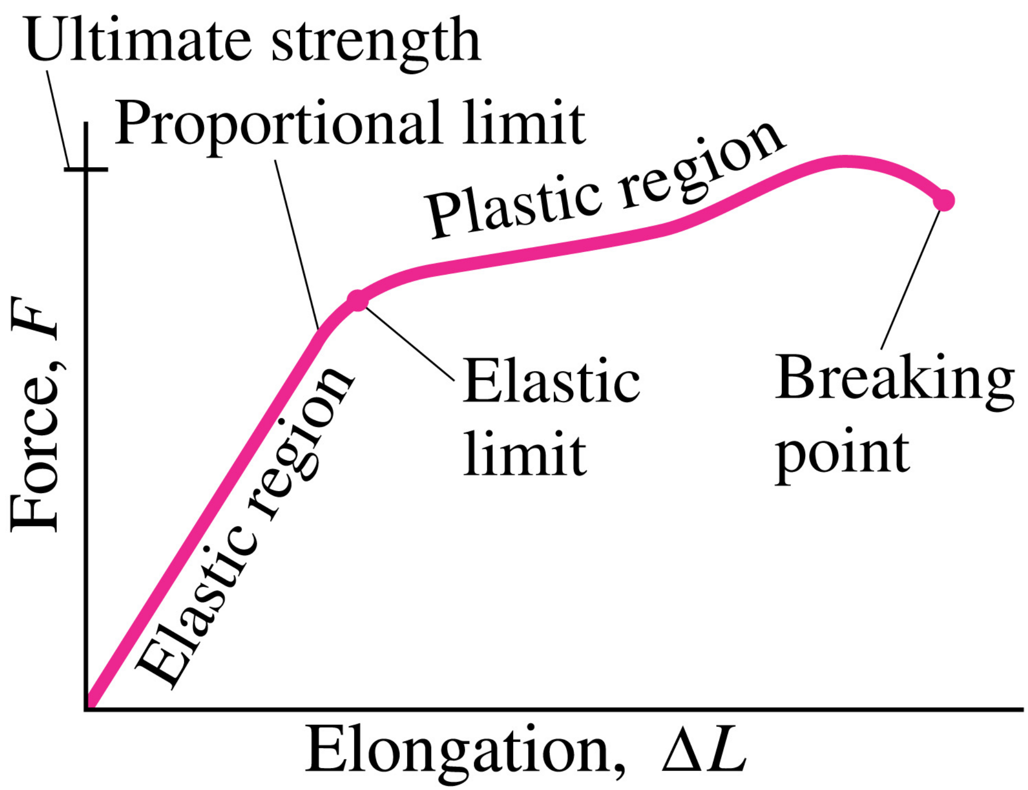


Strength of Materials

- Define strength!
- Squeeze, Stretch, or Twist?
- Being made of atoms, many materials are spring-like in both compression and tension
- Hooke's Law -> $F = k \Delta L$
  - But what do ΔL and k depend on?
  - Does the law break at some point?

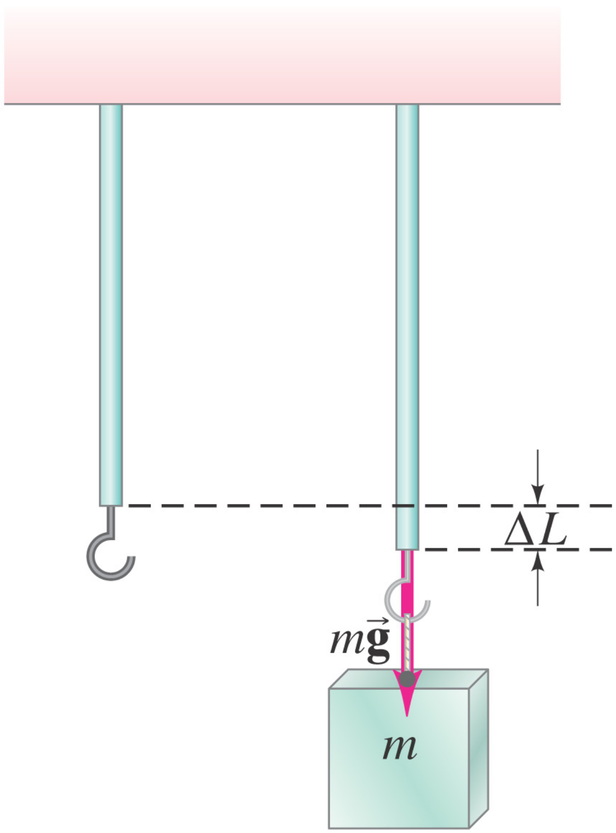
Elasticity and Fracture

This proportionality holds until the force reaches the **proportional limit**. Beyond that, the object will still return to its original shape up to the **elastic limit**. Beyond the elastic limit, the material is permanently **deformed**, and it **breaks** at the breaking point.



If we stretch an object, say a length of wire, or a tendon, what determines how much it stretches?

1. How stretchy the material is
2. How thick it is
3. How long it is
4. All of the above
5. None of the above



Elastic (Young's) Modulus

- $\Delta L \propto F$
- $\Delta L \propto L$
- $\Delta L \propto$ 1/(cross sectional area)

Therefore: $\Delta L \propto FL/A$

Or: $\Delta L = \dfrac{FL}{EA}$ Where E is Elastic modulus (Young's modulus)

Stress and Strain

- Force divided by area is Stress
- Change in length divided by original length is Strain
- Strain is the object's response to Stress!

- Note from Definition of Elastic modulus,

$$E = \frac{\text{Stress}}{\text{Strain}}$$

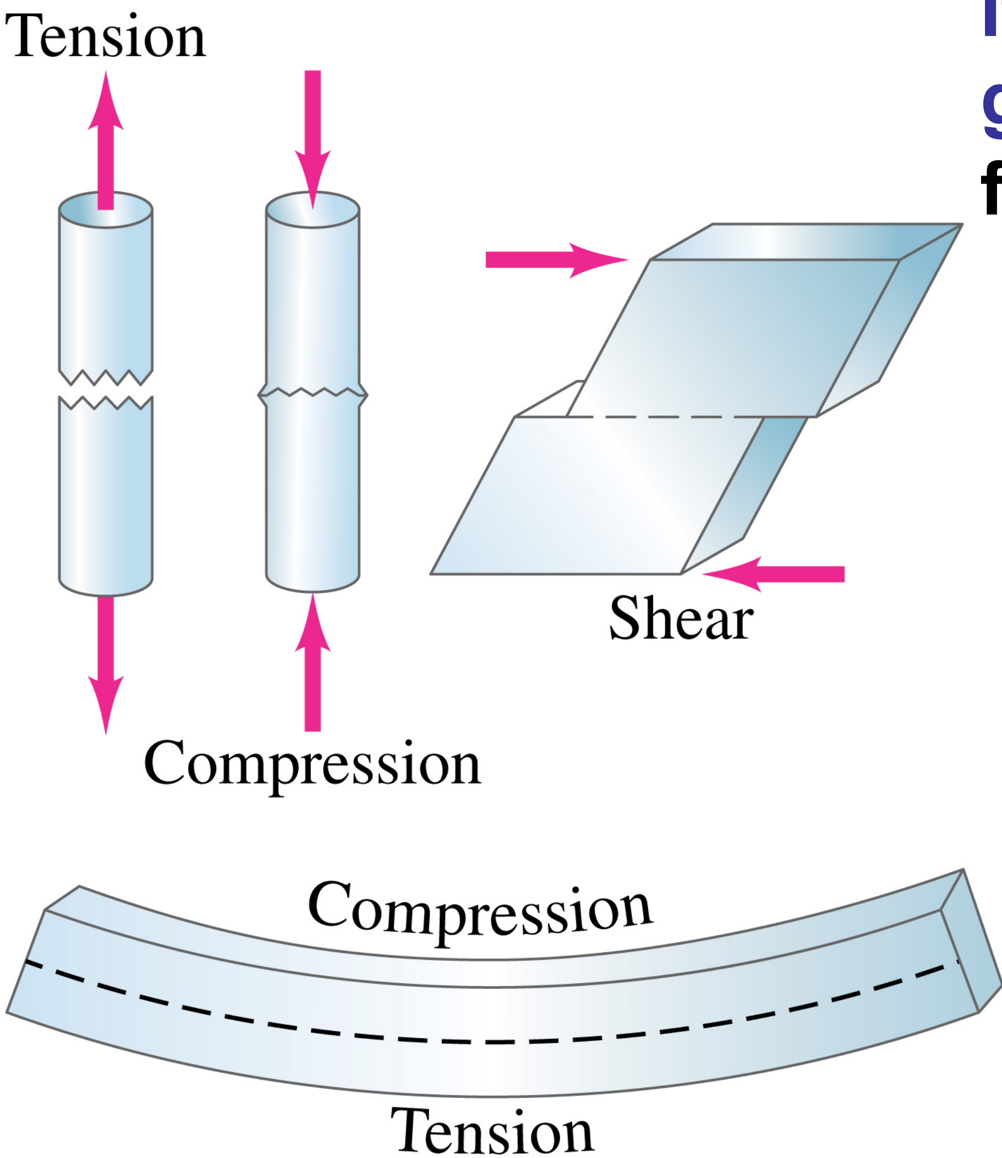
The Strength of Materials is usually given in terms of the maximum stress that a particular material can bear before fracturing. Lets see some values……

- Ultimate Strength of Materials
  - TABLE!!!!

TABLE 9–2 Ultimate Strengths of Materials (force/area)

Material		Tensile Strength (N/m^2)	Compressive Strength (N/m^2)	Shear Strength (N/m^2)
Iron, cast		170×10^6	550×10^6	170×10^6
Steel		500×10^6	500×10^6	250×10^6
Brass		250×10^6	250×10^6	200×10^6
Aluminum		200×10^6	200×10^6	200×10^6
Concrete		2×10^6	20×10^6	2×10^6
Brick			35×10^6	
Marble			80×10^6	
Granite			170×10^6	
Wood (pine)	(parallel to grain)	40×10^6	35×10^6	5×10^6
	(perpendicular to grain)		10×10^6	
Nylon		500×10^6		
Bone (limb)		130×10^6	170×10^6	

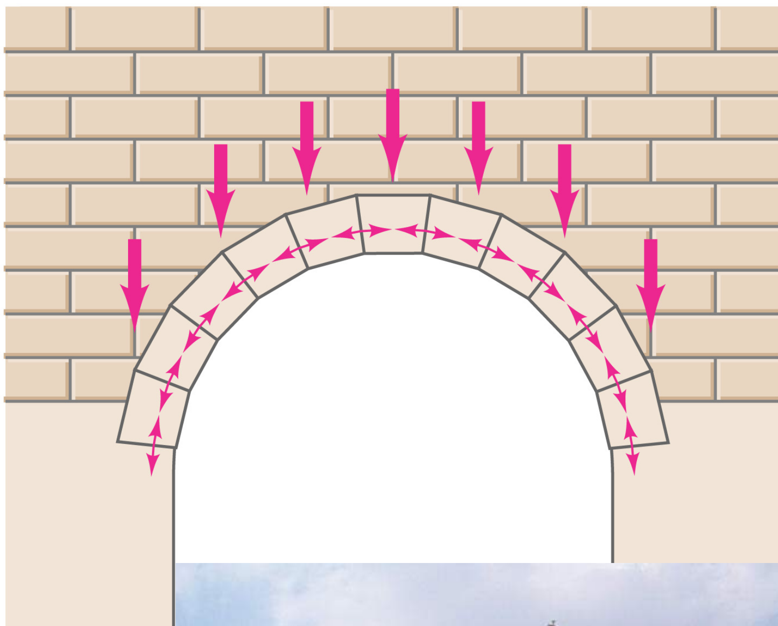
Summary



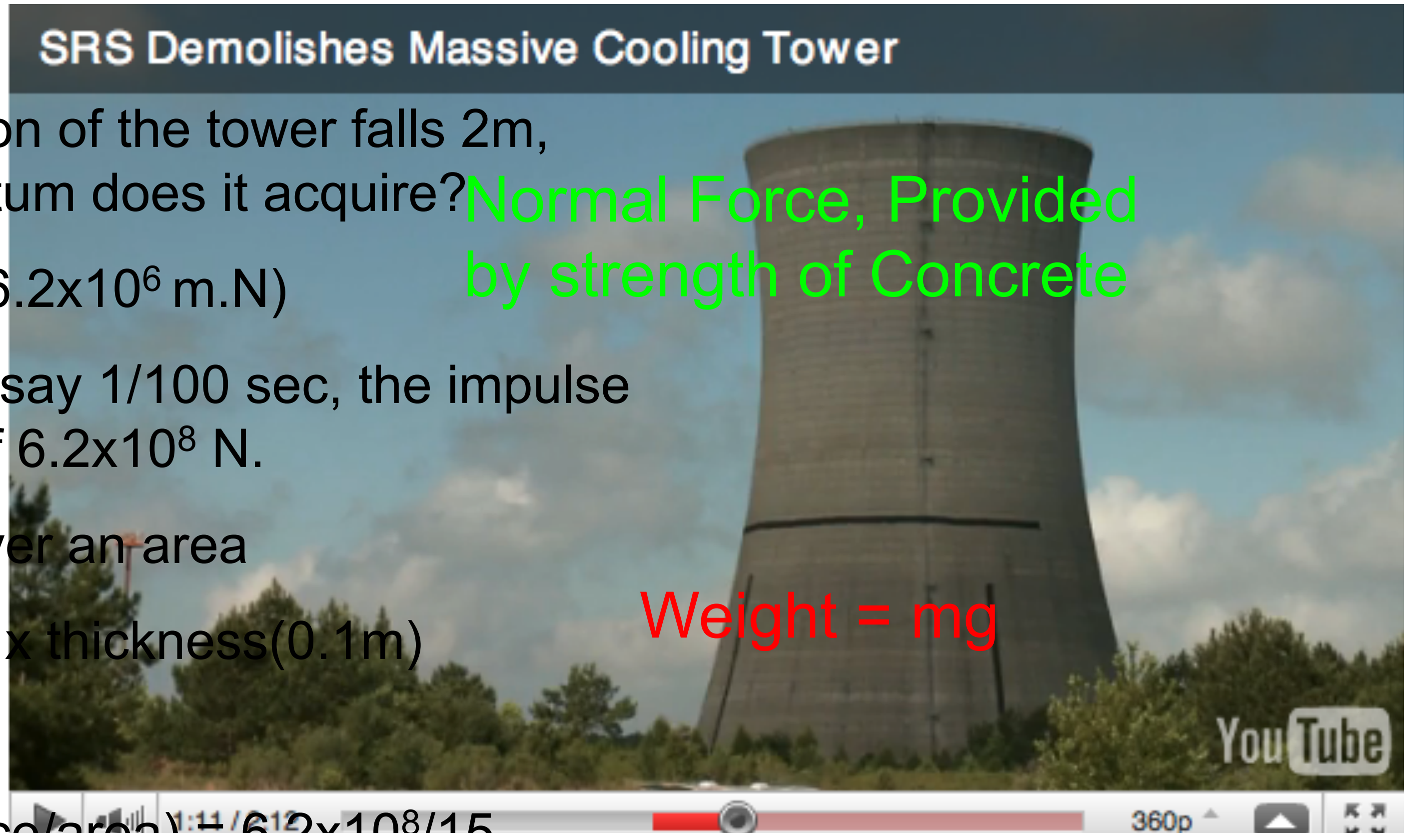
If the **stress** is too great, the object will **fracture**.

When designing a structure, it is a good idea to keep anticipated stresses less than 1/3 to 1/10 of the ultimate strength.

Arches and Stability of Buildings



Structural stability and the compressive strength of Concrete pushed to the limit…



If a 1000 Ton section of the tower falls 2m, how much momentum does it acquire?

(10^6kg x 6.2 m/s= 6.2×10^6 m.N)

If the impact takes say 1/100 sec, the impulse results in a force of 6.2×10^8 N.

Force is exerted over an area

A = circ($2\pi r$ = 150) x thickness(0.1m)

= 15 m^2

So the Stress (Force/area) = $6.2 \times 10^8/15$

= 4×10^7 N/m^2

> Double the strength of Concrete !