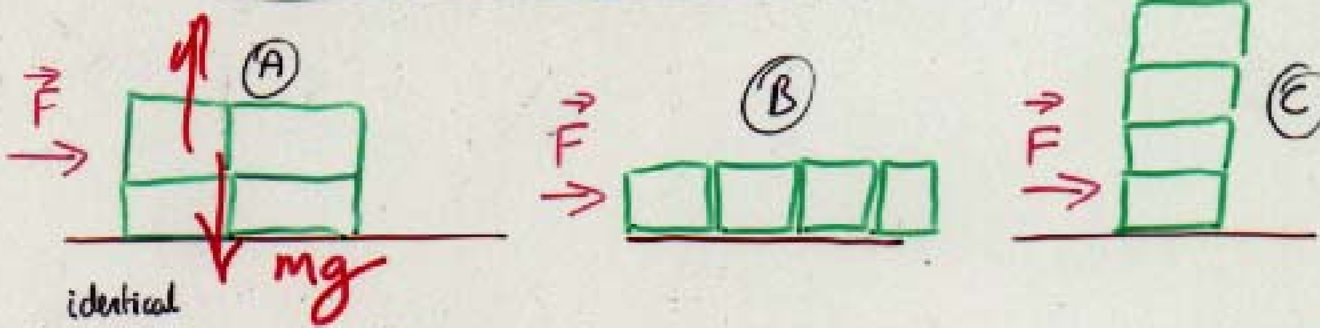
Reading Quiz #2



1. 4 identical boxes are stacked as shown and pushed by a force $\vec{F}$ which is increased until the boxes start to move, overcoming friction. The first (and so easiest) configuration to move will be:

   a) A

   $F_F \leq \mu F_N$

   b) B

   c) C

   d) They will all move at the same time.

2. The SI unit of work, 1 Joule (J) equals:

   a) 1 N/m

   $W = F \times$ path length.

   b) 1 N m

   c) 1 N m/s

   d) 1 N/m²

3. Two masses m_1, m_2 with $m_1 > m_2$ have the same momentum:

$p = mv$

Which object has the greater kinetic energy?

a) Mass m_1

b) Mass m_2

c) Both the same

d) Not enough information.

KE

[Hint: $p = mv$ so $\frac{1}{2}mv^2 = \frac{p^2}{2m}$]

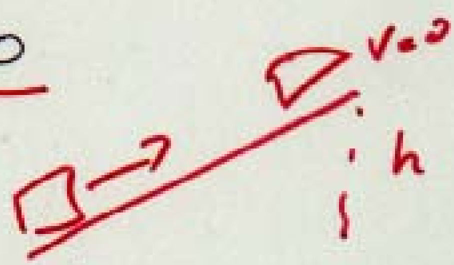
4. An object is given an initial push up a ramp (with friction). Which describes the changes in its Potential Energy, Kinetic Energy, and Total Energy at the top of the ramp.

a) $\Delta PE = 0$, $\Delta KE < 0$, $\Delta E = 0$

b) $\Delta PE > 0$, $\Delta KE < 0$, $\Delta E < 0$

c) $\Delta PE > 0$, $\Delta KE < 0$, $\Delta E = 0$

d) None of the above.



$\Delta (PE + KE) = W_F.$

Friction – the Real World!

- What causes objects to stop moving? Force.
- How does this force depend on: mass, speed, shape, ... ?
- Can friction be a "good" force? How would life change without it?
- What happens to all our "work" put in against friction?

DEFINE: Friction = any force $\vec{F}_F$ opposing motion!

Direction: $\vec{F}_F$ opposite to $\vec{v}$. Magnitude: experiment!

e.g. Fluid Friction (incl. air)

Apply constant force to object (e.g. gravity – drop it!), measure acceleration $\vec{a} = \left(\frac{m\vec{g} - \vec{F}_F}{m}\right)$

e.g. Skydiver

$mg > F_F$

$\Rightarrow a > 0$

$mg = F_F(v)$

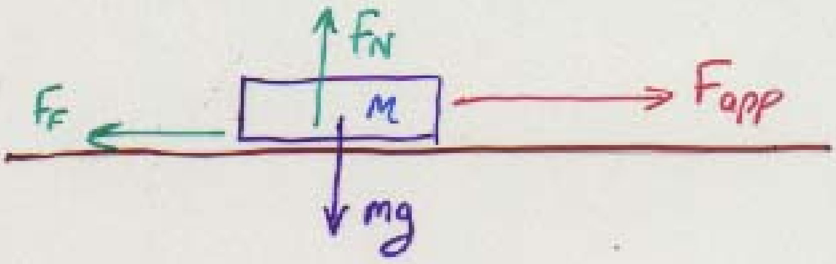
$a = 0$

Find: $F_F \propto$ frontal area, also F_F increases with $|\vec{v}|$ until

$mg = F_F \Rightarrow v = \text{constant}$: terminal velocity

(~180 km/h for skydiver)

Friction between Solids (Tribology)



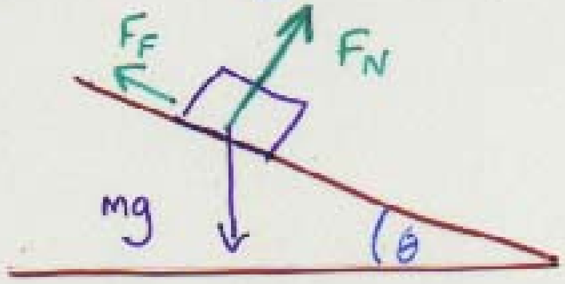
Da Vinci + others: increase F_{app} until mass starts to move over surface.

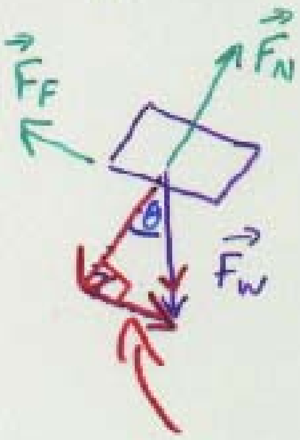
We find:

- F_F increases with F_{app}, so mass does not move, until we reach a critical force $(F_F)_{max}$

- Critical force:
  - does <u>not</u> depend on contact area!
  - " <u>not</u> " on v, once moving (c.f. fluids)
  - $\propto F_N$, normal force of surface on object

On flat surface, $F_N = mg$, but for inclined planes:





$\perp$ to plane: $F_N = mg\cos\theta$

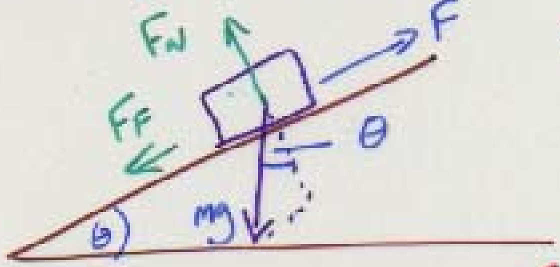
$\parallel$ to plane: net force down plane $= F_W \sin\theta - F_F$

$\Rightarrow$ starts moving ($a = F/m$) when $F_W \sin\theta > (F_F)_{max}$

$$\boxed{\text{From experiment: } F_F \leq \mu F_N}$$

Coeff. of friction μ depends on surfaces' "roughness", <u>not</u> mass, contact area etc.

e.g. To push mass up a slope



e.g. $m = 5\text{kg}$, $\theta = 60°$

$\mu = 0.8$

Req. force (up) $F = mg\sin\theta + \mu \overbrace{F_N}^{mg\cos\theta} = mg(\sin\theta + \mu\cos\theta)$

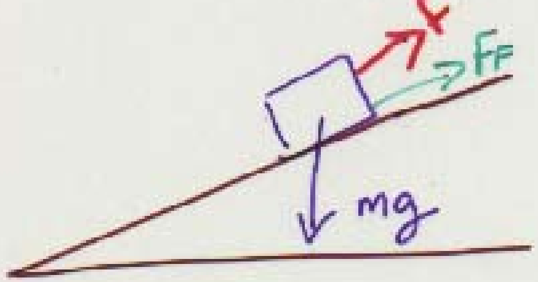
e.g. $F = 5\text{kg} \times 10\text{m/s}^2 \, (\sin 60° + 0.8\cos 60°) = 43.3\text{N} + \overbrace{20.0\text{N}}^{\mu F_N}$

$= 63.3\text{N}$ (c.f. weight 50N)

<u>BUT</u> to prevent same mass from sliding down,

(up): $F = mg\sin\theta - \mu F_N = mg(\sin\theta - \mu\cos\theta)$

$= 43.3\text{N} - 20.0\text{N} = \underline{23.3\text{N}}$.

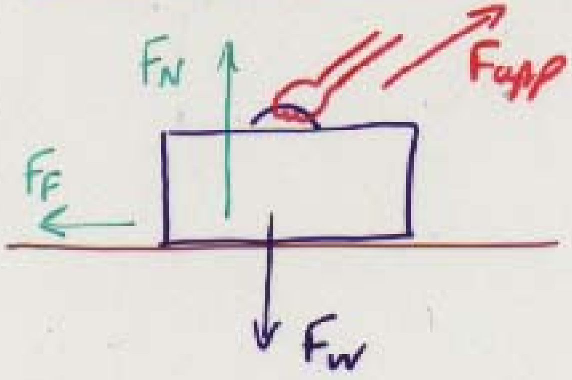


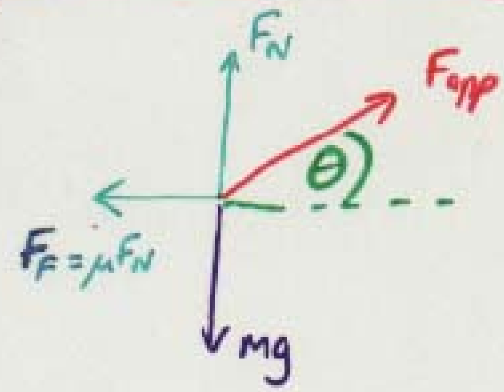
For smaller slopes, no force required as long as $\underline{mg\sin\theta} = \underline{F_F}$

i.e. up to a max. angle where $mg\sin\theta \geq (F_F)_{max} = \mu F_N$

i.e. $mg\sin\theta \geq \mu mg\cos\theta$, or $\tan\theta \geq \mu$

Example: Pull suitcase along floor





Find: required force F_{app}. Given $mg = 400\,N$ (40kg), $\mu = 0.6$

Assume that suitcase stays on surface, not lifted off

$\Rightarrow F_N > 0$, no vertical accel. Also no horizontal accel and $v > 0$ so $F_F = \mu F_N$

$\perp$ to surface: $F_N + F_{app}\sin\theta = mg \Rightarrow F_N = mg - F_{app}\sin\theta$ (1)

reduced weight on floor

$\parallel$ to surface: $F_{app}\cos\theta - F_F = 0 \Rightarrow F_{app}\cos\theta = \mu F_N$ (2)

Subs. (1) into (2) $\Rightarrow F_{app}\cos\theta = \mu mg - \mu F_{app}\sin\theta$

$$\Rightarrow F_{app} = \frac{\mu \overbrace{(mg)}^{F_W}}{\cos\theta + \mu\sin\theta}$$

$\therefore$ Required force depends on angle of arm:

e.g. $\theta = 45°$: $F_{app} = 0.53\,mg = 212\,N$

c.f. "lift" $\theta = 90°$: $F_{app} = mg = 400\,N$

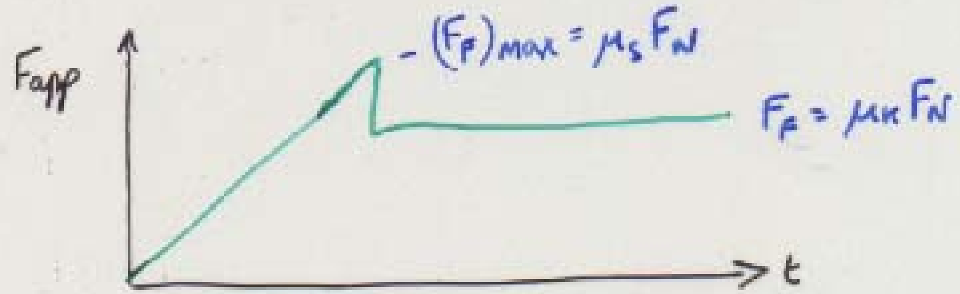
"drag" $\theta = 0°$: $F_{app} = \mu mg = \underline{240\,N}$

The Details:

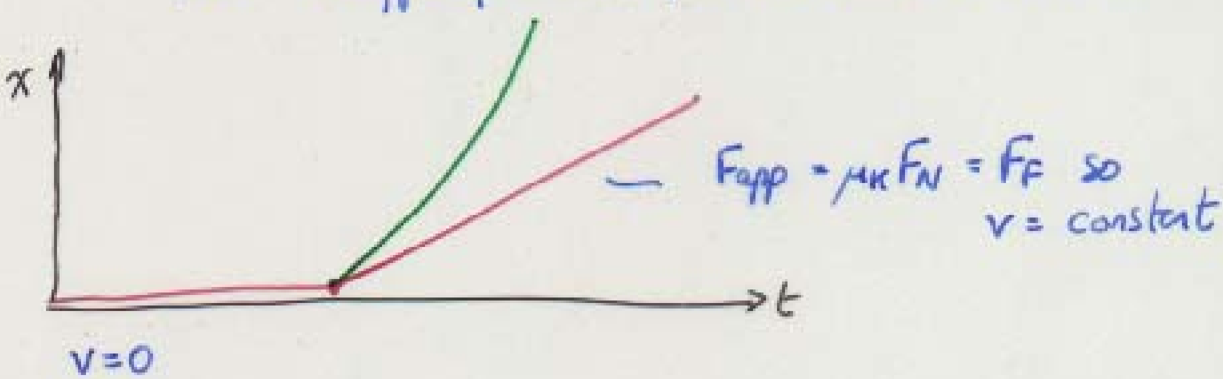
Themestius (~350 B.C.) found

- takes extra force to "un-stick" object at rest on surface

once moving, $(F_F)_{max}$ slightly reduced.



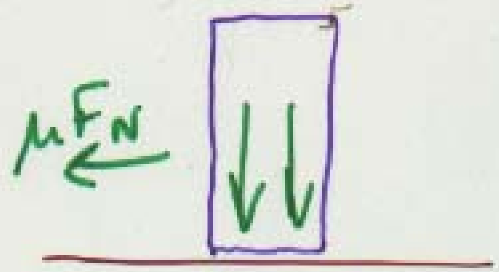
i.e. coeff of static friction $\mu_s > \mu_k$ (kinetic friction)



Friction $\propto F_N$ only, not contact area

See fig 4.31

large contact area, but
atomic force/unit area small



small contact area
but atoms "squeezed" together
$\Rightarrow$ fewer object-surface gaps

Friction is a macroscopic version of the electromagnetic forces between atoms

Work and Energy (ch. 6)

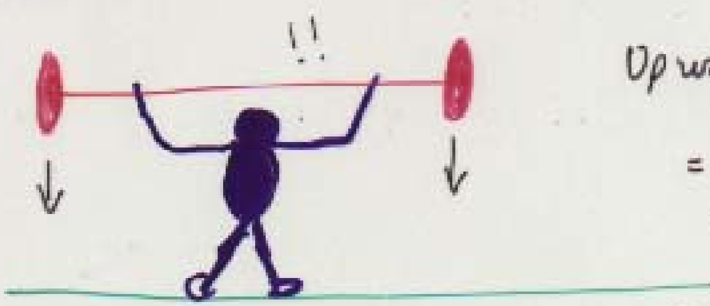
Vaguely: Energy transfer ~ measure of "change" to a system

Work = Energy transferred when a force moves its point of application.

DEFINE: Work done W = Force × path length moved

$= F \cdot \ell$ [Nm or Joule (J)]

Note: No <u>motion</u> → no work!



Upward <u>force</u> of lifter

$= F_W = mg$ downwards

BUT WORK = 0.