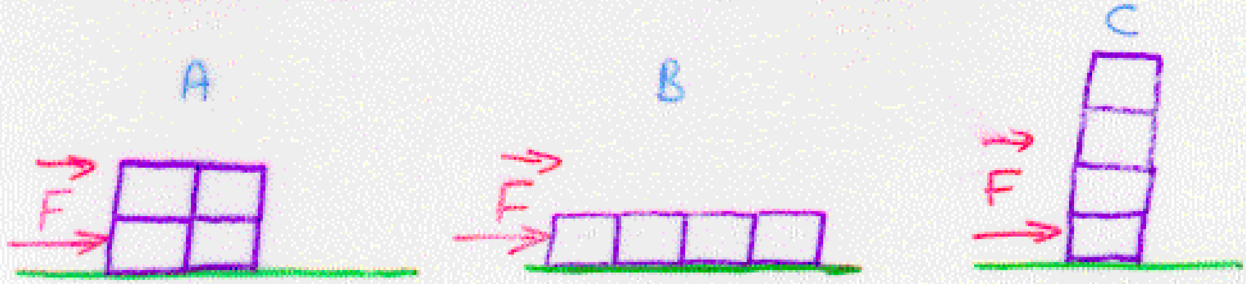
Reading Quiz 3 - Physics 1A

1.



4 wood blocks, 1kg each, are stacked as shown and pushed by an identical force $\vec{F}$, which is increased until the blocks start to move, overcoming friction.

The first setup to move will be:

a) A

b) B

c) C

d) They will all move at the same time.

$F_F = \mu F_N$

μmg

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

a) 1 N/m

b) 1 Nm

c) 1 Nm/s

d) 1 N/m²

W = force × distance

3. When a ball is thrown upwards (neglect friction) and follows ~~a~~ parabolic trajectory, its Potential Energy depends on:

a) height

b) height and total speed

c) height and vertical speed V_y

d) None of the above, something else instead.

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4. A toy car is given a push and rolls up a ramp, then comes back down to the starting point.

Which describes the change in Potential Energy ΔPE, the change in Kinetic Energy ΔKE, and the Work done against friction W_F:

a) $\Delta PE = 0$, $\Delta KE < 0$, $W_F = -\Delta KE$

b) $\Delta KE = \Delta PE$, $W_F = 0$

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

d) None of the above.

Physics of Friction – the Real World

"Friction" ≡ any force opposing motion

Direction : opposite to velocity $\vec{v}$

Magnitude : Find by experiment!

e.g. (1) Air / fluid resistance

— depends on frontal area and shape of object

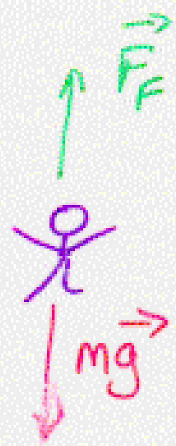
— force increases with speed $|\vec{v}|$

∴ with constant accel. force F (e.g. engine, or gravity), fluid friction ↑ as v ↑ until object reaches terminal velocity.

low $|\vec{v}|$

low $|\vec{v}|$

accel $a = \frac{(mg - F_F)}{m}$

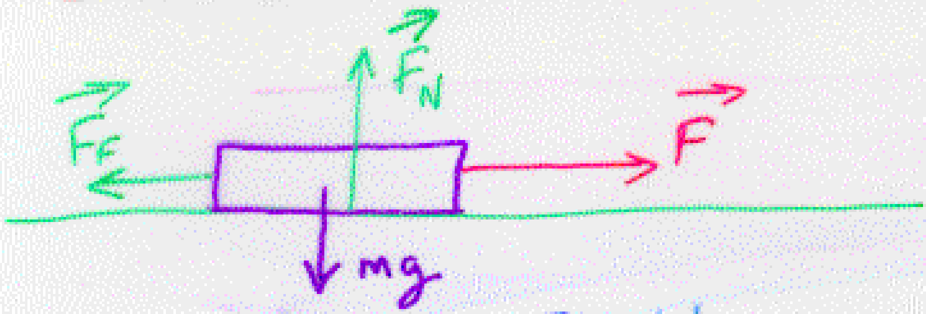


terminal $|\vec{v}|$

weight $mg = F_F$

$\Rightarrow a = 0$

Friction between Solids (Tribology)

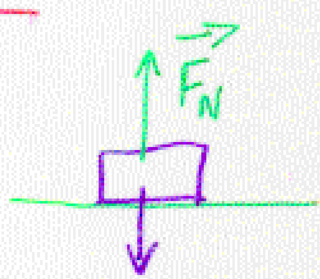


Increase applied force F until mass m starts to move. We find (da Vinci + others):

- Mass does not move until we reach a critical force
  ∴ friction force F_F increases with applied force

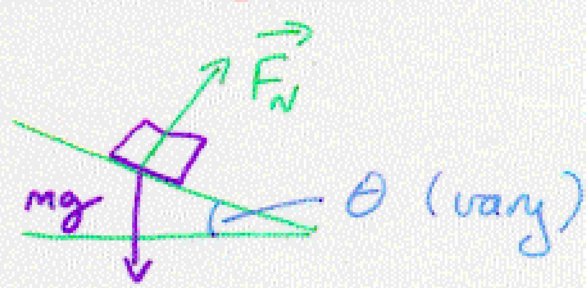
- Critical force required.....
  - does not depend on contact area
  - once moving, does not depend on v
  - proportional to normal force of surface on object F_N

Flat:



$F_N = mg$

Inclined Plane



$F_N = mg\cos\theta$

object starts moving when

$mg\sin\theta \geq F_F$

From experiment we can write

$$F_F \leqslant \mu F_N$$

with $\vec{F}_F$ opposing desired or actual motion

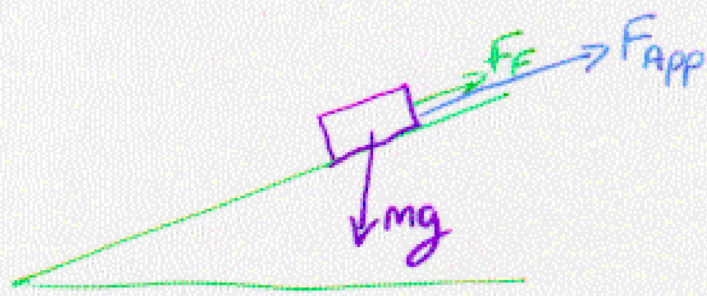
μ is the coefficient of friction

e.g. to push object up inclined plane:

Force required $F_{App} = mg\sin\theta + \overbrace{\mu F_N}^{F_F}$

$$= mg(\sin\theta + \mu\cos\theta)$$

c.f. Force required to prevent same object from sliding down:



Now $F_{App} + F_F = mg\sin\theta$ with $F_F \leqslant \mu mg\cos\theta$

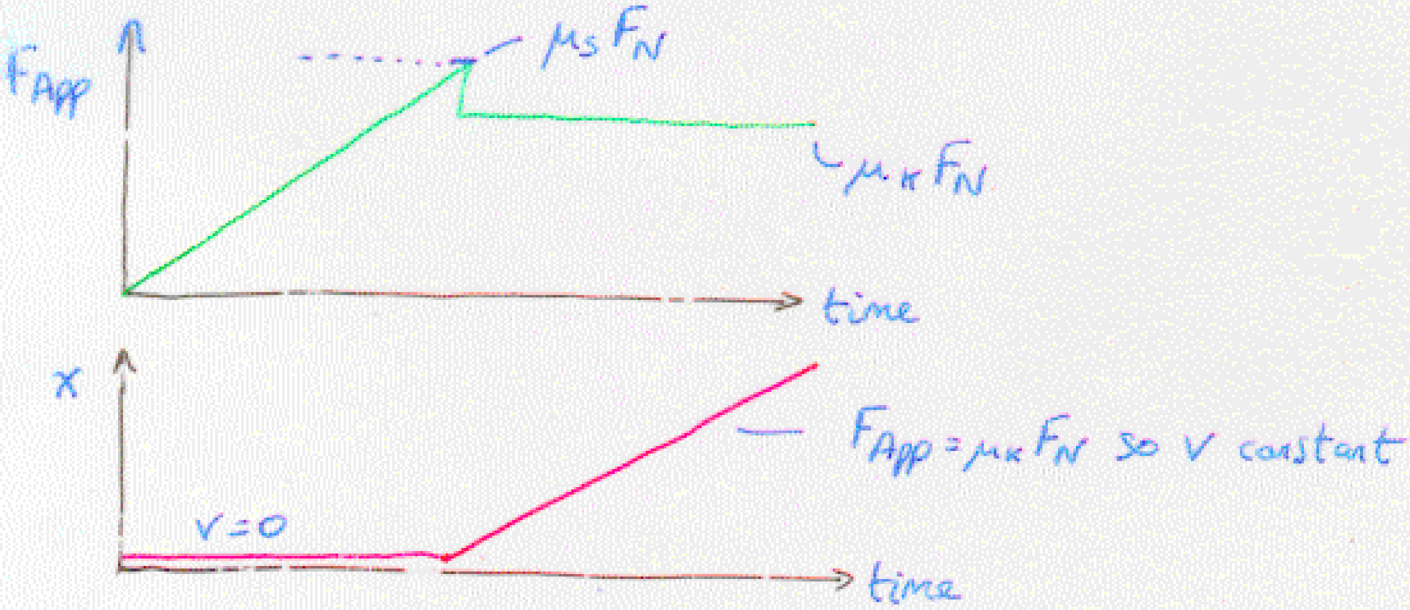
$\Rightarrow F_{App} \geqslant mg(\sin\theta - \mu\cos\theta)$ $F_{app} = 0$

less than before (and possibly zero!) $\Rightarrow \tan\theta = \mu$

Details: Static vs. Kinetic Friction

(Themestius ~350 B.C.) – we find that extra force required to "unstick" an object at rest. Once moving, F_F is slightly reduced

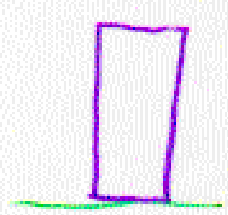
e.g. Pulling on a sliding object:



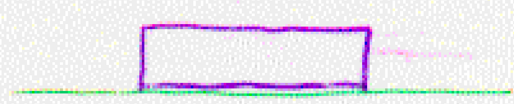
∴ Coeff. of static friction μ_S > Coeff. of kinetic friction μ_K.

Friction ∝ μF_N, not contact area: (fig 4.31)

Object + surface "squeezed" together:

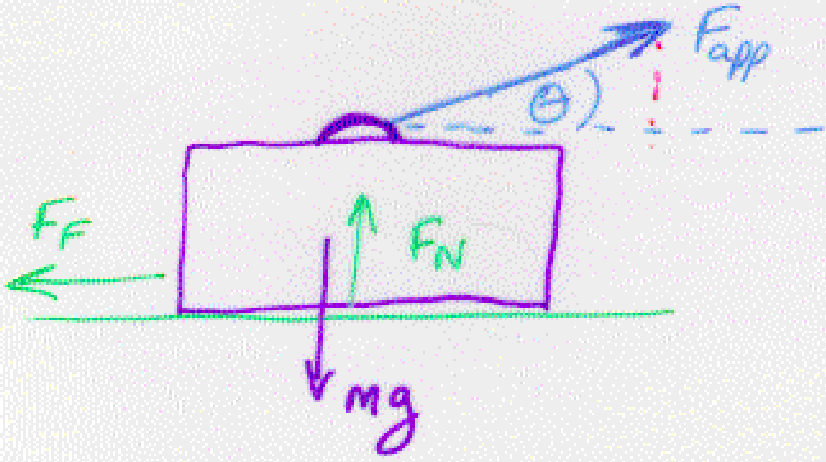


smaller area, but greater force/unit area



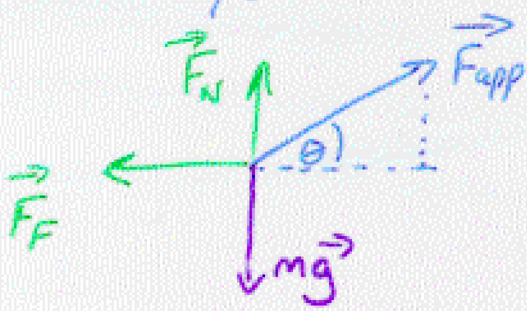
less force/unit area but greater area

Example: Dragging a Suitcase at constant speed



Let's have: $\mu = 0.2$, $mg = 800N$ (80kg)

Assuming that suitcase stays on surface ($F_N > 0$) equate horiz/vertical components:



Vertical: $F_N + F_{app}\sin\theta = mg \Rightarrow \underline{F_N} = mg - F_{app}\sin\theta$

Horiz: $F_{app}\cos\theta - \underbrace{F_F}_{\mu F_N} = 0$ (no net accel.)

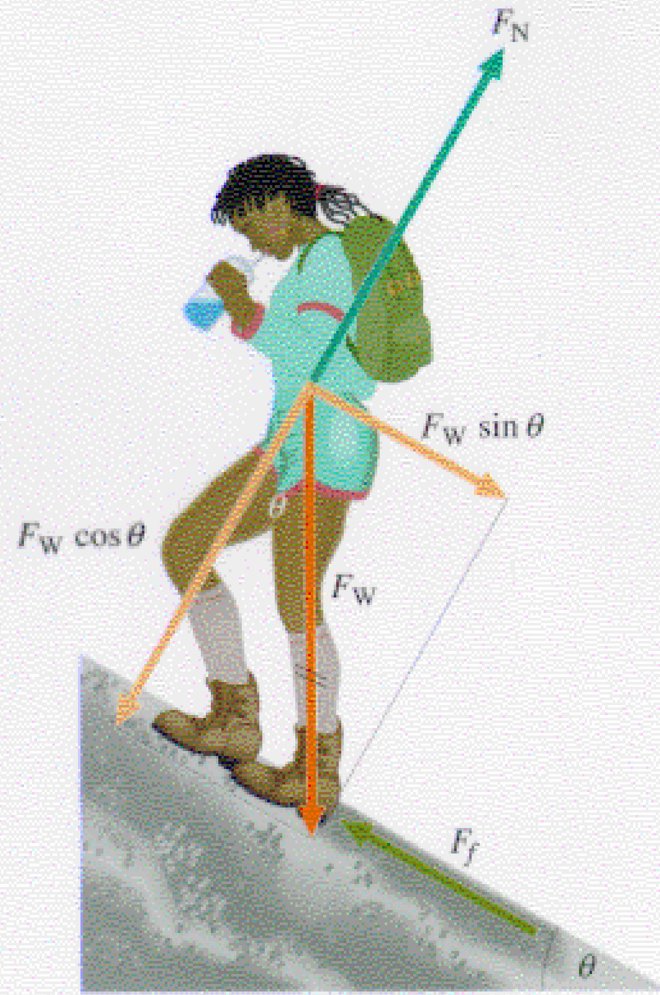
$$\Rightarrow F_{app}\cos\theta = \mu\,(mg - F_{app}\sin\theta)$$

or $$\underline{F_{app}} = \frac{\mu mg}{\cos\theta + \mu\sin\theta}$$

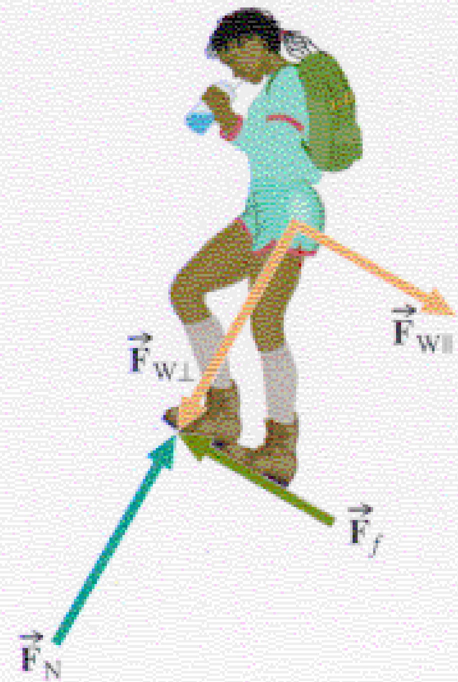
e.g. if $\theta = 45°$, $F_{app} = 0.235\,mg = \underline{188.5\ N}$

Figure 4.28

Climber at rest on an inclined surface



(a)



(b)

$F_N = mg\cos\theta$

We want $F_F = mg\sin\theta$

and $F_F \leq \mu_s F_N$

$\tan\theta_{max} = \mu$