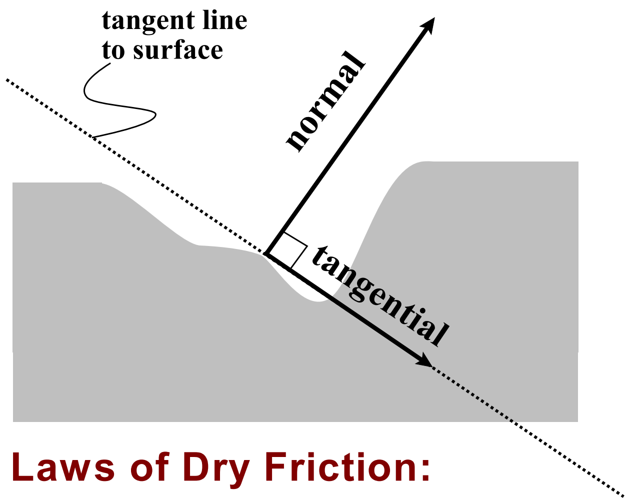
Friction

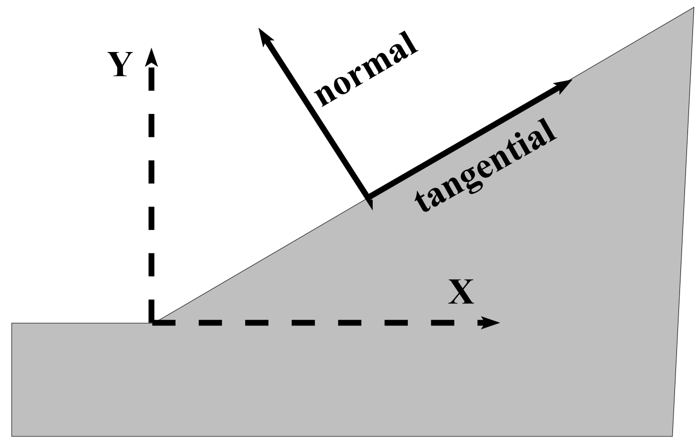
-the resistance between two contact forces (between the surfaces)

Normal and Tangential Axes:

- **normal axis** is perpendicular to surface
- **tangential axis** is parallel to surface

friction force is always the opposite of the applied force





Laws of Dry Friction:

Static: maximum static friction $= F_{static} = {}_{static} F_{normal}$ not moving

Kinetic: maximum kinetic friction $= F_{kinetic} = {}_{kinetic} F_{normal}$ moving

normal force is counteracting the weight

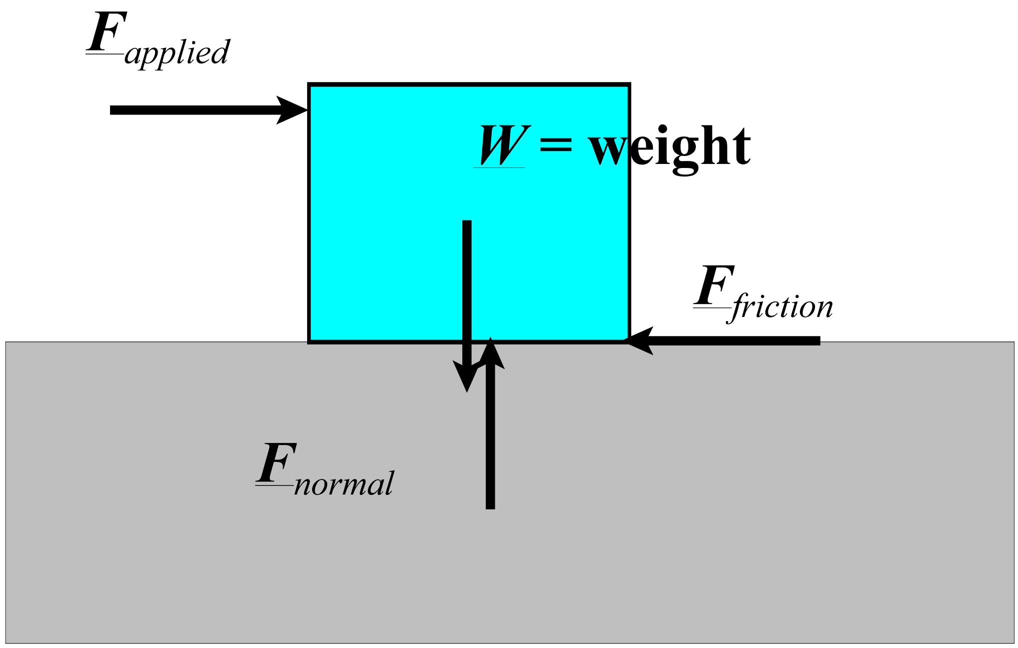
Coefficients of Static Dry Friction

Low friction - skating, air hockey (more fluid), ice and shoes, skiing, luge
High friction- running, baseball players when they plant there foot, rugby scrum, tug of war

Metal on metal	0.15 - 0.60
Metal on wood	0.20 - 0.60
Metal on stone	0.30 - 0.70
Wood on wood/leather	0.25 - 0.50
Stone on stone	0.40 - 0.70
Earth on earth	0.20 - 1.00
Rubber on concrete	0.60 - 0.90
Nylon on nylon	0.15 - 0.25
Bone on bone (cartilage)	0.10 - 0.20
Steel on Teflon	0.04 - 0.05
Metal of ice	0.02 - 0.05

-has to be between two objects
-coffecient of kinetic friction is always going to be less than static because it takes more to start moving than to keep it moving

Forces of Friction:

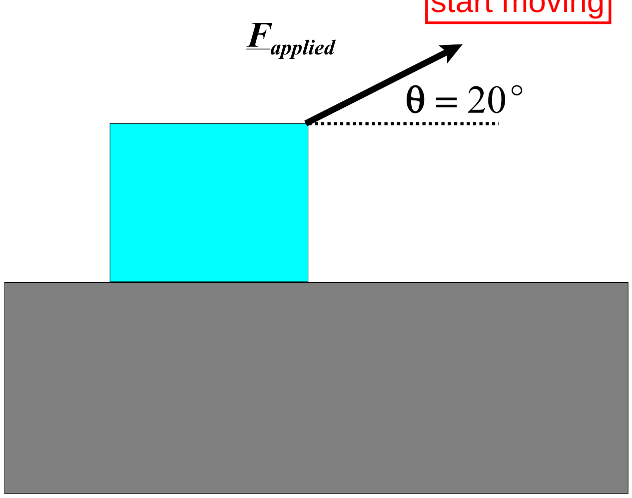


Example:

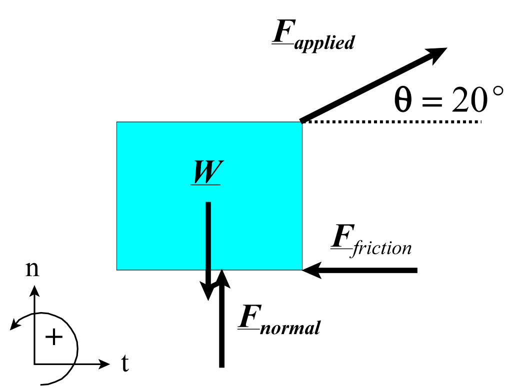
If $F_{applied} = 25.0$ N, $F_{static} = 100$ N, $W = 30.0$ N, compute $F_{friction}$.

have to overcome 100N to start moving

Space diagram



Free-body diagram



$$F_t = 0: F_{friction} + F_{applied} \cos 20^\circ = 0$$

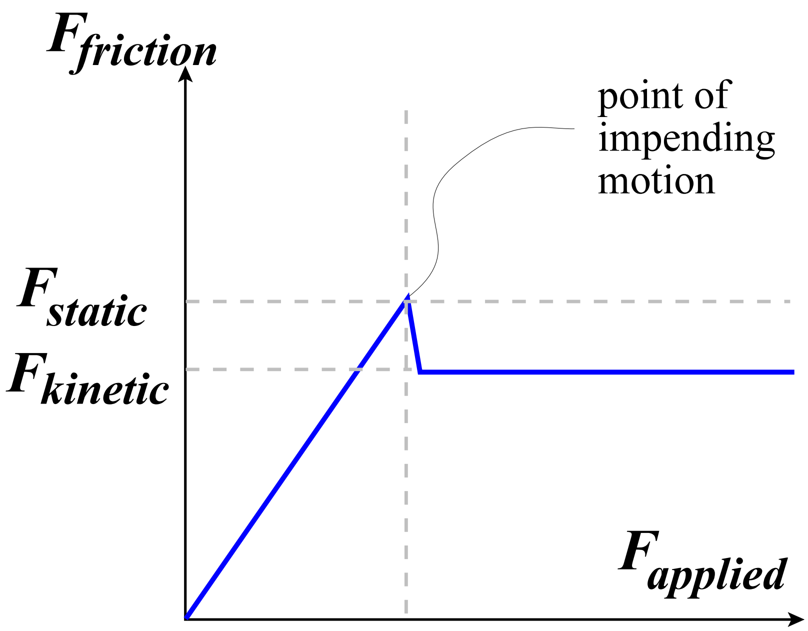
therefore $F_{friction} = -25.0 \cos 20^\circ = -23.5$ N

(note answer must be > 100 newtons, i.e., max. static friction)

when the static friction and applied force are equal there is constant velocity, if it is less than it does not move, if it is more than it does move

Relationship between Applied Force and Friction

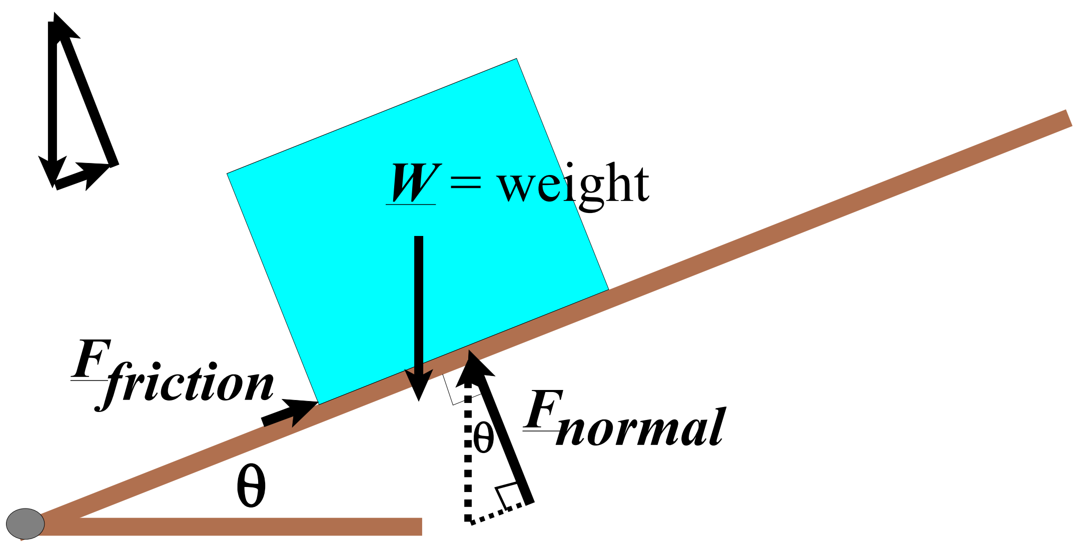
- as applied force increases friction increases until a maximum is reached and slipping occurs
- maximum is called F_{static}
- after body starts to move frictional force drops to a new level called $F_{kinetic}$
- any further increase in the applied force is resisted by $F_{kinetic}$
- figure below is called the "standard model of friction"



-your pulling and pulling and then it slips and moves faster at the impending motion point and then you hit kinetic friction, if you have overcome the kinetic friction will stay constant (static will continue to increase until it moves)

Empirical Method for Calculating Coefficient of Static Friction

- cover a load and incline with two surfaces to be tested
- place load on an incline that can be raised at one end
- make sure incline and load are flat and clean
- increase incline until load just starts to slip
- measure angle of incline,
- repeat and obtain average angle
- coefficient of static friction = $_{static}$ = tan
- proof follows

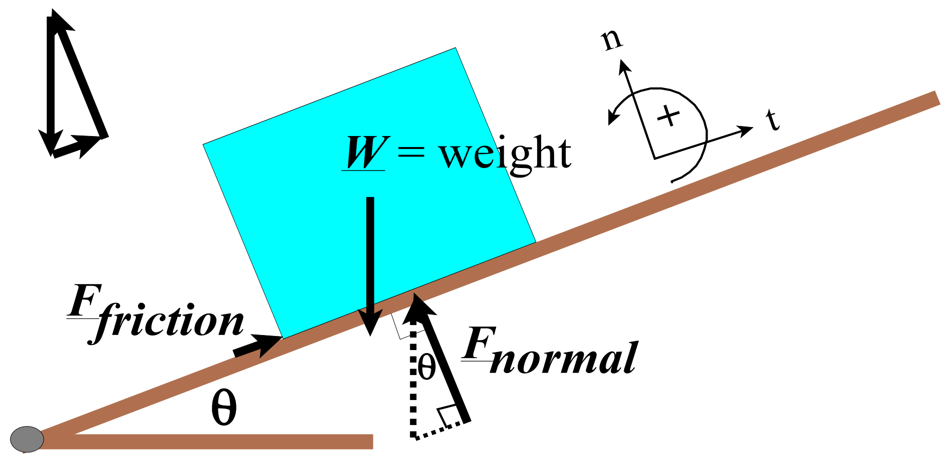


At instant of impending motion: $\mu_{static} = \tan\theta$

- coefficient of kinetic friction is more difficult to obtain
- tan of angle that keeps load moving at constant velocity

Angles of Friction

- angle of an incline at the point of **impending motion**
- tangent (tan) of this angle is the same as the coefficient of static friction



At instant of impending motion: $\mu_{static} = \tan\theta$

Proof:

$$\sum F_n = 0: \quad F_{normal} - W\cos\theta = 0$$

$$F_{normal} = W\cos\theta$$

$$\sum F_t = 0: \quad F_{static} - W\sin\theta = 0$$

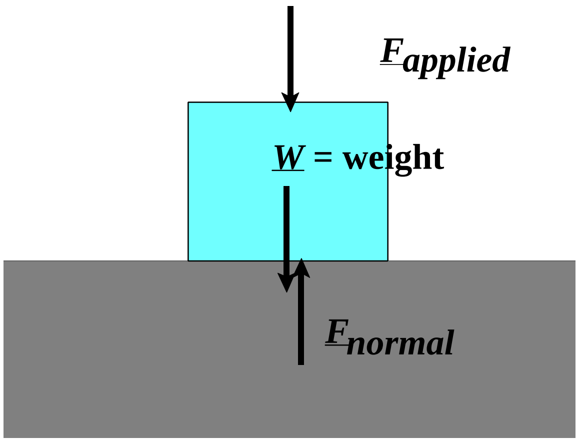
$$F_{static} = W\sin\theta$$

$$\mu_{static} = \frac{F_{static}}{F_{normal}} = \frac{W\sin\theta}{W\cos\theta} = \tan\theta$$

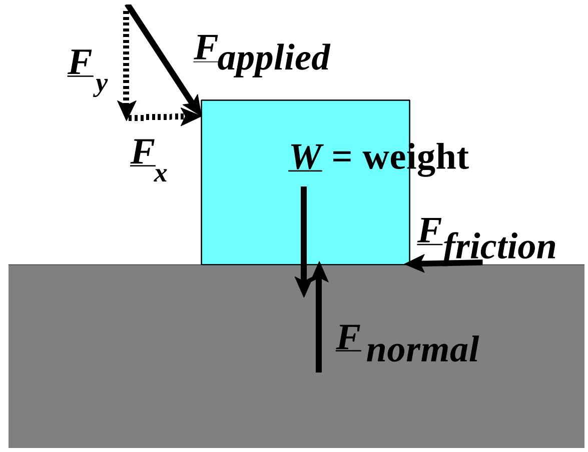
- To compute the **coefficient of kinetic friction**, lower the incline slowly until the mass just stops–this is the angle of kinetic friction.
- The tan of this angle is the coefficient of kinetic friction.

Frictional States

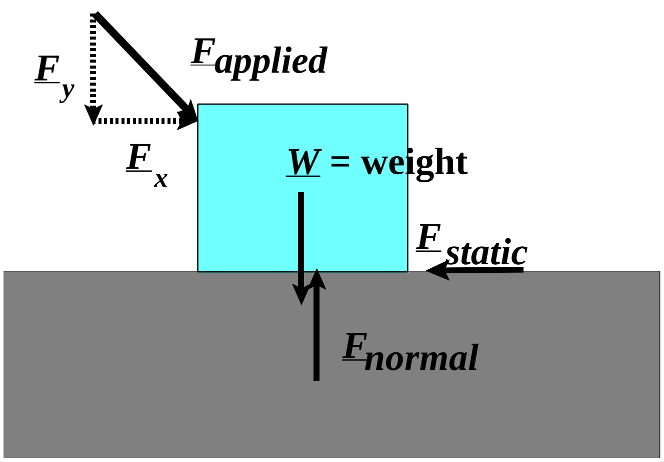
(a) no friction



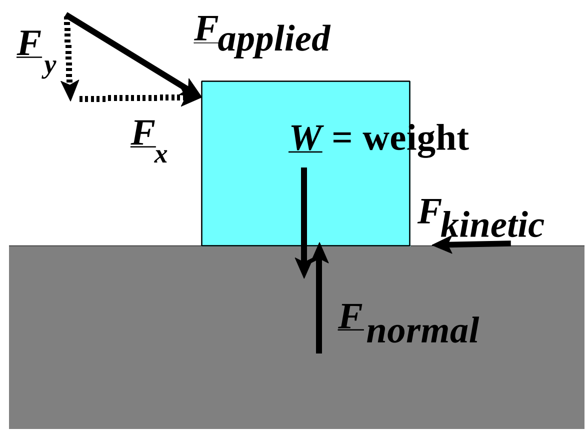
(b) no motion ($F_x < F_{static}$)



(c) motion impending ($F_x = F_{static}$)

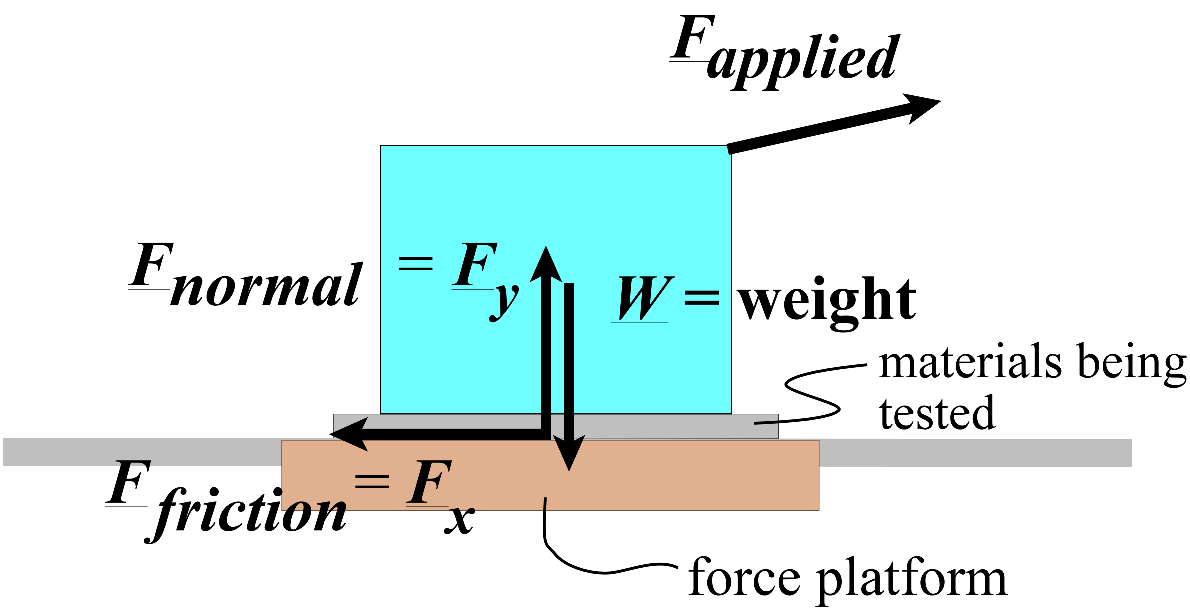


(d) motion ($F_x > F_{static}$)



Measuring Friction using Force Platforms

- line load and force platform with surfaces to be tested
- pull load across clean level force platform
- record maximum horizontal force (F_x) at point load starts to move
- $_{static}$ = horizontal force / vertical force
- record horizontal force when load is moving
- $_{kinetic}$ = horizontal force / vertical force



Homework:
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