L10 – Static Equilibrium and Friction

1. Statics
2. Stability and Toppling
3. Friction and Force of Friction
4. Coefficient of *Static* Friction and coefficient of *Kinetic* Friction

1. Statics: Recall Conditions of Equilibrium

For an object to be static, two conditions must be fulfilled:

- *No resultant force in any direction*

($F_{up} = F_{down}$, and $F_{right} = F_{left}$)

- *No resultant torque about any axis.*

(Moments acting to give a cw rotation= Moments acting to give an acw rotation)

Mathematically:

$$\sum \vec{F} = 0 \quad \text{(Eq.1)}$$

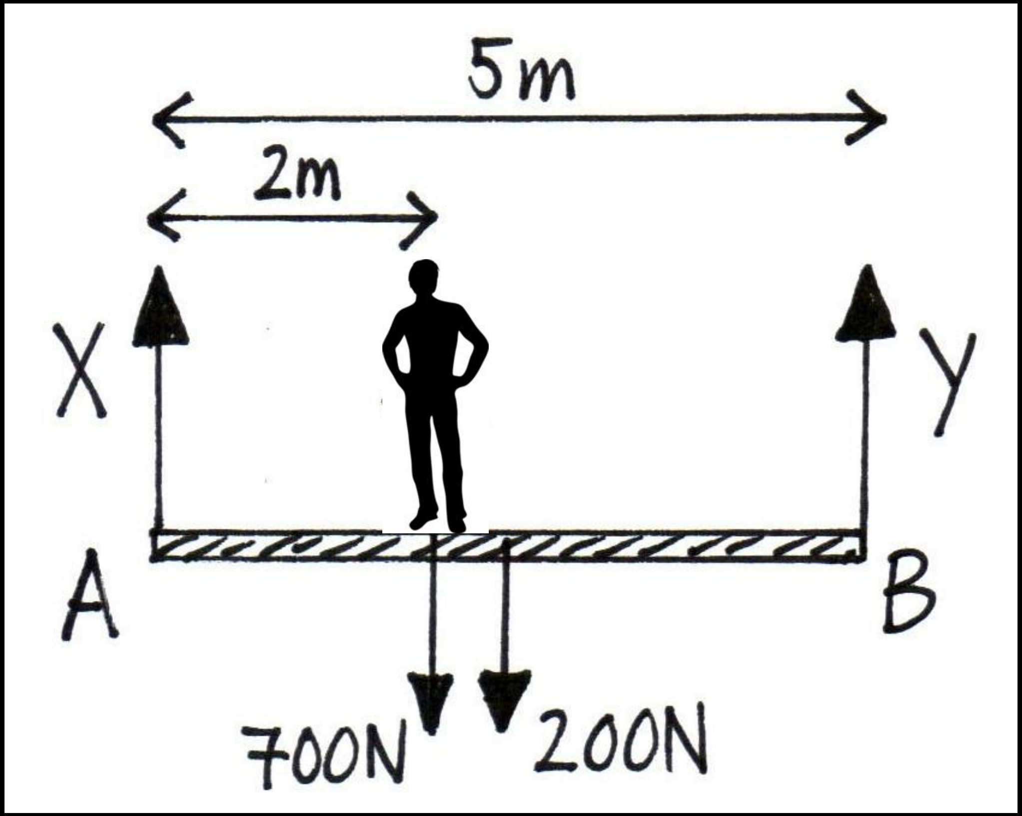
$$\sum \vec{\tau} = 0 \quad \text{(Eq.2)}$$

Static Equilibrium Examples

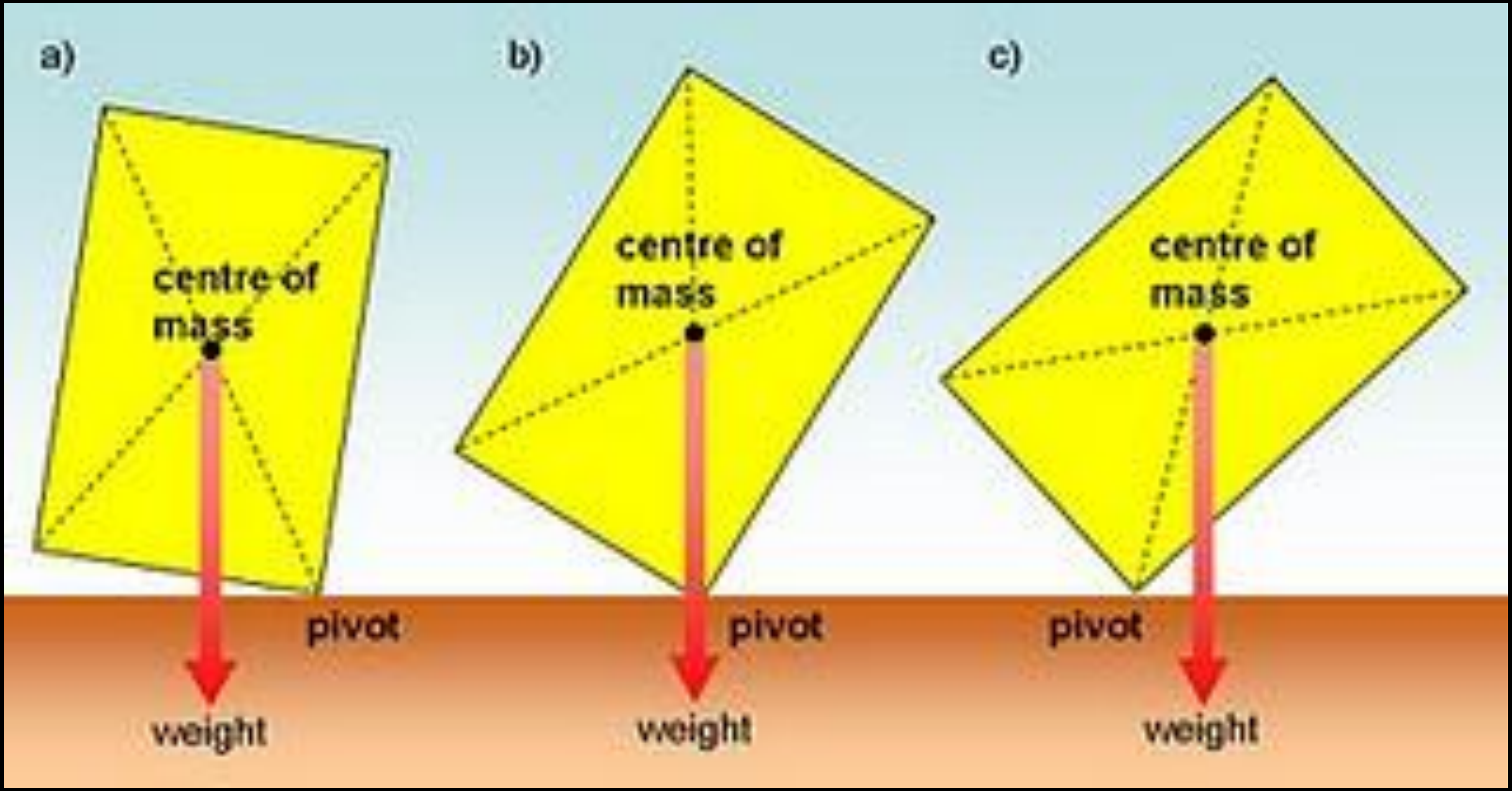
Static Equilibrium Examples

Example 1:

A beam AB of length 5.00 m, weight 200 N is supported horizontally by two vertical ropes x, y at A and B respectively. Calculate the tensions in the ropes if a man weighing 700 N stands on the beam at 2.00 m from A.



2. Stability and Toppling

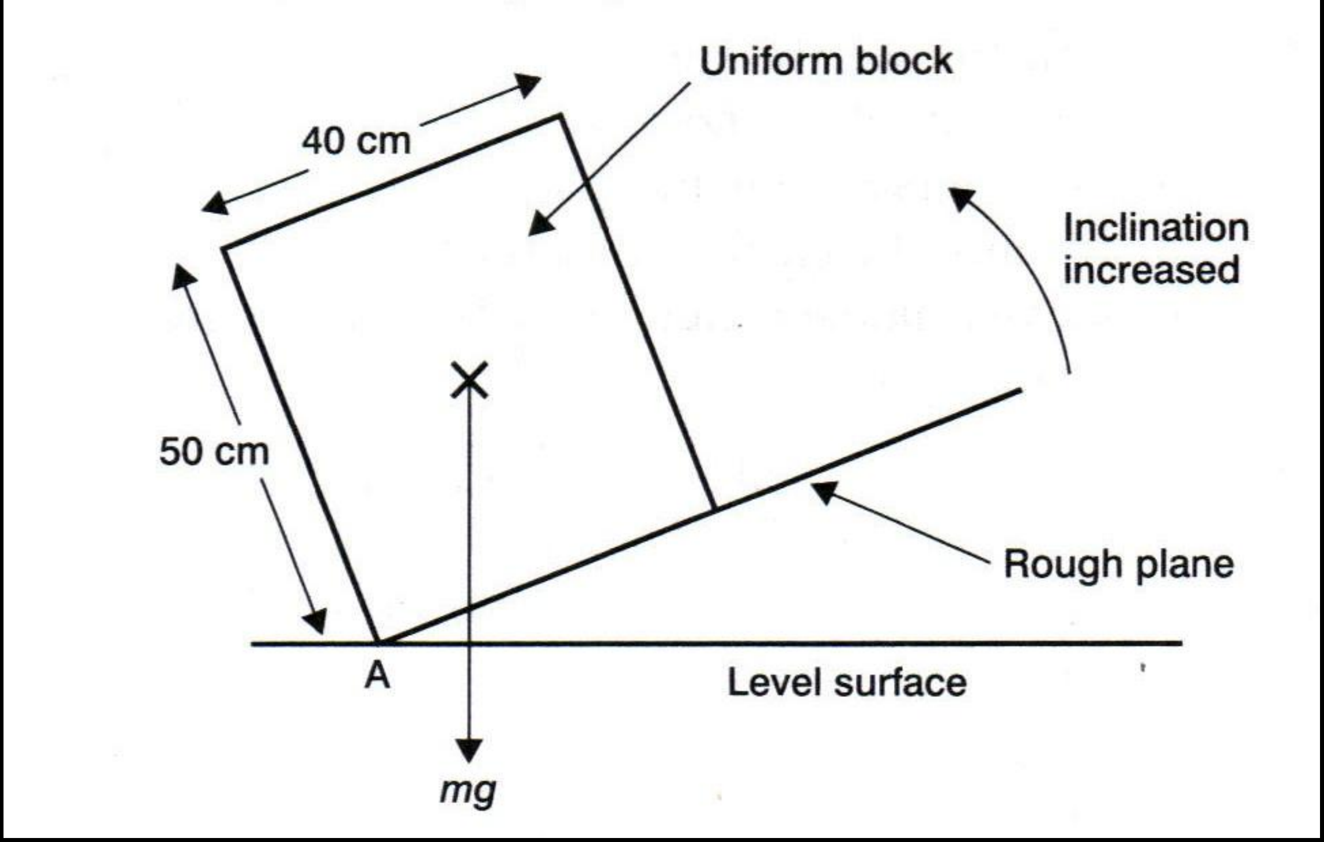


Example 2: Stability and toppling

A 40.0 x 50.0 cm block sits on a rough plane. The inclination of the plane is increased gradually.

1) When will the block topple to the left?

2) At what angle of inclination will the block topple?



3. Friction

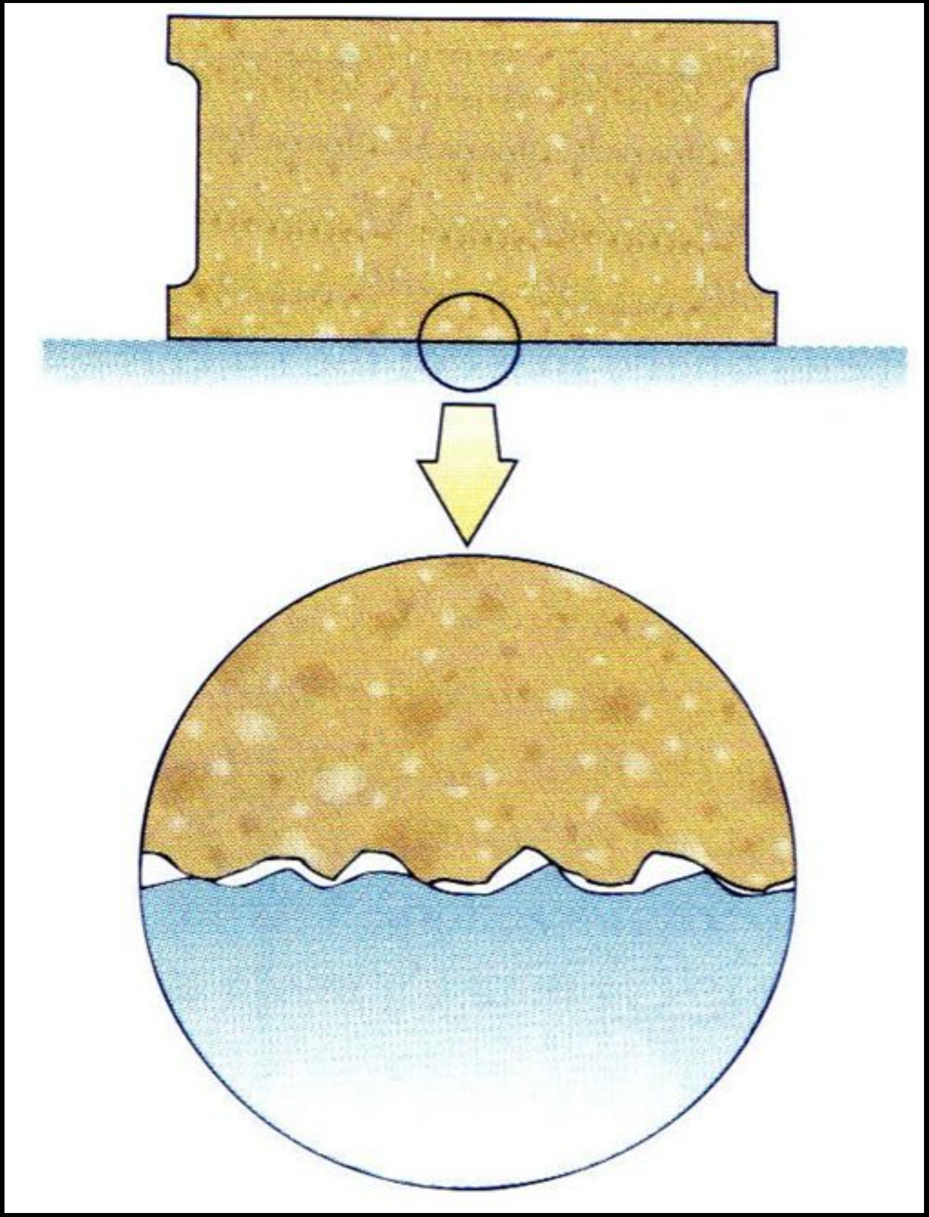
Friction plays a dual role in our lives:

- Impedes motion of objects, causes abrasion
- On the other hand, without it, we could not walk, drive cars, climb ropes or use nails.
- Friction is a contact force that opposes the relative motion of two bodies
- In 1748, Euler made a distinction between *static* and *kinetic* friction
- If an object does not move, *then the applied force* must be exactly equal (in magnitude) to the force of *static friction*. (if these are the only 2 forces acting in the direction of motion, of course)

3.1. Origin of Friction

Where points of contact cause very high pressure, temporary bonding occurs.

To slide the brick horizontally, some work must be done, lifting and deforming the surface.



3.2. Measuring Frictional Force

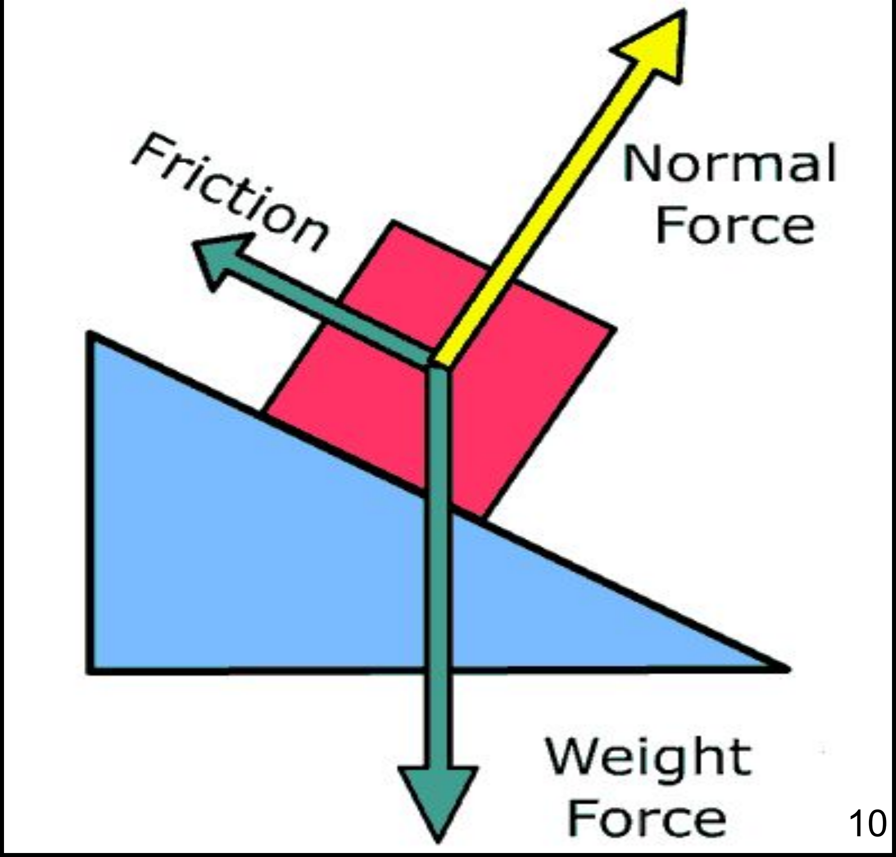
Experimentally, it is found that the limiting frictional force, F_f is proportional to the normal reaction force, N. Therefore:

$$|F_f| = \mu|N| \quad \text{(Eq.3)}$$

where μ is the coefficient of friction.

F_f is perpendicular to the Normal Force

Often taken from Some point – Centre of Mass



4. Coefficient of friction, μ

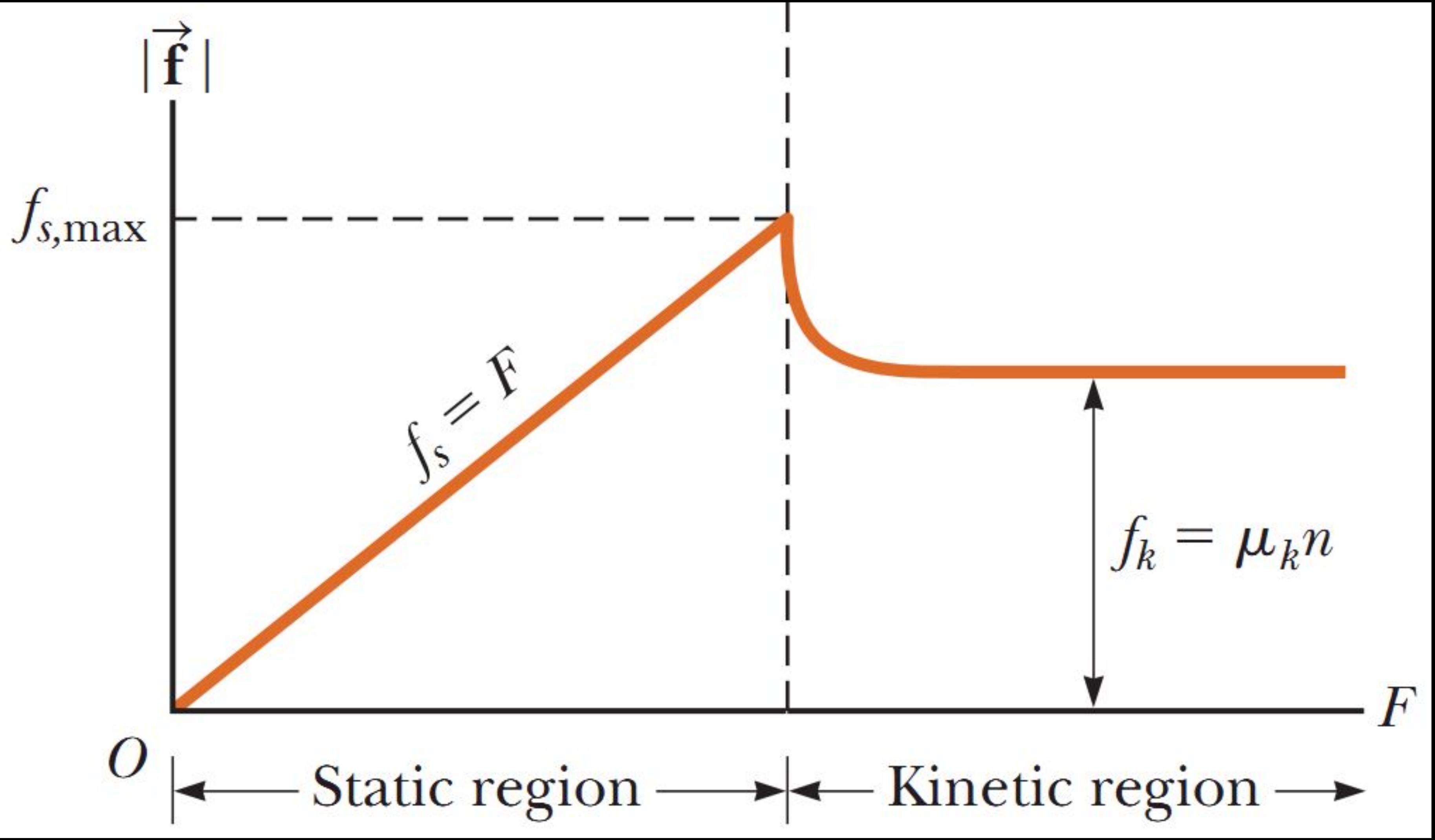
You must distinguish between

- the coefficient of sliding (*kinetic*) friction μ_k
- and the coefficient of *static* friction $\boldsymbol{\mu}_s$.

- Generally $\mu_k < \mu_s$.

E.g. for rubber on dry concrete, $\mu_s = 1.00$ and $\mu_k = 0.8$; on wet concrete, $\mu_s = 0.300$ and $\mu_k = 0.250$

4.1. Static vs. Kinetic Forces of Friction



4.2. Frictional Force does Work

Friction does work:

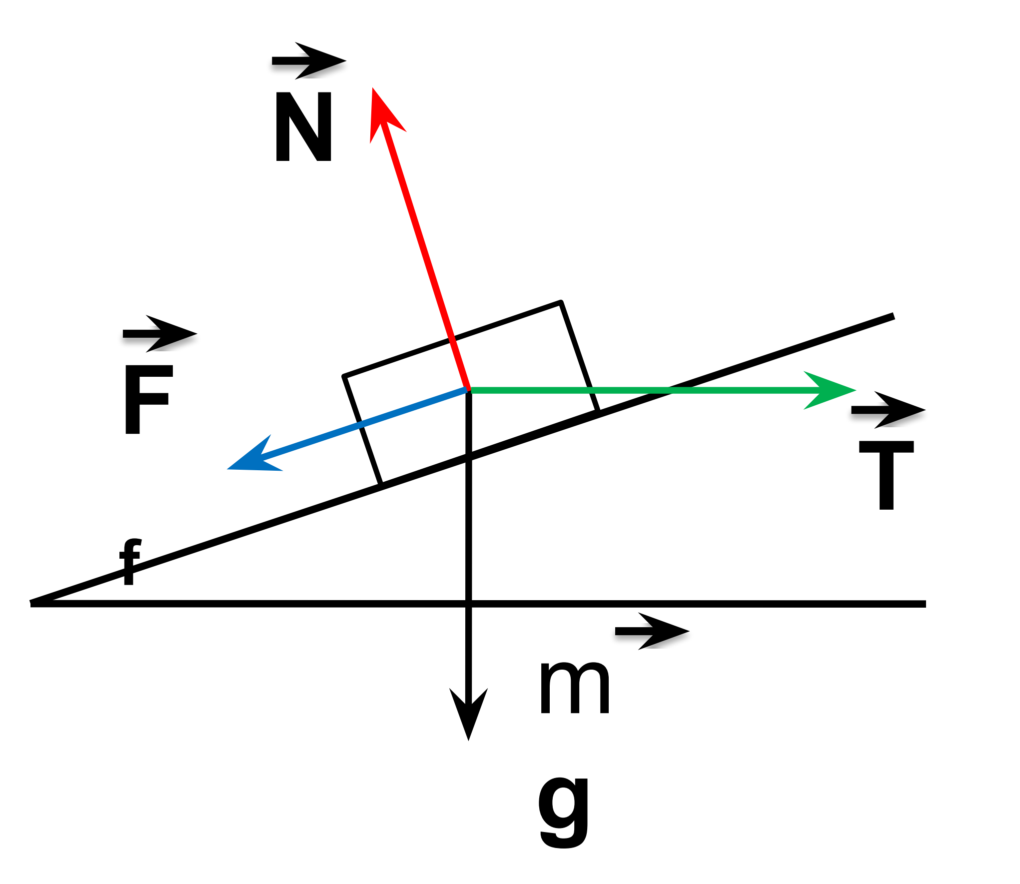
$$W = F_f\, d \cos\theta$$

This energy becomes heat and sound and is usually not useful. F_f is an example of a <u>dissipative force</u>.

Example 3:

A box of 2.00 kg sits on a rough slope.

If $\mu_s = 0.200$ and the angle of inclination is 20.0º, find force T if the box is just about to slide up the slope.



Example 4: Ladder Problem

A uniform 6.00 m long ladder of 10.0 kg leans against a wall. The wall is smooth and the floor is rough.

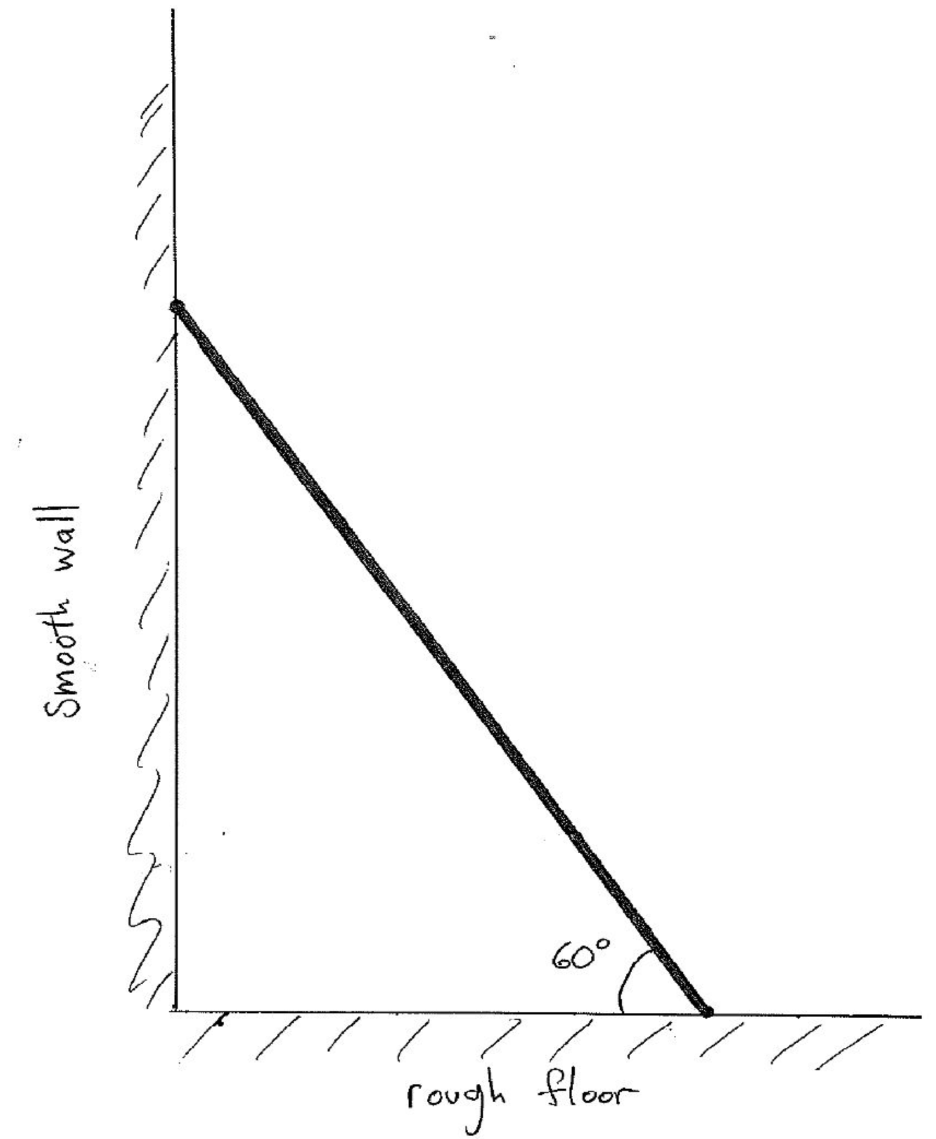
Draw a FBD.

Find:

a) The reaction force from the wall;

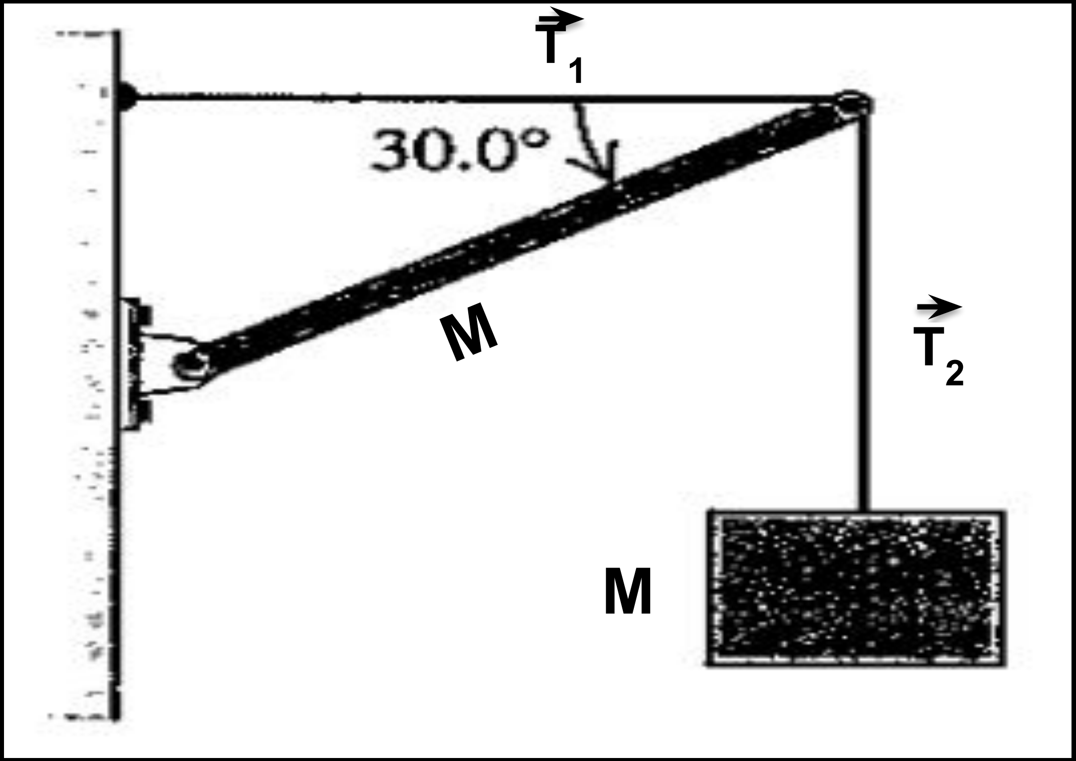
b) N and F_f at ground;

c) $\mu_{s,min}$ so that the ladder does not slide.



Example 5:

The box and the uniform strut have equal masses.



Find the:

a) Tension in each cable;

b) Reaction force of the hinge acting on the strut.

CHECK LIST and READING

READING :

Serway - Section 4.6 , Examples 4.8, 4.9 (pages 77-78)

Section 8.2 – Example 8.3 (pages 178-179)

Section 8.4 – Examples 8.5, 8.6 (pages 181-183)

Adams and Allday - Sections: 3.5, 3.7, 3.25.

<u>At the end of this lecture you should</u>

- State the 2 conditions for *static equilibrium* of a *rigid body*
- Understand the nature of *friction* and that it is a contact force proportional to the normal reaction force
- Understand the origin of the *coefficient of static friction*
- Be able to perform calculations to find the forces and torques acting on different bodies in a number of different situations of static equilibrium

Numerical Answers to Examples

- Ex. 1 : X = 0.520 kN, Y = 0.380 kN
- Ex. 2 : a) Block topples when CM is not supported.
  b) angle = 38.7 degrees
- Ex. 3 : T = 11.9 N
- Ex. 4 : a) R = 28.3 N b) N = 98.1 N, F_f = 28.3 N c) $\mu_s \geq 0.289$
- Ex. 5 : a) T_1 = (2.60)Mg, T_2 = Mg, b) F = (3.28) Mg
  at 37.6 degrees from horizontal ‘x’ axis