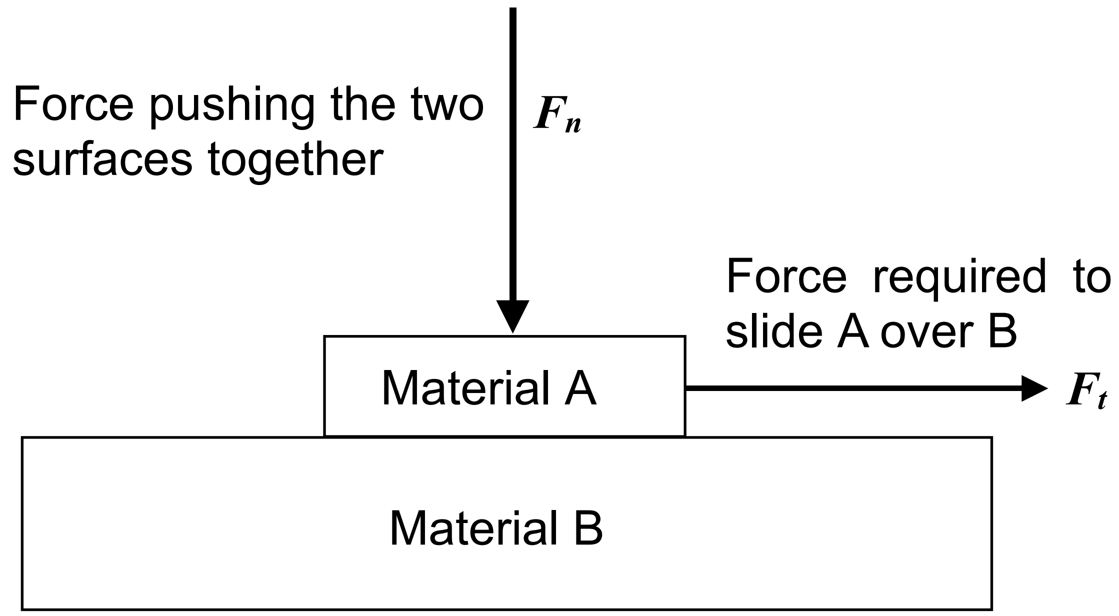
5. FRICTIONAL EFFECTS

Friction is both a necessity and a disadvantage in engineering design. Without it we could not walk or bring our cars to a halt. When it acts to impede motion and waste energy we try to minimise it using lubricants and special surface finishes.

The force required to overcome the friction between two surfaces in contact is proportional to the force acting to push the two surfaces together, i.e. the normal force, the exact nature of surfaces and the materials involved..
It does not depend on the area of contact between the surfaces.



The force required to move A over B (F_t) is given by :

$$F_t = \mu \times F_n$$

μ is known as the coefficient of friction.

This force, however, is usually different depending on whether it is required to begin movement or sustain movement.
We therefore distinguish between static friction,
(that which resists the movement beginning), and
dynamic friction (that which resists the movement continuing).

For static friction:

$$F_t = \mu_s \times F_n$$

μ_s is known as the coefficient of static friction.

For dynamic friction:

$$F_t = \mu_k \times F_n$$

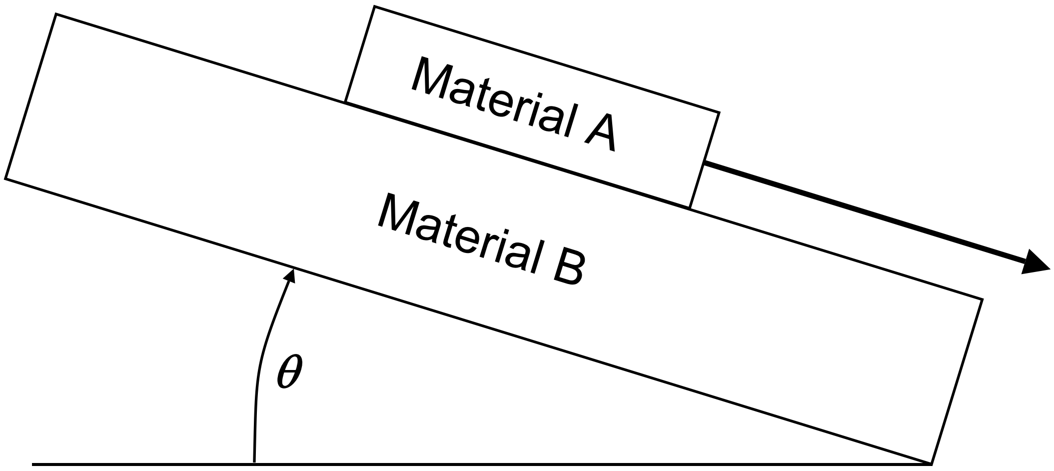
μ_k is known as the coefficient of dynamic (or kinetic) friction.

μ_s is typically greater than μ_k

It is often evident from the context of the problem or situation which coefficient is relevant so the subscripts are not always used.

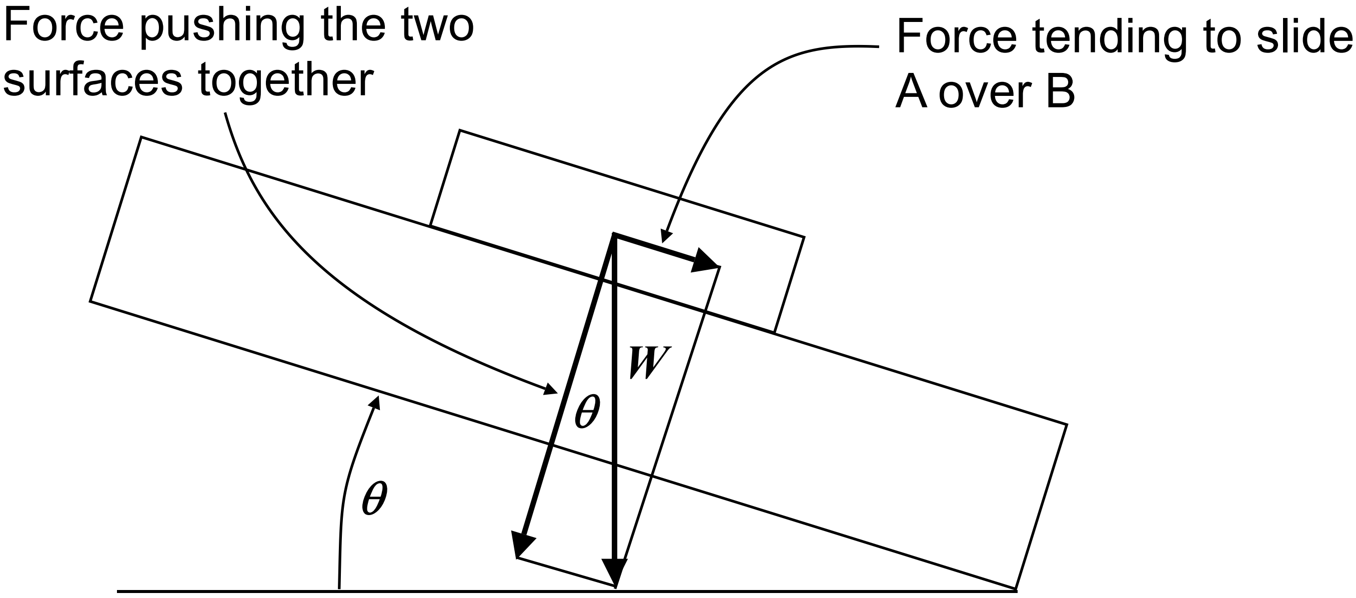
Sliding friction

The effect of both types of friction is evident when we look at an object sliding down a slope:



As angle θ increases the block remains stationary until the force tending to slide it down the slope reaches the force required to overcome the friction between the two blocks. Once it begins to move it tends to accelerate down the slope because the coefficient of dynamic friction is less than the coefficient of static friction.

We can analyse the situation by looking at the force components of the block's weight normal and parallel to the surface



By taking force components we can see that:

$$F_t = W \sin\theta$$

$$F_n = W \cos\theta$$

For as long as F_t is less than $\mu_s \times F_n$ no sliding will occur.

When F_t equals $\mu_s \times F_n$ sliding will occur.

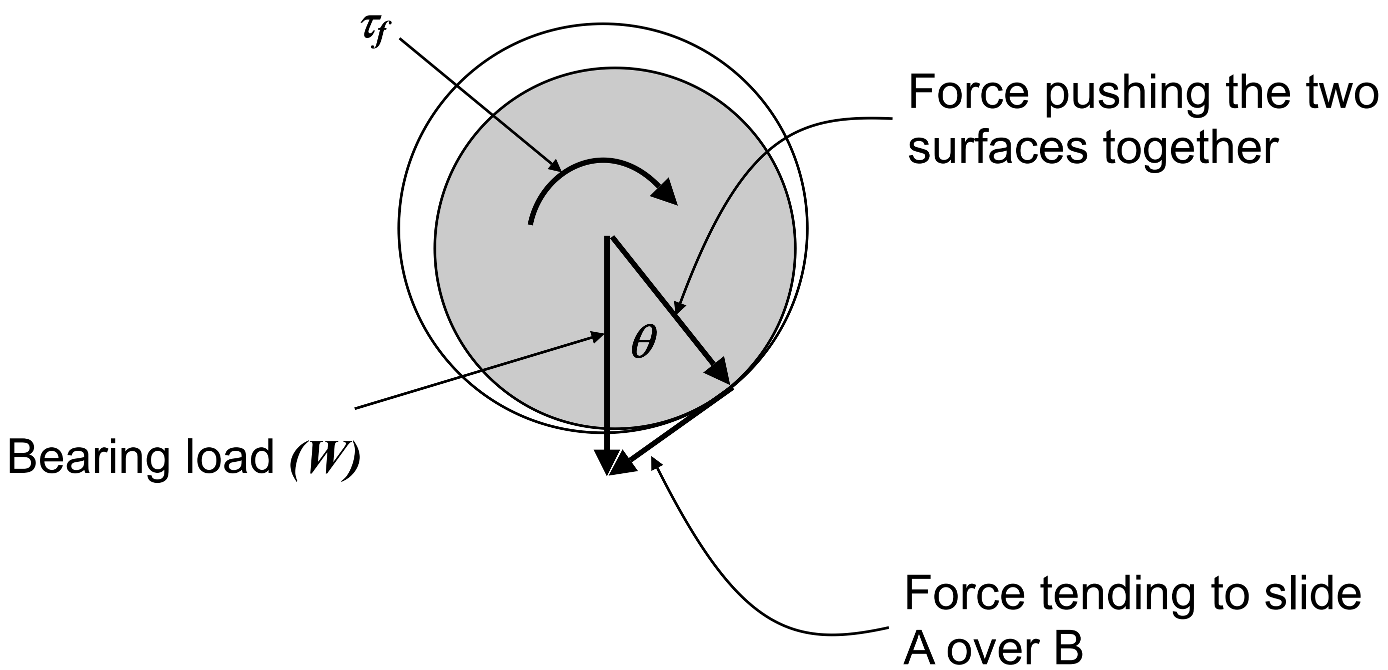
i.e. $F_t = \mu_s \times F_n$

$$W \sin\theta = \mu_s \times W \cos\theta$$

i.e. $\mu_s = \tan\theta$

This gives a method for measuring μ_s, simply by measuring the slope at which sliding commences.

Bearing friction



$$F_t = \mu_k \times F_n$$

$$F_n = W \cos\theta$$

$$\therefore \quad F_t = \mu_k \times W \cos\theta$$

$$\text{but} \quad \mu_k = \tan\theta$$

If μ_k is reasonably small (because of lubrication) then $\tan\theta$ is small and θ is small. Therefore $\cos\theta$ = 1.

$$\therefore \quad F_t = \mu_k \times W$$

The torque needed to overcome friction is given by $F_t \times r$

$$\therefore \quad \textit{Frictional torque} \quad \tau_f = \mu_k W r$$