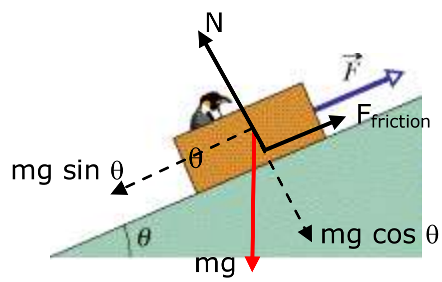
Q- A loaded penguin sled weighing 90 N rests on a plane inclined at angle θ= 30° to the horizontal. Between the sled and the plane, the coefficient of static friction is 0.27 and the coefficient of kinetic friction is 0.20.

The weight of the sledge acts on it vertically down but as we know that the sledge can move along the incline, we resolve the weight mg of the sledge as mg sin θ down the incline and mg cos θ normal to incline. The component of the weight normal to incline is balanced by the normal reaction of the surface N and the component down the incline will try to slide it down the incline.

(a) What is the minimum magnitude of the force $\vec{F}$, parallel to the plane, that will prevent the sled from slipping down the plane?



As due to mg sin θ pulls the sledge down the incline the friction on it will be up the incline.

The component of the weight pulling the sledge down = mg sin θ = 90*sin 30 = 45 N

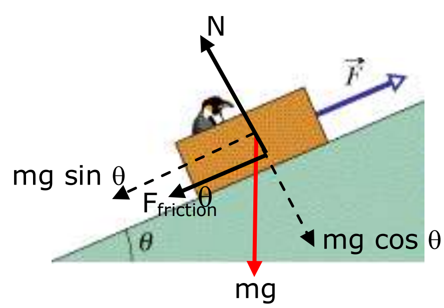
The limiting friction force in this situation will have a magnitude

$$F_{friction} = \mu_s * mg * \cos\theta = 0.27*90*\cos 30 = 21.04 \text{ N}$$

As the limiting friction force is less than the force sliding the sledge down we have to apply an additional force F up the incline to prevent it to slide and its minimum value will be

$$F = mg \sin\theta - F_{friction} = 45.00 - 21.04 = 23.96 \text{ N}$$

(b) What is the minimum magnitude *F* that will start the sled moving up the plane?



If the sledge is to move up the incline the friction force will be down the incline and hence the minimum force required will be given by

$$F = mg \sin\theta + F_{friction} = 45.00 + 21.04 = 66.04 \text{ N}$$

(c) What value of *F* is required to move the sled up the plane at constant velocity?

If the sledge is to move up the incline with constant velocity net force on it must be zero but the friction now will be kinetic and will be

$$F_{friction} = \mu_k * N = \mu_k * mg \cos\theta = 0.20*90*\cos 30 = 15.59 \text{ N}$$

And the required force will be

$$F = mg \sin\theta + F_{friction} = 45.00 + 15.59 = 60.59 \text{ N}$$