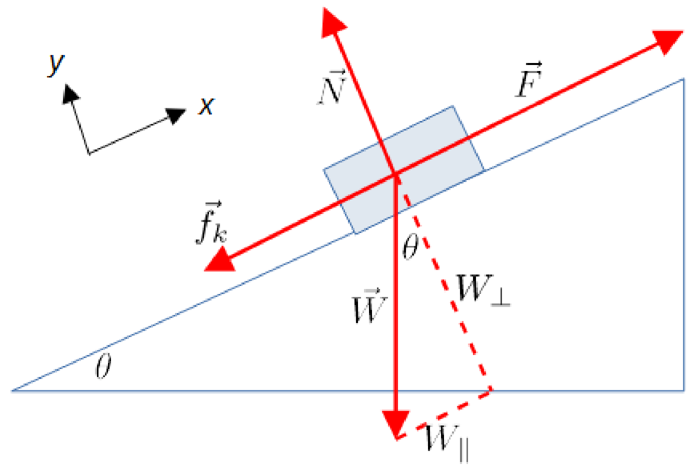
Q: A 100 kg object is pushed up a 30° ramp at constant speed. If the coefficient of friction is 0.2, how much force is required?

A: Begin by setting up Newton's second law in the x direction



$$\sum F_x = F - f_k - W_\parallel = 0$$

$$F - N\mu_k - mg\sin\theta = 0$$

$$F - mg\mu_k\cos\theta - mg\sin\theta = 0$$

$$F = mg\mu_k\cos\theta + mg\sin\theta$$

$$= (100\text{ kg})(9.81\text{ m/s}^2)(0.2)(\cos 30°) + (100\text{ kg})(9.81\text{ m/s}^2)(\sin 30°)$$

$$\approx \boxed{660\text{ N}}$$

(Note that $N = mg\cos\theta$ can be found by setting up Newton's laws in the y-direction.)

Q: Supposing that the box is pushed *d* = 10 m up the ramp, calculate the work done by each of the forces (normal, applied, friction, weight).

A: (The work done by the normal force is easy to do; since it is acts at a direction perpendicular to the displacement, it does no work)

$$W_N = mg\cos\theta \cdot d\cos 90° = \boxed{0\text{ J}}$$

$$W_F = (660\text{ N})(10\text{ m})\cos 0° \approx \boxed{6600\text{ J}}$$

$$W_f = (mg\mu_k\cos\theta)(d\cos 180°) \approx (100\text{ kg})(9.81\text{ m/s}^2)(0.2)(\cos 30°)(10\text{ m})(-1) \approx \boxed{-1700\text{ J}}$$

$$W_W = (mg)(d\cos 120°) = (100\text{ kg})(9.81\text{ m}^2)(10\text{ m})(-0.5) \approx \boxed{-4900\text{ J}}$$

Notice that the work done by forces opposing the motion is negative. Also, the total work done by all the forces

$$W_{\text{TOT}} = W_N + W_F + W_f + W_W = 0\text{ J} + 6660\text{ J} - 1700 + \text{ J} - 4900\text{ J} = 0\text{ J}$$

is zero. This makes since because according to the work-energy theorem, if an object's kinetic energy does not change, no work is done on it (and vice versa).