Friction

In general, frictional force is force which is responsible to oppose the relative motion between two surfaces. It is of two types:

1. Static Friction: When no relative motion exists between two contact surfaces after application of a force, the force along the surface and opposite to the direction in which the motion tends to take place is known as static friction. For Example when a box is placed on the floor of a truck and the truck accelerates the box moves with the truck (remaining at rest relative to the truck). It is the force of static friction that acts on the box to prevent it from sliding along the surface of the truck.

To determine the direction of the force of static friction, think about the motion that would result if there were no friction then decide in which direction relative motion will take place, the static friction will be oppose to the relative motion between contact surfaces.

For example to start a walk one should push back his foot on the floor. If there were no friction the foot will slide back. Static friction opposes this motion and thus is directed in forward direction.

Figure: On a frictionless floor, your shoe slides backward over the floor when you try to walk forward (a). Static friction opposes this motion, so the static force of friction, applied by the ground on you, is directed forward (b).

The static force of friction opposes the relative motion that would occur if there were no friction. Another interesting feature is that the static force of friction adjusts itself to whatever it needs to be to prevent relative motion between the surfaces in contact. Within limits the static force of friction has a maximum value, $F_{S,\max}$, and the coefficient of static friction μ_s is defined in terms of this maximum value:

$$\mu_S = \frac{F_{S,\max}}{F_N} \text{ so } F_S \le \mu_S F_N \qquad \text{where } F_N \text{ is normal force on the block}$$

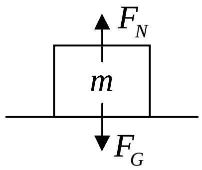
Key ideas for static friction: The static force of friction is whatever is required to prevent relative motion between surfaces in contact. The static force of friction is adjustable only up to a point. If the required force exceeds the maximum value $F_{S,\max} = \mu_S F_N$,then relative motion will occur then kinetic friction will apply which is equivalent to $\mu_k N$

2. Kinetic Friction: If there is relative speed between surface and mass m then frictional force is identifying as $f_k = \mu N$ where μ is coefficient of kinetic friction and N is normal force. The direction of f is directed opposite to the relative motion between block and friction

Example: Let us now explore a situation that involves the adjustable nature of the force of static friction .A box with a weight of $mg = 40\,N$ is at rest on a floor. The coefficient of static friction between the box and the floor is $\mu_S = 0.50$, while the coefficient of kinetic friction between the box and the floor is $\mu_K = 0.40$.

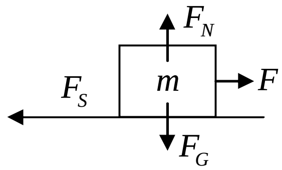
Step 1 - ***What is the force of friction acting on the box if you exert no force on the box?***

Let's draw a free-body diagram of the box (see Figure) as it sits at rest. Because the box remains at rest, its acceleration is zero and the forces must balance. Applying Newton's Second Law tells us that $F_N = mg = 40\,N$. There is no tendency for the box to move, so there is no force of friction.



Step 2 - ***What is the force of friction acting on the box if you push horizontally on the box with a force of*** $10\,N$ ***, as in Figure ?***

Nothing has changed vertically, so we still have $F_N = mg = 40\,N$. To determine whether or not the box will move we determine the maximum possible force of static friction in this case.

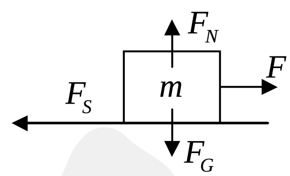


$$F_S \le \mu_S F_N = 0.50 \times 40\,N = 20\,N$$

The role of static friction is to keep the box at rest. If we exert a horizontal force of $10\,N$ on the box, the force of static friction acting on the box must be $10\,N$ in the opposite direction, to keep the box from moving. The free-body diagram for the present situation is shown in Figure.$10\,N$ is below the $20\,N$ (maximum value) so the box will not move.

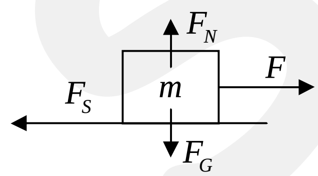
Step 3 - ***What is the force of friction acting on the box if you increase your force to*** $15\,N$ **?**

This situation is similar to step 2. Now, the force of static friction adjusts itself to $15\,N$ in the opposite direction of your $15\,N$ force. $15\,N$ is still less than the maximum possible force of static friction ($20\,N$), so the box does not move.



Step 4 - ***What is the force of friction acting on the box if you increase your force to*** $20\,N$ **?**

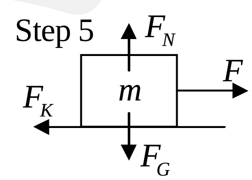
If your force is $20\,N$, the force of static friction matches you with $20\,N$ in the opposite direction. We are now at the maximum possible value of the force of static friction. Pushing even a tiny bit harder would make the box move.



Step 5 - ***What is the force of friction acting on the box if you increase your force to*** $25\,N$ **?**

Increasing your force to $25\,N$ (which is larger in magnitude than the maximum possible force of static friction) makes the box move.

$$F = \mu_K F_N = 0.40 \times 40\,N = 16\,N$$

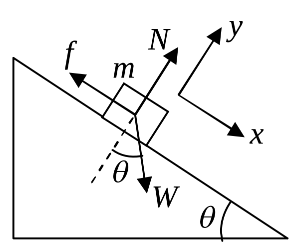


Example: Block and Wedge with Friction

A block of mass m rests on a fixed wedge at an angle θ and the coefficient of friction is μ. (For wooden blocks, μ is of the order of 0.2 to 0.5). Find the value of θ at which the block starts to slide.

Solution: In the absence of friction the block would slide down the plane hence the friction force f is in upward direction. With the coordinates shown the equation of motion is given by

$$m\ddot{x} = W\sin\theta - f \quad \text{and} \quad m\ddot{y} = N - W\cos\theta = 0$$



when sliding starts. f has its maximum value μN, and $\ddot{x} = 0$. The equation then give

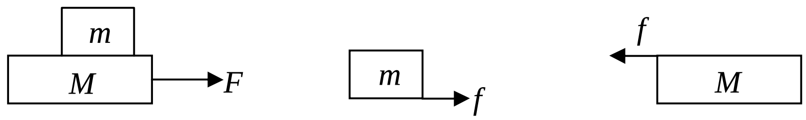
$$W\sin\theta_{\max} = \mu N \quad \text{And} \quad W\cos\theta_{\max} = N$$

Hence, $\tan\theta_{\max} = \mu$

Notice that as the wedge angle is gradually increased from zero, the friction force grows in magnitude from zero toward its maximum value μN since before the block begins to slide we have $f = W\sin\theta, \quad \theta \le \theta_{\max}$

Example: A block of mass m kept on the surface of another block of mass M. There is friction between the surfaces of two blocks. Find the direction of frictional force on both blocks.

Case 1- Two block move together when force F is applied on block M as shown in figure.

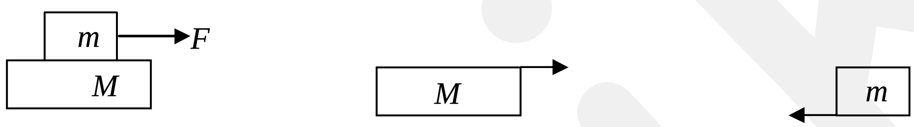


(a) No relative speed between blocks M and m.

(b) If no friction was there between block m and M then block M will move in direction of applied force and the block m will move opposite to the block M.

(c) The frictional force on block m will be in the direction of force F and due to Newton's third law frictional force on block M will in opposite direction of applied force F as shown in figure.

Case 2- Two block move together where force F is applied on block M as shown in figure



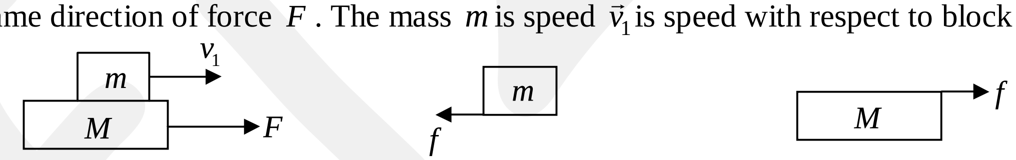
(a) No relative speed between blocks M and m.

(b) If no friction was there between block m and M then block m will move in direction of applied force and the block M will move opposite to the block m.

(c) The frictional force on block M will be in the direction of force F and due to Newton's third law frictional force on block m will in opposite direction of applied force F as shown in figure.

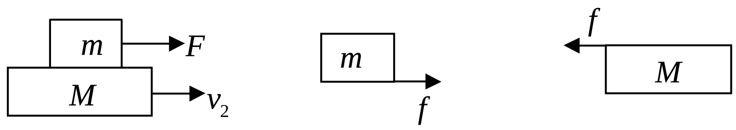
Case 3- The force is applied on block M and block and block m is moving with velocity v_1

In same direction of force F. The mass m is speed $\vec{v}_1$ is speed with respect to block M



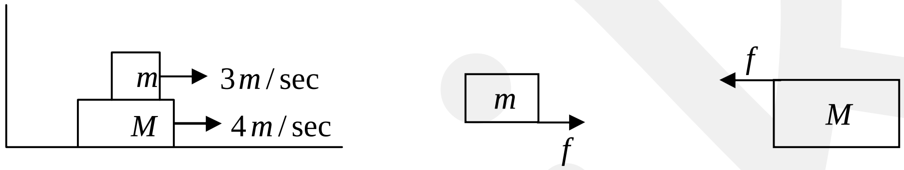
If block m is moving with speed v_1 with respect to block in a direction of force F then frictional force on block m will in opposite direction of v_1 and block M is moving with respect to mass m in the opposite direction of force F so frictional force on mass M is in same direction of force F

Case 4- The force is applied on block m and block M is moving with velocity v_2 in same direction of force .



If block M is moving with speed v_2 with respect to block in a direction of force F then frictional force on block M will in opposite direction of v_2 and block m is moving with respect to mass M in the opposite direction of force F so frictional force on mass M is in same direction of force F

Case-5 Both block m and M moving with speed $3m/\sec$ and $4m/\sec$ moving with respect to ground .



In this case block m and mass M is moving with respect to ground in same direction lets say positive x direction. The speed of block m with respect to block M is $3m/\sec - 4m/\sec = -1m/\sec$ which means block m is moving in negative x direction so frictional force is in positive x direction .

Similarly, block M is moving with respect to block m with speed $4m/\sec - 3m/\sec = 1m/\sec$, which means block M is moving in positive x direction with respect to block m so frictional force is in negative x direction .