Forces, Friction, and Motion

For each problem, draw a free-body diagram, show your calculations, and state the magnitude and direction of your answer where appropriate.

Mild

1. A 50.0 kg object is sliding to the right across a horizontal floor while being pushed horizontally with 300 N. The coefficient of kinetic friction is $\mu_k = 0.55$. Determine the acceleration of the object.

2. A horizontal force of 40.0 N causes a 5.0 kg block to accelerate to the right at 6.0 m/s^2 while sliding across a level floor.
   a. Determine the kinetic frictional force acting on the block.
   b. Determine the coefficient of kinetic friction between the block and the floor.

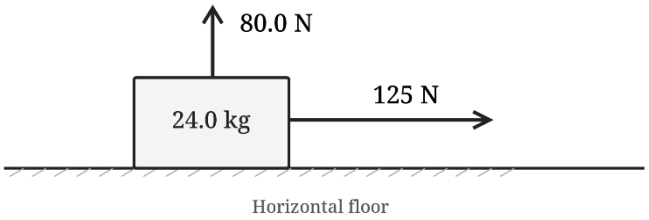
Medium

3. A 50.0 kg sled rests on horizontal, snow-covered ground. The static friction coefficient is $\mu_s = 0.30$ and the kinetic friction coefficient is $\mu_k = 0.10$.
   a. Determine the maximum possible static frictional force on the sled.
   b. Once the sled is sliding, determine the horizontal applied force required to accelerate it at 3.0 m/s^2.

4. Snorlax has a mass of 460 kg. The coefficients of friction with the level ground are $\mu_s = 0.70$ and $\mu_k = 0.60$. Ash and his friends push horizontally with a combined force of 2600 N.
   a. Can they move Snorlax from rest? Justify your answer.
   b. How much additional horizontal force must they apply to start moving Snorlax?
   c. Suppose they increase their total horizontal push to 3400 N. Determine Snorlax's acceleration once it begins sliding.

Spicy

5. A 24.0 kg crate is sliding to the right across a rough, level floor. The coefficient of kinetic friction is $\mu_k = 0.35$. One student pulls horizontally to the right with 125 N.



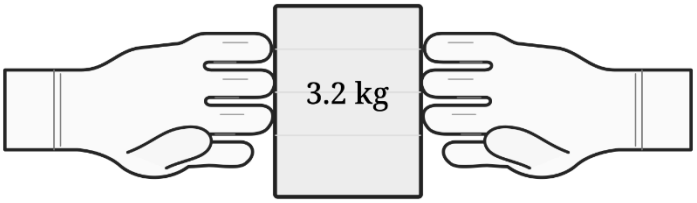
   a. Determine the acceleration of the crate.
   b. A second student now pulls vertically upward on the crate with 80.0 N, while the first continues pulling horizontally with 125 N. The crate remains in contact with the floor. Determine its new acceleration.
   c. Explain why the acceleration changes even though the horizontal applied force stays the same.

6. Golem pushes a 100 kg boulder horizontally to the right with 900 N. Psyduck pushes vertically downward on the boulder with 150 N. The boulder slides to the right and accelerates at 6.8 m/s^2. Determine the coefficient of kinetic friction between the boulder and the ground.



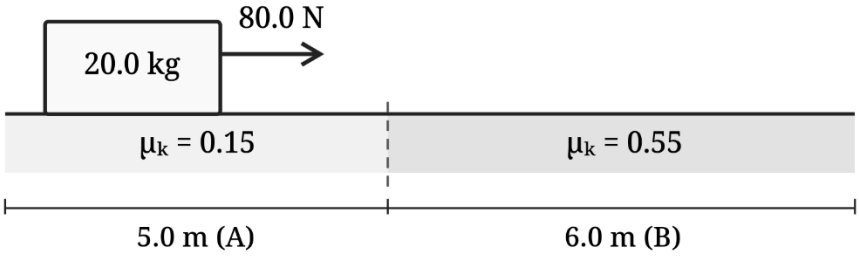
Extra-Spicy

7. A 3.2 kg wooden block is held motionless between two hands pressing horizontally against opposite vertical sides. The coefficient of static friction at each contact is $\mu_s = 0.53$. Assume both hands apply equal horizontal normal forces and support the block equally.



   a. Determine the minimum horizontal pressing force each hand must exert to prevent the block from falling.
   b. If each hand instead presses with 40.0 N, determine the actual upward static frictional force from each hand.
   c. Explain why actual static friction need not equal maximum static friction.

8. A 20.0 kg crate slides rightward at 2.0 m/s when a worker begins pushing horizontally to the right with a constant force of 80.0 N. The crate crosses two consecutive horizontal surfaces: Surface A is 5.0 m long with $\mu_k = 0.15$, and Surface B is 6.0 m long with $\mu_k = 0.55$. The crate continues sliding throughout.



   a. Determine the acceleration of the crate on each surface.
   b. Determine its speed at the boundary between the surfaces.
   c. Determine its speed after crossing Surface B.
   d. Explain how the crate can continue moving right while its net force acts left.