Weight, the Normal Force, and the Force of Friction

**Force Due to Gravity:** A field force (a vector quantity) that always is directed towards the center of the earth.

**Weight:** The magnitude of the Force due to gravity

\[ F_g = W = mg \]

\[ g_{\text{earth}} = 9.8 \text{ m/s}^2 \quad g_{\text{moon}} = 1.6 \text{ m/s}^2 \]

**Mass vs. weight**

| Mass: A measure of an objects inertia (its tendency to resist a change in its motion). Inherent property of an object. |
| Weight: Decreases as you move away from the center of the earth. NOT an inherent property of an object |

**Normal Force:** A “reactionary” contact force exerted on one object by another in a direction perpendicular to the surface of contact.

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a) A bully is pushing a boy against a locker as shown with a force of 500N. The angle between his arms and the ground is 40°. Draw a free-body diagram of the boy and then find the normal force between the boy and the wall.

b) A 200 kg block, on a VERY rough surface, is being pulled/pushed by two people, one on each end. The first person is pulling with a force of 20 N at an angle of 40° above the ground, while the other person is pushing with a 30 N force at an angle of 50° above the ground. Find the normal force on the block.

c) In terms of the normal force, explain what is necessary for an object to physically “lift” off of the ground.
Force of Friction Worksheet

- Opposes motion (opposes an applied force).
- Slows down instead of speeds up.
- If an object is moving at a constant velocity, friction must balance any other applied forces.
- Static (motionless) vs. Kinetic (moving)

**Static Friction:** the force of friction that keeps a MOTIONLESS object from moving when an external force acts on the object.

\[ F_{s,\text{max}} = sF_N \]

- \( F_{s,\text{max}} \) = maximum static frictional force before movement is caused.
- \( s \) = Coefficient of static friction (0 < \( s \) < 1)

**Kinetic Friction:** the force of friction exerted on a moving object.

\[ F_k = kF_N \]

- \( F_k \) = maximum static frictional force before movement is caused.
- \( k \) = Coefficient of static friction (0 < \( k \) < 1)

- Static friction is always greater than kinetic friction (\( s > k \))
- \( F_{\text{friction}} = F_N \)
- The frictional coefficients, \( \mu \) (\( s \), \( k \)), depend on the surfaces in contact.

<table>
<thead>
<tr>
<th>Materials in Contact</th>
<th>Coefficient of Static Friction</th>
<th>Coefficient of Kinetic Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood on wood</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Waxed ski on snow</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Ice on ice</td>
<td>0.1</td>
<td>0.03</td>
</tr>
<tr>
<td>Rubber on concrete (dry)</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Rubber on concrete (wet)</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Glass on glass</td>
<td>0.94</td>
<td>0.4</td>
</tr>
<tr>
<td>Steel on aluminum</td>
<td>0.61</td>
<td>0.47</td>
</tr>
<tr>
<td>Steel on steel (dry)</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Steel on steel (lubricated)</td>
<td>0.12</td>
<td>0.07</td>
</tr>
<tr>
<td>Teflon on steel</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Teflon on Teflon</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Synovial joints (in humans)</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>
“OLD” Friction Problems

(friction is given → simply use)

1) A 50 kg box is pulled across a surface by a force of 100 N. A constant force of friction of 25 N acts against the object. Find the objects acceleration.

(constant velocity → find the frictional force)

2) A wagon is pulled at a constant velocity by a force of 100 N at an angle of 30° above the horizontal. Find the frictional force acting on the block.

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“NEW” Friction Problems

• Find the normal force
• Calculate the frictional force (static or kinetic)
• Use the frictional force to solve a problem

3. A 10 kg box is motionless on the floor. If the coefficient of static friction is 0.4 and the coefficient of kinetic friction is 0.3 (between the box and the floor), find the force required to start the block in motion.

4. It takes a 50 N horizontal force to pull a 20 kg object along the ground at a constant velocity. What is the coefficient of kinetic friction?

5. A cart with a mass of 2.0 kg is pulled across a level desk by a horizontal force of 4.0 N. If the coefficient of kinetic friction is 0.12, what is the acceleration of the cart?

6. A girl pushes a 2kg snow shovel at a uniform velocity across a sidewalk. If the handle of the shovel is inclined at 55° to the horizontal and she pushes along the handle with a force of 100 N, what is the force of friction? What is the coefficient of kinetic friction?

7. A 5g block is being dragged across a floor by a constant force of 100 N. The coefficient of kinetic friction is 0.3. Find the acceleration of the block.

8. A 50 kg block sits on the ground. A force PULLS on the block at an angle of 45° above the horizontal. Find …
   a) the weight of the block.
   b) the normal force on the block just as the block lifts off the ground.
   c) the pulling force necessary to just barely lift the block off the ground.

9. A small 10 kg cardboard box is thrown across a level floor. It slides a distance of 6.0 m, stopping in 2.2 s. Determine the coefficient of friction between the box and the floor.
10. A can of soda is given a shove. It slides across a table, eventually coming to a stop. If its initial velocity is 2.0 m/s, and the coefficient of kinetic friction between the two surfaces is 0.20, how far will it travel across the table?

11. How hard does a bully need to push a small boy (35 kg) against the wall in order to keep the kid from sliding down due to gravity? Assume that the small boy is wearing a jacket rated to have a coefficient of friction of 0.3 with the wall. You may also assume that the bully only pushes the boy horizontally against the wall.

12. What is the greatest amount of friction between a 5 kg box and the ground if the coefficient of friction between the box and the surface is 0.35?

13. A 1200 kg tranquilized elephant (they are not going to harm it, they just need a blood sample to protect it from disease) is being pulled at a constant speed of 2 m/s onto a stretcher by a force of 7000 N.
   a) Determine the force of friction.
   b) Determine the coefficient of friction between the elephant and the ground.

14. A farmer is pushing down a 4 kg shovel with a force of 40 N at an angle of 60° with the ground. Determine the acceleration of the shovel if the coefficient of friction between the shovel and the icy ground is 0.15.

15. A 5g bullet is fired into a large oak tree. The bullet leaves the gun at a speed of 300 m/s. If the block of wood slows the bullet down in 5ms (5 millisecond, or 5 thousandths of a second), then …
   a) what is the “retarding” force on the bullet.
   b) how far into the tree does the bullet penetrate?

16) A 2000 kg car is driving down the road at a speed of 30 m/s. It suddenly slams on its brakes and stops in 40 m. Assuming a constant acceleration, find…
   a) the force applied by the brakes on the car.
   b) the time required to stop.
   c) Does friction play a roll in this problem? Explain.

17) A 2 kg block of wood is sliding across a frictionless surface at a speed of 10 m/s. Suddenly, it hits a shaggy carpet, where the coefficient of kinetic friction is unknown. If the carpet stops the block in 3 seconds, find the missing coefficient. How would this answer have differed if the mass of the block was 8 kg? 1,000,000 kg?

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**Buffa HW:**

Day 6: Buffa pg. 131 #41

Day 7: pg. 137 #'s 90-94