Name ______________________

Work: $W = F\cos\theta d$ where F is the magnitude of the force, d is the magnitude of displacement, and θ is the angle between the displacement vector and the force vector.
To find θ: start with displacement vector, measure counterclockwise angle to force vector.
Positive Work: F (or component of F) points in same direction as d, $\cos\theta > 0$, the Force adds energy to the object
Negative Work: F (or component of F) points in opposite direction as d, $\cos\theta < 0$, the Force takes energy away from object
$W_{total} = W_{F_1} + W_{F_2} + W_{F_3} + ... = F_{net}\cos\theta d$

1. Since Work depends on the cosine of the angle between the force and the displacement, let's first review the cosine of some important angles:

   - $\cos 0° =$
   - $\cos 90° =$
   - $\cos 180° =$
   - $\cos 270° =$

   In general, $\cos\theta$ is positive for angles between $270° - 360°$ and $0 - 90°$, and negative for angles between $90°$ and $270°$. Verify that for yourself by calculating the cosine of a few different angles.
   cos = cos = cos =

2. You push horizontally on a 3kg box with a pushing force of $+25N$ and the box moves $+2m$ across the floor. The coefficient of kinetic friction between the box and the floor is 0.3. Draw a free-body diagram for the box:

   What is the angle between your **pushing force** and the displacement? $\theta =$
   How much work did your pushing force do on the box?
   What is the angle between the **normal force** and the displacement? $\theta =$
   How much work was done by the normal force?
   What is the angle between the **weight force** and the displacement? $\theta =$
   How much work was done by the weight?
   What is the angle between the **kinetic friction force** and the displacement? $\theta =$
   How much work was done by the kinetic frictional force?

   What was the total work done on the box by all of the forces? Find this first by adding up the work done by all the forces.

   Now find the Net Force acting on the box and use $W_{tot} = F_{net}\cos\theta d$

   If you push on the box at an angle of $20°$ with respect to the horizontal instead, how much work did your pushing force do on the box?

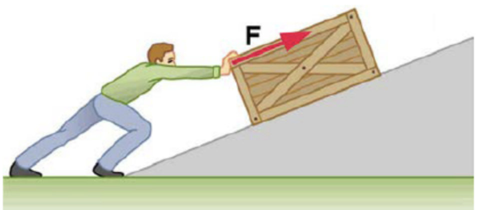
Which of the following are true regarding the work done by kinetic friction? **A** It will sometimes be positive and sometimes negative, depending on the direction of the displacement. **B** It will always be negative because it always acts opposite the displacement. **C** It will always be negative because it always takes energy away from the object. **E** Both B and C

3. If you pull on an object with a constant velocity, what is the net work done on the object? **A** 0 **B** positive **C** negative **D**: Cannot be determined.

4. If you deadlift a $80kg$ barbell off the ground a distance of $0.4m$ at a constant speed, how much total work was done on the barbell?
   What is the angle between the Weight force and the displacement? **A** 0° **B** 90° **C** 180° **D** 270°
   How much work did gravity do?

   How much work did you do on the barbell?

5. You push a 1kg box 5m up a frictionless ramp using a 100N force pointed in the direction of the ramp. The ramp is 3m high.



   (a) Find the work done by your pushing force on the box.

   (b) What is the work done by the weight force?

   (c) What is the work done by the normal force?

   (d) What is the total work done on the box?

   Can the normal force ever do work?
   A Yes, always **B** Yes, in some cases **C** Never