Friction Practice Activity

OBJECTIVES:
After completion of this activity, you will be able to:

- calculate the coefficients of friction,
- calculate the normal force, and
- understand the coefficients of static and kinetic friction.

MATERIALS:
For completion of this activity, you will need the following:

- Rough surface (e.g., concrete),
- smooth surface (e.g., table top),
- mass hanger,
- masses, and
- spring scale.

Mass hanger

Spring scales

Masses

PROCEDURE:

1. Using the gram side of the spring scale, carefully record the mass of the hanger below. It must be converted to kg. 1 kg = 1000 g.

   The mass of the hanger is _____ kg.

2. Place the mass hanger on a **rough surface** (e.g., concrete).

3. Attach the spring scale to the **empty** mass hanger. Carefully and gently pull the mass hanger with enough force to JUST start the empty hanger moving. In "Data Table #1" below, record the force **in Newtons**—as registered on the spring scale—required **to just start the hanger moving**. Repeat four times, and then find the **average**. Input the force measurements from all five trials and the average in "Data Table #1" below.

Data Table #1: Rough Surface	
Trial	**Force Required to JUST Start the Empty Hanger Moving (in Newtons)**
First trial	
Second trial	
Third trial	
Fourth trial	
Fifth trial	
Average (This is the **force of static friction** between the empty mass hanger and the **rough** surface, $F_{s,\ empty,\ rough}$.)	

4. Use the spring scale to measure the force in Newtons you exert on the **empty** hanger when you slide it across the rough surface **at a constant speed**. Repeat four times, and then find the **average**. Input your measurements from all five trials and the average in "Data Table #2" below.

Data Table #2: Rough Surface	
Trial	**Force Required to Pull the Empty Hanger at a Constant Speed (in Newtons)**
First trial	
Second trial	
Third trial	
Fourth trial	
Fifth trial	
Average (This is the **force of kinetic friction** between the empty mass hanger and the **rough** surface, $F_{k,\ empty,\ rough}$.)	

5. Repeat steps 3 and 4 after adding **an additional 1 kg of masses** (e.g., two 500 g masses) to the mass hanger. Input your data into "Data Table #3" below.

Data Table #3: Rough Surface	
Trial	**Force Required Just Start the Hanger + 1 kg of Additional Mass Moving (in Newtons)**
First trial	
Second trial	
Third trial	

Fourth trial	
Fifth trial	
Average (This is the **force of static friction** between the **rough** surface and the hanger + 1 kg of mass, $F_{s,\ masses,\ rough}$.)	
Trial	**Force Required to Pull the Hanger + 1 kg at a Constant Speed (in Newtons)**
First trial	
Second trial	
Third trial	
Fourth trial	
Fifth trial	
Average (This is the **force of kinetic friction** between the **rough** surface and the hanger + 1 kg of mass, $F_{k,\ masses,\ rough}$.)	

6. Repeat steps 3, 4, and 5 using the **smooth** surface (e.g., a table top) instead of the rough surface. Input your measurements in "Data Table #4" below.

Data Table #4: Smooth Surface	
Trial	**Force Required to JUST Start the Empty Hanger Moving (in Newtons)**
First trial	

Second trial	
Third trial	
Fourth trial	
Fifth trial	
Average (This is the **force of static friction** between the empty mass hanger and the **<u>smooth</u>** surface, $F_{s,\ empty,\ smooth}$.)	
Trial	**Force Required to Pull the Empty Hanger at a Constant Speed (in Newtons)**
First trial	
Second trial	
Third trial	
Fourth trial	
Fifth trial	
Average (This is the **force of kinetic friction** between the empty mass hanger and the **<u>smooth</u>** surface, $F_{k,\ empty,\ smooth}$.)	
Trial	**Force Required Just Start the Hanger + 1 kg of Additional Mass Moving (in Newtons)**
First trial	
Second trial	
Third trial	
Fourth trial	
Fifth trial	
Average (This is the **force of static friction** between the **<u>smooth</u>** surface and the hanger + 1 kg of mass, $F_{s,\ masses,\ smooth}$.)	

Trial	Force Required to Pull the Hanger + 1 kg at a Constant Speed (in Newtons)
First trial	
Second trial	
Third trial	
Fourth trial	
Fifth trial	
Average (This is the **force of kinetic friction** between the **smooth** surface and the hanger + 1 kg of mass, $F_{k,\ masses,\ smooth}$.)	

CALCULATIONS:

1. Magnitudes of Weight (W)

   a. Calculate the magnitude of the **weight of the hanger without any masses** on it. Because you were moving the mass hanger across a horizontal surface, the magnitude of the weight of the empty hanger, W_{empty}, is equal to the mass of the empty hanger, m_{empty}, multiplied by the magnitude of the acceleration due to gravity, 9.8 m/s/s.

   $W_{empty} = (m_{empty}) \times (9.8\ m/s/s)$

   W_{empty} = _____ N

   b. Calculate the magnitude of the **weight of hanger with the additional 1 kg of masses**. Because you were moving the mass hanger with its masses across a horizontal surface, the

magnitude of the weight of the hanger and masses, W_{masses}, is equal to the mass of the hanger, m_{empty}, plus the mass of the additional masses, 1 kg, multiplied by the magnitude of the acceleration due to gravity, 9.8 m/s/s.

$W_{masses} = (m_{empty} + 1\ kg) \times (9.8\ m/s/s)$

W_{masses} = _____ N

2. Coefficients of Friction (μ)

   a. Let's find the coefficient of static friction, $\mu_{s,\ empty,\ rough}$, for the empty hanger on a rough surface. The magnitude of the **force of static friction** between the **empty mass hanger** and the **rough surface**, $F_{s,\ empty,\ rough}$, is equal to the coefficient of static friction between the hanger and the rough surface, $\mu_{s,\ empty,\ rough}$, multiplied by the magnitude of the weight of the mass hanger without any masses on it, W_{empty}.
   $F_{s,\ empty,\ rough} = \mu_{s,\ empty,\ rough} \times W_{empty}$

   $\mu_{s,\ empty,\ rough} = (F_{s,\ empty,\ rough}) / (W_{empty})$

   $\mu_{s,\ empty,\ rough}$ = _____

   b. Let's find the coefficient of static friction, $\mu_{s,\ empty,\ smooth}$, for the empty hanger on a smooth surface. The magnitude of the **force of static friction** between the **empty mass hanger** and the **smooth surface**, $F_{s,\ empty,\ smooth}$, is equal to the coefficient of static friction between the hanger and the smooth surface, $\mu_{s,\ empty,\ smooth}$, multiplied by the magnitude of the weight of the mass hanger without any masses on it, W_{empty}.

$F_{s,\ empty,\ smooth} = \mu_{s,\ empty,\ smooth} \times W_{empty}$

$\mu_{s,\ empty,\ smooth} = (F_{s,\ empty,\ smooth}) / (W_{empty})$

$\mu_{s,\ empty,\ smooth}$ = _____

c. Let's find the coefficient of kinetic friction, $\mu_{k,\ empty,\ rough}$, for the empty hanger on a rough surface. The magnitude of the **force of kinetic friction** between the **empty mass hanger** and the **rough surface**, $F_{k,\ empty,\ rough}$, is equal to the coefficient of kinetic friction between the hanger and the rough surface, $\mu_{k,\ empty,\ rough}$, multiplied by the magnitude of the weight of the mass hanger without any masses on it, W_{empty}.

$F_{k,\ empty,\ rough} = \mu_{k,\ empty,\ rough} \times W_{empty}$

$\mu_{k,\ empty,\ rough} = (F_{k,\ empty,\ rough}) / (W_{empty})$

$\mu_{k,\ empty,\ rough}$ = _____

d. Let's find the coefficient of kinetic friction, $\mu_{k,\ empty,\ smooth}$, for the empty hanger on a smooth surface. The magnitude of the **force of kinetic friction** between the **empty mass hanger** and the **smooth surface**, $F_{k,\ empty,\ smooth}$, is equal to the coefficient of kinetic friction between the hanger and the smooth surface, $\mu_{k,\ empty,\ smooth}$, multiplied by the magnitude of the weight of the mass hanger without any masses on it, W_{empty}.

$F_{k,\ empty,\ smooth} = \mu_{k,\ empty,\ smooth} \times W_{empty}$

$\mu_{k,\ empty,\ smooth} = (F_{k,\ empty,\ smooth}) / (W_{empty})$

$\mu_{k,\ empty,\ smooth}$ = _____

e. Let's find the coefficient of static friction, $\mu_{s,\ masses,\ rough}$, for the hanger + 1 kg masses on a rough surface.

$\mu_{s,\ masses,\ rough} = (F_{s,\ masses,\ rough}) / (W_{masses})$

$\mu_{s,\ masses,\ rough}$ = _____

f. Let's find the coefficient of static friction, $\mu_{s,\ masses,\ smooth}$, for the hanger + 1 kg masses on a smooth surface.

$\mu_{s,\ masses,\ smooth} = (F_{s,\ masses,\ smooth}) / (W_{masses})$

$\mu_{s,\ masses,\ smooth}$ = _____

g. Let's find the coefficient of kinetic friction, $\mu_{k,\ masses,\ rough}$, for the hanger + 1 kg masses on a rough surface.

$\mu_{k,\ masses,\ rough} = (F_{k,\ masses,\ rough}) / (W_{masses})$

$\mu_{k,\ masses,\ rough}$ = _____

h. Let's find the coefficient of kinetic friction, $\mu_{k,\ masses,\ smooth}$, for the hanger + 1 kg masses on a smooth surface.

$\mu_{k,\ masses,\ smooth} = (F_{k,\ masses,\ smooth}) / (W_{masses})$

$\mu_{k,\ masses,\ smooth}$ = _____

ANALYSIS:

1. Which is usually larger, the coefficient of friction for a rough surface or the coefficient of friction for a smooth surface?

2. Compare the coefficients of static friction and the coefficients of kinetic friction for a given mass and kind of surface. Which is usually larger, the coefficient of kinetic friction or the coefficient of static friction?

3. Compare the coefficients of friction for the empty mass hanger with the coefficients of friction for the mass hanger + 1 kg. How do the coefficients compare?