Advanced Placement Physics
John Dewey High School
Mr. Klimetz

Forces of Friction

Understanding the Relationships Between Mass and the System of Forces Acting on a Body Experiencing Constant Speed Translational Motion Across Horizontal and Inclined Planar Surfaces

Laboratory

Introduction. When a smooth block is set sliding on a smooth horizontal floor, we note that it moves in a straight line but gradually slows down and comes to a stop. Why does it not obey the Law of Inertia (Newton's First Law) and continue at constant speed? The answer is that there is an *unbalanced force* acting on it. This is the force of friction exerted upon it by the floor. Friction may be defined as *the force that resists a body when it moves over or through another body.* Thus a projectile, once set in motion, is slowed down by friction as it moves through the air. The block in our example is therefore slowed down by friction as it moves over the floor.

Friction explains why a car, once set in motion, will not continue to move at constant speed on a horizontal road without further help from the engine. The frictional resistance of the road to its forward motion and of its axles to the motion of its wheels over them gradually brings the car to a halt once the engine is turned off. It follows that, to keep the car moving at constant speed, the engine must supply just enough force to overcome the retarding force of friction. With the force of friction neutralized in this manner, there are no unbalanced forces acting on the car and it obeys the Law of Inertia.

Equipment (See pictures below)
12.0 inch x 4.0 inch x 2.0 inch solid pine friction block
Threaded brass attaching hook
Five mass-fastening screws
Set of assorted slotted masses
Spring scale
Inclined plane apparatus
Sandpaper friction surface

Tasks
1. The rectangular friction blocks employed in this laboratory exercise are constructed of solid pine, each possessing a length of 12.0 inches, a width of 4.0 inches, and a height of 2.0 inches. Assuming that each and every block is internally consistent and uniform, and neglecting the attached hardware (mass-fastening screws and attaching hook),

a. Mass
measure the mass [m_1] of your unladen friction block: __________ (kg)
calculate the mass [m_2] of your friction block with added 200 g mass: __________ (kg)
calculate the mass [m_3] of your friction block with added 500 g mass: __________ (kg)

b. Weight and Normal Force

calculate the weight [F_{g1}] of your unladen friction block: ___________ (N)

Equation: $F_{g1} = m_1 g = F_{N1}$

calculate the weight [F_{g2}] of your friction block with added 200 g mass: ___________ (N)

Equation: $F_{g2} = m_2 g = F_{N2}$

calculate the weight [F_{g3}] of your friction block with added 500 g mass: ___________ (N)

Equation: $F_{g3} = m_3 g = F_{N3}$

2. **Static Coefficient.** Place the friction block on the sandpaper friction surface which has been affixed to the inclined plane apparatus. Incline the sandpapered surface until the friction block begins to slide. Record the angle θ below. Compute the tangent of θ. This is the coefficient of static friction μ_k. Repeat for the block with 200 g added and repeat again for the block with 500 g added. Record the calculations on the lines in section 3a below.

Kinetic Force and Coefficient. Place the friction block on the sandpaper friction surface which has been affixed to the inclined plane apparatus. Attach the hook of the spring scale to the hook on the friction block. While holding the spring scale horizontally, apply a steady force [while carefully observing the motion of the pointer on dial of the spring scale] until the friction block begins to slide. The **highest force reading** to which the pointer has rotated will be the force of static (starting) friction [F_s]. Repeat for the block with 200 g added and repeat again for the block with 500 g added. Record the measurements on the lines in section 3b below. Then, compute the coefficient of kinetic friction for each of the three different slider masses, and enter into the lines in section 3c below.

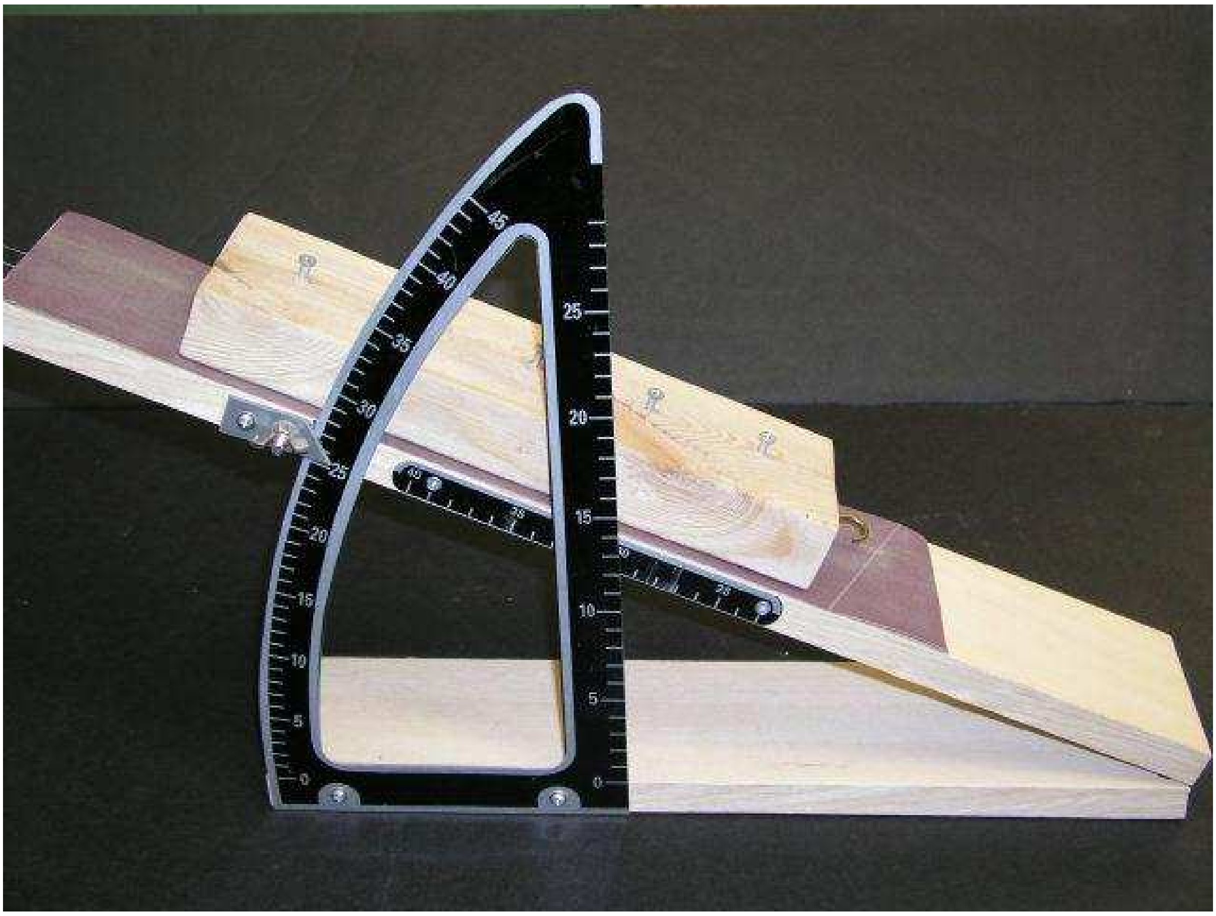
3. Data and Computations

3a. Based on your lab data calculate
the coefficient of static (starting) friction [μ_s] for
the unladen block [μ_{s1}] ___________ $\mu_{s1} = \tan \theta_1$
the block with 200 g added [μ_{s2}] ___________ $\mu_{s2} = \tan \theta_2$
the block with 500 g added [μ_{s3}] ___________ $\mu_{s3} = \tan \theta_3$

3b. Based on your lab data express
the force of kinetic (sliding) friction [F_k] φορ
the unladen block [μ_{k1}] ___________ $\mu_{k1} = F_{k1}/F_{N1}$
the block with 200 g added [μ_{k2}] ___________ $\mu_{k2} = F_{k2}/F_{N2}$
the block with 500 g added [μ_{k3}] ___________ $\mu_{k3} = F_{k3}/F_{N3}$

3c. Based on your lab data calculate
the coefficient of kinetic (sliding) friction [μ_k] for
the unladen block [μ_{k1}] ___________ $\mu_{k1} = F_{k1}/F_{N1}$
the block with 200 g added [μ_{k2}] ___________ $\mu_{k2} = F_{k2}/F_{N2}$
the block with 500 g added [μ_{k3}] ___________ $\mu_{k3} = F_{k3}/F_{N3}$

Apparatus and Set-up for Measuring μ_s



A. Based on your lab data, your calculations above and your knowledge of forces, briefly explain the observed relationship between:

the mass of an object and the pulling force required to overcome the force of friction to keep an object traveling at a constant speed

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the pulling force applied to keep an object in motion at a constant speed and the frictional force opposing such motion

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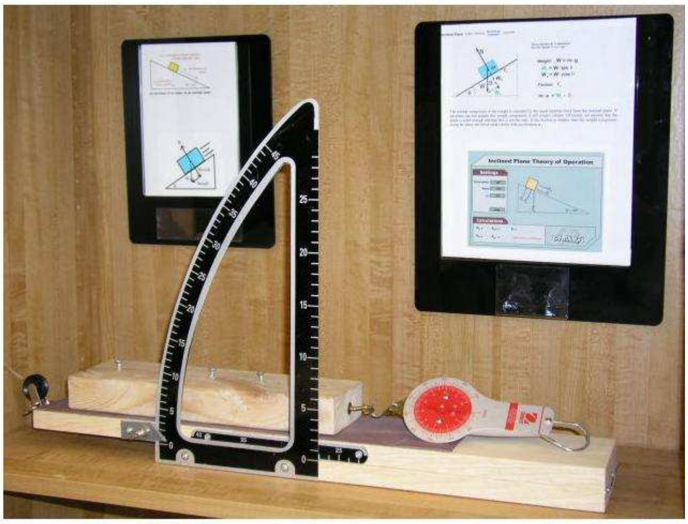
the mass of a sliding body and the coefficient of friction ____________________________

B. Prepare graphs of your F_k (pulling force) versus F_N (normal force) data acquired in each kinetic friction experimental situation. The graph should present your data acquired from sliding the friction block along the side with the greatest contact area. Pulling forces required to overcome **kinetic (sliding) friction** and maintain a constant rate of motion are to be plotted *only*. Organize your graphs so that pulling force (F_p, which also incidentally equals F_k in magnitude) appears on the ordinate and F_N (which also incidentally equals weight in magnitude) appears on the abscissa. How do the *slopes* of your graphed lines compare with one another? What does the slope of each line reveal about the relationship between mass, pulling force, and frictional force? To which *numerical value* that we have previously analyzed is the slope equal? Explain.



Apparatus and Set-up for Measuring F_k