Experiment
29

TEACHER INFORMATION

Static and Kinetic Friction

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. For consistent results in this experiment, be sure that the wooden block and table surfaces are clean and free of grease. A missing peak in the static friction force or a variable force during the constant-speed portion of the motion are both indications that the surfaces of the block or table need cleaning. One way to prepare a new, clean surface is to wrap the block in a sheet of paper.

3. You may choose to use the 50 N range instead of the 10 N range if friction forces are large.

4. Dynamics carts with friction pads can be used as an alternative to the wooden block.

5. Coach students to increase the applied force very slowly and evenly. The tendency is to increase the applied force too rapidly.

6. You may want to prepare special wooden blocks for this experiment with drilled holes for your particular mass sets. It is then very easy for students to change the total mass of the block system, and the holes prevent the masses from shifting.

7. Blocks can be stacked to increase mass, but take care that the system moves as a rigid unit.

8. In using the Motion Detector, it is important to realize that the ultrasound is emitted in a cone about 30º wide. Anything within the cone of ultrasound can cause a reflection and possibly an accidental measurement. A common problem in using Motion Detectors is getting unintentional reflections from a desk, chair, or computer in the room.

9. Motion detectors without a mode switch do not properly detect objects closer than 0.5 m. As a result, such motion detectors must be farther away from the experiment than described in the student notes. In contrast, Motion detectors *with* a mode switch will detect objects as close as 0.15 m. Ideally, an experiment will be set up so that the target is nearly this close at the point of closest approach, giving the best possible data.

10. Sometimes a target may not supply a strong reflection of the ultrasound. Attaching a piece of rigid card stock to the block can improve the reflection but it will also increase the error as air resistance will also act to stop the block.

11. A natural break point is between Parts II and III. If the lab needs to be shortened, Part III could be omitted. Many physics teachers feel, however, that the best part of the lab is Part III because it connects Newton's second law directly to the friction equation in the solution of the problem. It also addresses the most confusing concepts to the student – the forces on a freely moving object.

12. **Note on Extension 2:** An alternative way of measuring friction coefficients is to tilt an inclined plane up until the block just starts sliding. At that point, the normal force is $mg\cos\theta$ and the force down the ramp is $mg\sin\theta$, so you can find the coefficient of static friction from $\mu_s = F_{static}/F_N = \tan\theta$. If you tip it up but bump the block until it slides with a constant

velocity, you can find the kinetic friction coefficient by $\mu_k = F_{kinetic}/F_N = \tan\theta$. Have students compare the coefficients of static friction measured using the two methods.

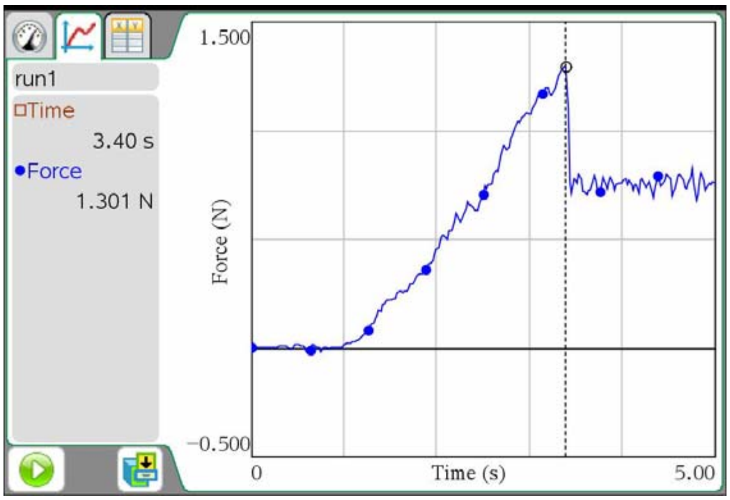
13. It is not necessary to calibrate the Force Sensors because a small error in friction coefficient is not important for this lab; some teachers may nevertheless want to add calibration to the procedure.

ANSWERS TO PRE-LAB QUESTIONS

1. From everyday experience, it is more difficult (that is, it requires more force) to start a box sliding than to keep it sliding.
2. The force of friction increases with the weight of the box. You see this from everyday experience again, since light boxes are generally easier to push than are heavy boxes.

SAMPLE RESULTS

Part I Investigating Friction



For all Force Sensor runs, the data will have the same qualitative shape as shown here. The magnitudes will vary as the mass carried by the block is changed.

Mass of block	0.28	kg

Part II Peak Static Friction and Kinetic Friction

Total mass (kg)	Normal force (N)	Peak static friction			Average peak static friction (N)
		Trial 1	Trial 2	Trial 3	
0.28	2.74	0.55	0.54	0.53	0.54
0.78	7.64	1.84	1.66	1.75	1.75
1.28	12.54	3.26	3.34	2.88	3.16

Total mass (kg)	Normal force (N)	Kinetic friction			Average kinetic friction (N)
		Trial 1	Trial 2	Trial 3	
0.28	2.74	0.46	0.45	0.48	0.46
0.78	7.64	1.26	1.24	1.32	1.27
1.28	12.54	2.25	2.19	2.33	2.26

Part III Kinetic Friction

Data: Block with No Additional Mass			
Trial	Acceleration (m/s^2)	Kinetic friction force (N)	μ_k
1	3.43	0.96	0.35
2	3.46	0.97	0.35
3	3.49	0.98	0.36
Average coefficient of kinetic friction:			0.35

Data: Block with 500 g Additional Mass			
Trial	Acceleration (m/s^2)	Kinetic friction force (N)	μ_k
1	3.06	2.39	0.31
2	3.36	2.62	0.34
3	3.23	2.52	0.33
Average coefficient of kinetic friction:			0.32

ANSWERS TO QUESTIONS

1. The block started to move just at the peak of the static friction force. Then the applied force was smaller, indicating the kinetic friction force is smaller than the peak static friction force.
2. The coefficient of static friction would then be larger than the coefficient of kinetic friction.

3. The line should pass through the origin.
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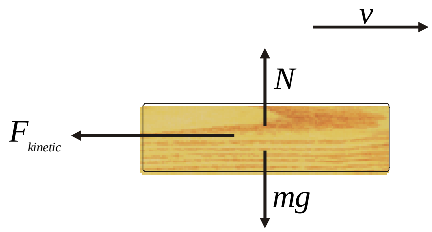
5. As sketched here, the block is moving to the right so the friction force is to the left. The normal force and weight are of the same magnitude and are in opposite directions. Considering the forces in the horizontal direction, $\sum F_x = ma_x$, so the mass and acceleration product is equal to the friction force.



6. No, the coefficient of kinetic friction does not depend on speed, at least in the range of speeds used in this experiment. We can see this from the constant acceleration of the block as it slows. A constant force creates a constant acceleration.
7. Yes, the data show that as the weight of the block increases, the force of kinetic friction increases.
8. No, the coefficient of kinetic friction does not depend on the weight of the block. We can see this from the approximate constancy of the various measurements of μ_k.
9. The values are approximately the same, which is consistent with the model for kinetic friction of $F_{kinetic} = \mu_k N$. The model does not distinguish between constant-acceleration and constant-speed motion.