1. On page 23 we gave an object a short, quick push on a level surface and watched it coast to a stop. Sketch a speed-time graph describing the motion before and after release. Label the release point.
   a. On page 31 you saw that a force can be exerted ***on*** an object only ***by*** a different __________.
   b. Does a forward force propel the sliding block after you stop pushing it? ____ (* *If so, please name the thing which exerts that force and explain how you know that the force acts on the block*.)
   * c. Write an *opening statement* describing and naming the force which caused the object to slow down.
   * d. Exactly when did that force *begin* to act on the object? *Please explain your evidence.*
   * e. What happens to that force when the coasting motion stops?

2. Find the part of the speed-time graph which describes the forward *coasting* motion that occurs after you stop pushing on the block. Label that part with the words "coasting forward".
   a. We used *signs* to describe the directions of the vectors in this exercise. All vectors in the forward direction were said to be "positive", so vectors pointing in the _____ward direction were "negative".
   b. The direction of the coasting object's *velocity* was ___ward, so the *sign* of that velocity was ____tive.
   c. "Acceleration" was defined on RS I as the *slope* of the object's ________-time graph.
   d. According to the graph sketched in #1, the block's acceleration was ______tive (or ____ward) when it was being propelled, and ______tive (____ward) when it was coasting.

3. The acceleration of the *coasting* block must have been caused by the ______ force exerted on the sliding block by table top, since the other two forces acting on the block at that time cancel each other.
   a. That acceleration was ______tive because the *total force* on the coasting block at that time was in the ____tive direction. Please illustrate 3a with a tail-to-head vector diagram, labelled clearly.
   b. While the block was being propelled it had a ______tive acceleration *because* the ______ force on it was in the ____tive direction. *Please illustrate with a tail-to-head vector diagram, labelled clearly*.
   c. When we stopped pushing, the direction of the total force was ______ed. (increased, decreased, unchanged, reversed) -Did the direction of the block's *velocity* also change suddenly at that time? __
   d. If the *acceleration* of an object changes suddenly, as in 3c, the object's velocity _________ changes suddenly. (always, sometimes, never) -Does the sketch in #1 illustrate this fact? ___

4. Whenever the ____ force acting on an object is in the backward direction (as in 3a) the object's *acceleration* is in the _____ward direction. -Does this tell you anything about the direction of the object's velocity? ___ (*If so, please explain *without* contradicting 2a or 2b.)
   a. When the ______ force acting on an object is forward, the object's ___________ must be ____ward. Does 3b agree? ___ -Does this tell you which way the object is moving? ____ If so, please explain.
   b. These discoveries have been recorded in part __ of #__ on RS ___.

5. When a hockey puck is sliding *eastward*, it slows down gradually because the ice exerts a small _____ward friction force on it, causing it to have a _____ward acceleration. (east, west, up, down)

6. Imagine an object resting on a level surface. Mr. A pulls northward on it while Miss B pulls westward on it with an equal amount of force. If those forces are strong enough, the object will begin to slide in the direction called _________. If the surface exerts a friction force on the object, the direction of that friction force will be _________. -Do your answers to 5 *and* 6 agree with #4? ____

7. According to #4, which two vectors in the list below *always* have the same direction, *regardless* of whether the object is coasting or propelled? [___ and ___] -Does this contradict #5 or #6? ___
   a. acceleration of a sliding object
   b. displacement of object
   c. friction force acting on a sliding object
   d. velocity of object relative to the surface
   e. total force acting on a sliding object
   f. strongest force acting on object

8. Which two vectors in #7 always have *opposite* directions, whether the sliding object is coasting or propelled? [__ & __] -Do 5 & 6 agree? __ The answers to 7 & 8 are recorded in #__ & __ on RSIII.

9. For the process described in #1, sketch graphs of forward force vs time, friction force vs time, and total force vs time. Label the release point on each graph. (Use 15 on RS III and 1b, 2a & 3c above.)

10. Review: Using friction, a certain automobile can accelerate uniformly for 200 feet from a standing start, finishing in 5.1 seconds. Show in *algebraic* language how its acceleration can be calculated from the given data. (Use 13 & 6 on RS II.) *Then* do the calculation. *Remember to round off properly.*

1. According to #14 on RS III, the direction of the friction force exerted on a sliding object by the surface it slides on is always _______ to the direction of the object's ________ relative to the ______. Whenever the velocity of an object is *constant*, the total force on the object is ___ newtons. *That fact is recorded in #___ on RS III. If there are any exceptions, explain them clearly.*

2. Place weighted block on a sheet of paper on a *level* surface. Drag the block along the surface at a *constant* velocity, using a *horizontal* forward force. Select an appropriate spring scale to measure the forward force. Connect the spring scale to the block with a long rubber band to help keep the applied force steady. Measure the propelling force needed for a very slow, steady forward velocity. *Remember to use the best scale for the job. Estimate the uncertainties of all measurements.*

* 3. Four significant forces act on the block while it is being dragged: the propelling force, friction, gravitational force, and the “normal” force. Describe the *direction* of each one, and name the ***object*** that exerts each force. (See #6 on page 35.) Use the phrase "*exerted on the block by...*". Remember that forces and motions are *not* objects. *Draw and label a diagram to illustrate your descriptions.*

4. Find out what happens if the propelling force is suddenly increased or decreased: Whenever the propelling force is stronger than the friction force the block’s forward speed __creases. If the forward speed decreases, it means that the propelling force has become _____er than the friction. If the block is dragged *horizontally* with *constant* velocity the forward force is _____ ___ the backward force on the block. (stronger than, weaker than, equal to) -Do #4 & 16b on RS III agree? ___

5. Can you measure the friction force in #2 directly, with a spring scale? ____ (*If so, explain how.)

* 6. What **indirect** method for measuring a sliding friction force is suggested by #4? Please include *all three* of the necessary details emphasized above so that even a teacher can understand your method.

* 7. Use your new indirect measuring technique to find out if the friction force exerted by the counter on the block *depends* on sliding speed. If there is a relationship, describe it with a data table and a graph. If there is no significant relationship then write a short, clear *statement* on the back of this paper.

8. Does #7 agree with #10 on RS II?____ --With #9 on page 37? ____ **If not, please explain.*

9. Now find out what happens when you pull *harder*, so the forward force is *doubled:*
   a. Does the block's velocity remain constant while the new force is acting? ___ -Does #4 agree? ___
   b. Does the block accelerate? _______ -Does this agree with 9a?___ -With #4 on RS III? ___
   c. Does the total force acting on the block remain the same as it was in #2 & 7? ____
   d. Does the friction increase when the forward force is increased? ___ (* If so, give evidence.)
   e. Does the friction force depend upon the forward force? ___ (* If so, explain your evidence.)
   f. Is your friction-measuring method valid if the velocity is changing? ___ -Does #6 agree? ___
   g. What must you do to make the velocity increase? _____ _______ (two words *italicized above*)
   h. Does 9c contradict 9d?___ Does 9d contradict 9e or 9f?___ Does 9g contradict #7, 9a or 9b? __

10. Turn the block on its side and repeat #2. Then repeat it with the block standing up on its end. Those changes clearly cause the area of contact between the block and the tabletop to be altered. Use your observations to decide if sliding friction *depends* upon contact area.
   * a. If there is a relationship, describe it with a graph. (Don't forget the data table, uncertainty estimates, and error bars.) If *no* relationship is evident, state your conclusion as a clear and simple sentence.
   b. Is 10a necessarily correct for other kinds of friction, such as dragging a blanket across a carpet?

11. **"Static"** is a greek word that means "not moving". When your horizontal pull on the block is not strong enough to make it move, the block is held back by a **static friction force.** After reviewing page 31 and #4 above, please write a clear paragraph answering the questions below. *Save a copy.*
   * a. What do you know about the total force acting on a static object? *Don't contradict 1 or 4.*
   * b. What can we conclude about the strengths of the static friction force and the horizontal forward force on a block when it is stationary on a level surface? *-Does 11b contradict 11a?* ___
   * c. How must the directions of those two forces compare? *-Does 11c contradict 11a?* ____
   d. If you increase the forward force on a block without making it slide, the static friction force must ___crease. Does 11a agree? ___ Is there an upper limit which the static friction cannot exceed? ___