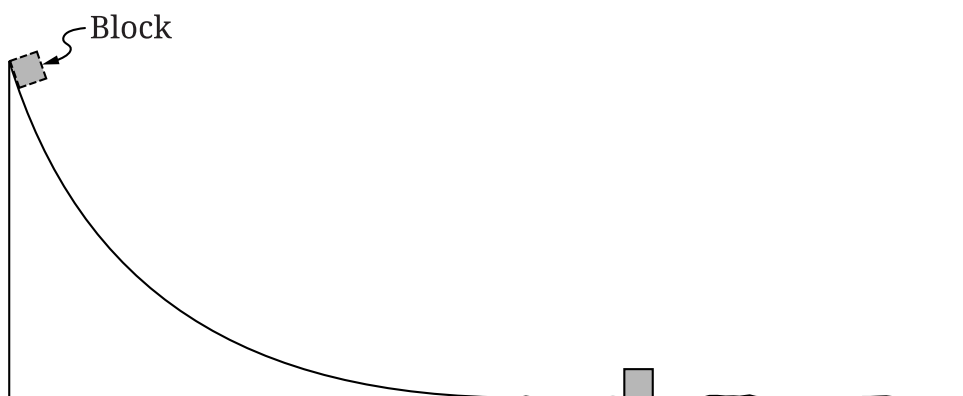


Question 3: Version J

The following information applies to parts A and B.

3. A group of students are investigating friction using the following procedure. The students release a block of unknown mass near the top of a curved ramp. The block slides down the ramp. The block then transitions to a horizontal surface, as shown in Figure 1. Frictional forces are negligible between the block and the curved ramp, but there is friction between the block and the horizontal surface.

Figure 1



The students are asked to perform an experiment in which a single quantity is varied in order to collect data that could be graphed to determine the value μ_k of the coefficient of kinetic friction between the block and the horizontal surface. The students have access to only a meterstick.

Part A

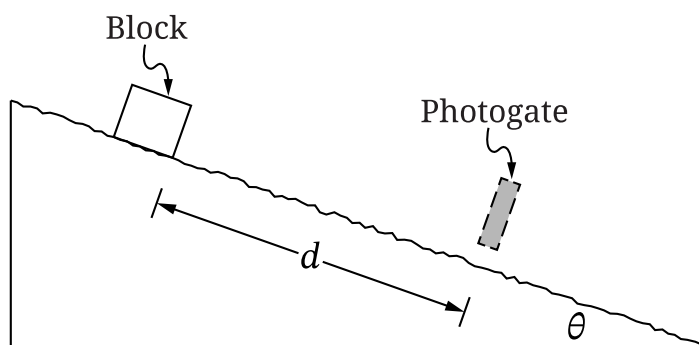
- i. **Indicate** quantities that could be measured by the students that would allow them to determine μ_k using a linear graph.
- ii. Briefly **describe** a method to reduce experimental uncertainty for the measured quantities.

Part B

- i. **Indicate** what quantities the students could graph on the horizontal and vertical axes to create a linear graph that can be used to determine μ_k . Clearly state which quantity will be graphed on each axis.
- ii. Briefly **describe** the relationship between μ_k and a feature of the graph from part B (i). Your answer may include an equation that relates μ_k and the chosen feature of the graph.

The following information applies to parts C and D.

In a different experiment, the students release a block from rest on a rough ramp. The block is released a distance d from a photogate. The ramp is inclined at an angle θ above the horizontal, as shown in Figure 2. The block slides down the ramp and passes through the photogate, which is positioned near the bottom of the ramp. The photogate determines the speed v of the block as it passes through the photogate. The unknown coefficient of kinetic friction between the block and the ramp is μ_k .

Figure 2

The experiment is repeated several times with different release distances d for the same block. Table 1 shows the measured values of d and v .

Table 1

d (m)	v (m/s)
0.20	0.29
0.30	0.38
0.40	0.41
0.50	0.49
0.60	0.52

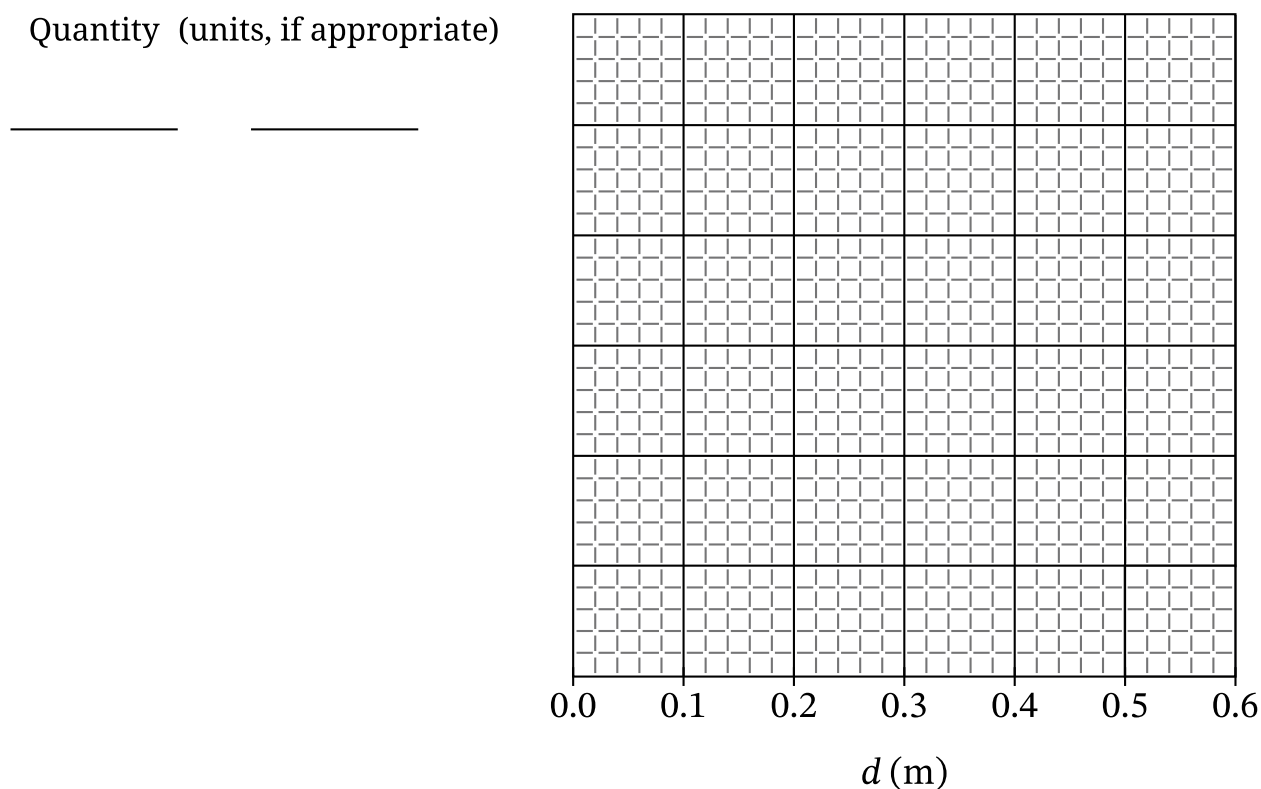
The students correctly determine that the relationship between d and v is given by

$$v^2 = [2g(\sin \theta - \mu_k \cos \theta)]d,$$

where $\theta = 30^\circ$. The students want to determine μ_k . The students create a graph with d plotted on the horizontal axis.

Part C

- i. **Label** the vertical axis of Figure 3 with a measured or calculated quantity. Include units, as appropriate. The graphed quantities should yield a linear graph that can be used to determine μ_k .
- ii. On the grid provided in Figure 3, create a graph that can be used to determine μ_k .
- Clearly **label** the vertical axis with a numerical scale.
 - Plot** the corresponding data points on the grid.
 - Table 2 is provided in your booklet for scratch work and will not be scored.

Figure 3

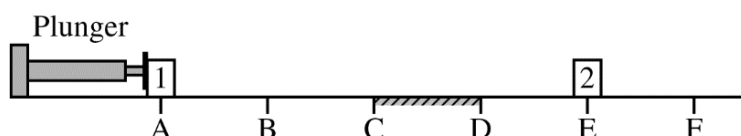
- iii. **Draw** a best-fit line for the data plotted in part C (ii).

Part D

Using the best-fit line that you drew in part C (iii), **calculate** an experimental value for μ_k .

PHYSICS 1**Section II****Time—1 hour and 30 minutes****5 Questions**

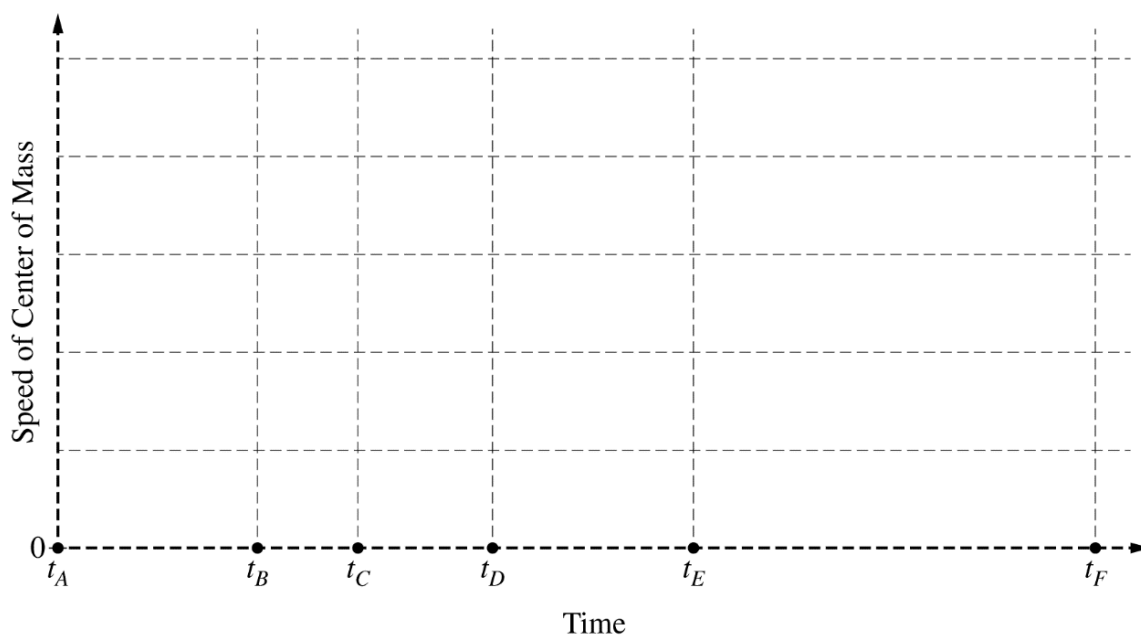
Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.

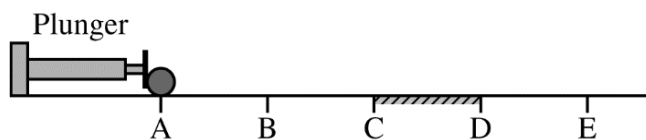


1. (7 points, suggested time 13 minutes)

Identical blocks 1 and 2 are placed on a horizontal surface at points A and E, respectively, as shown. The surface is frictionless except for the region between points C and D, where the surface is rough. Beginning at time t_A , block 1 is pushed with a constant horizontal force from point A to point B by a mechanical plunger. Upon reaching point B, block 1 loses contact with the plunger and continues moving to the right along the horizontal surface toward block 2. Block 1 collides with and sticks to block 2 at point E, after which the two-block system continues moving across the surface, eventually passing point F.

- (a) On the axes below, sketch the speed of the center of mass of the two-block system as a function of time, from time t_A until the blocks pass point F at time t_F . The times at which block 1 reaches points A through F are indicated on the time axis.





- (b) The plunger is returned to its original position, and both blocks are removed. A uniform solid sphere is placed at point A, as shown. The sphere is pushed by the plunger from point A to point B with a constant horizontal force that is directed toward the sphere's center of mass. The sphere loses contact with the plunger at point B and continues moving across the horizontal surface toward point E. In which interval(s), if any, does the sphere's angular momentum about its center of mass change? Check all that apply.

☐ A to B ☐ B to C ☐ C to D ☐ D to E ☐ None

Briefly explain your reasoning.

2. (12 points, suggested time 25 minutes)

A student wants to determine the coefficient of static friction between a long, flat wood board and a small wood block.

- (a) Describe an experiment for determining the coefficient of static friction between the wood board and the wood block. Assume equipment usually found in a school physics laboratory is available.
- Draw a diagram of the experimental setup of the board and block. In your diagram, indicate each quantity that would be measured and draw or state what equipment would be used to measure each quantity.
 - Describe the overall procedure to be used, including any steps necessary to reduce experimental uncertainty. Give enough detail so that another student could replicate the experiment.
- (b) Derive an equation for the coefficient of static friction in terms of quantities measured in the procedure from part (a).

A physics class consisting of six lab groups wants to test the hypothesis that the coefficient of static friction between the board and the block equals the coefficient of kinetic friction between the board and the block. Each group determines the coefficients of kinetic and static friction between the board and the block. The groups' results are shown below, with the class averages indicated in the bottom row.

Lab Group Number	Coefficient of Kinetic Friction	Coefficient of Static Friction
1	0.45	0.54
2	0.46	0.52
3	0.42	0.56
4	0.43	0.55
5	0.74	0.23
6	0.44	0.54
Average	0.49	0.49

- (c) Based on these data, what conclusion should the students make about the hypothesis that the coefficients of static and kinetic friction are equal?

_____ The static and kinetic coefficients are equal.

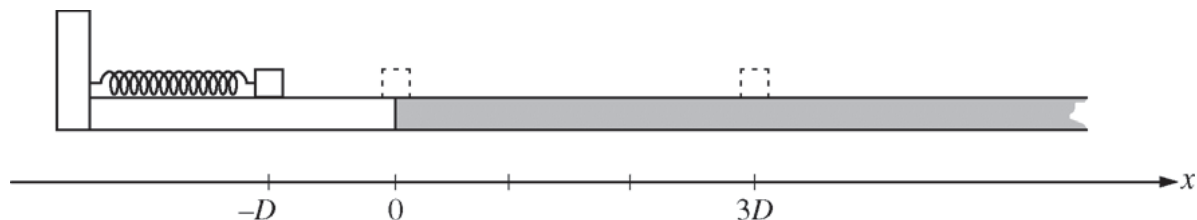
_____ The static and kinetic coefficients are not equal.

Briefly justify your reasoning.

- (d) A metal disk is glued to the top of the wood block. The mass of the block-disk system is twice the mass of the original block. Does the coefficient of static friction between the bottom of the block and the board increase, decrease, or remain the same when the disk is added to the block?

_____ Increase _____ Decrease _____ Remain the same

Briefly state your reasoning.

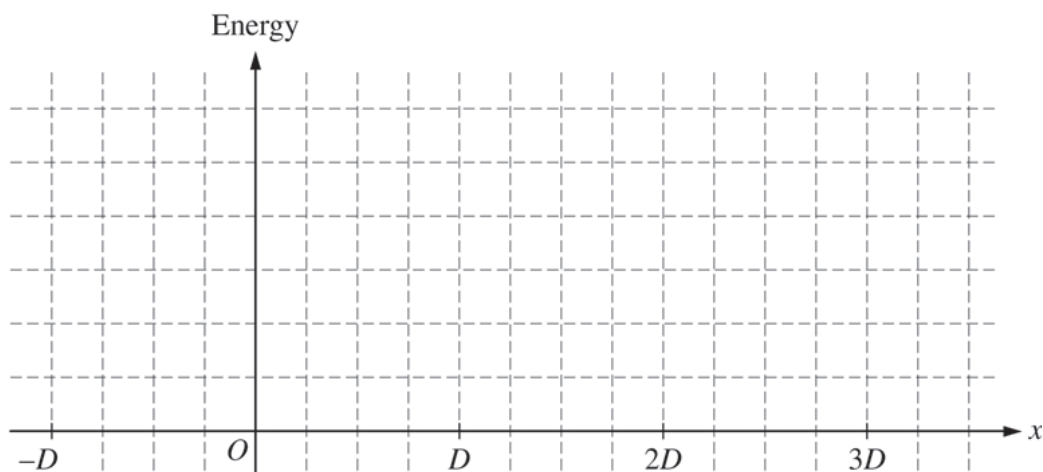


3. (12 points, suggested time 25 minutes)

A block is initially at position $x = 0$ and in contact with an uncompressed spring of negligible mass. The block is pushed back along a frictionless surface from position $x = 0$ to $x = -D$, as shown above, compressing the spring by an amount $\Delta x = D$. The block is then released. At $x = 0$ the block enters a rough part of the track and eventually comes to rest at position $x = 3D$. The coefficient of kinetic friction between the block and the rough track is μ .

(a) On the axes below, sketch and label graphs of the following two quantities as a function of the position of the block between $x = -D$ and $x = 3D$. You do not need to calculate values for the vertical axis, but the same vertical scale should be used for both quantities.

- The kinetic energy K of the block
- The potential energy U of the block-spring system



The spring is now compressed twice as much, to $\Delta x = 2D$. A student is asked to predict whether the final position of the block will be twice as far at $x = 6D$. The student reasons that since the spring will be compressed twice as much as before, the block will have more energy when it leaves the spring, so it will slide farther along the track before stopping at position $x = 6D$.

- (b)
- i. Which aspects of the student's reasoning, if any, are correct? Explain how you arrived at your answer.
 - ii. Which aspects of the student's reasoning, if any, are incorrect? Explain how you arrived at your answer.
- (c) Use quantitative reasoning, including equations as needed, to develop an expression for the new final position of the block. Express your answer in terms of D .
- (d) Explain how any correct aspects of the student's reasoning identified in part (b) are expressed by your mathematical relationships in part (c). Explain how your relationships in part (c) correct any incorrect aspects of the student's reasoning identified in part (b). Refer to the relationships you wrote in part (c), not just the final answer you obtained by manipulating those relationships.