Question 3

3. A box is connected to one end of a rigid rod. Both the box and the rod have negligible mass. The other end of the rod is connected to a pivot. The box is open on one side, and a block is placed inside the box.

The center of mass of the block is displaced a vertical distance h, as shown in Figure 1. The block-box system is then released from rest and swings downward. There is negligible friction about the pivot. When the system is at the lowest point of its swing, the rod collides with a rigid stopper, as shown in Figure 2. The box comes to rest, and the block is launched horizontally out of the box. The block moves across a horizontal surface toward a motion sensor that measures the speed of the block. All frictional forces are negligible.

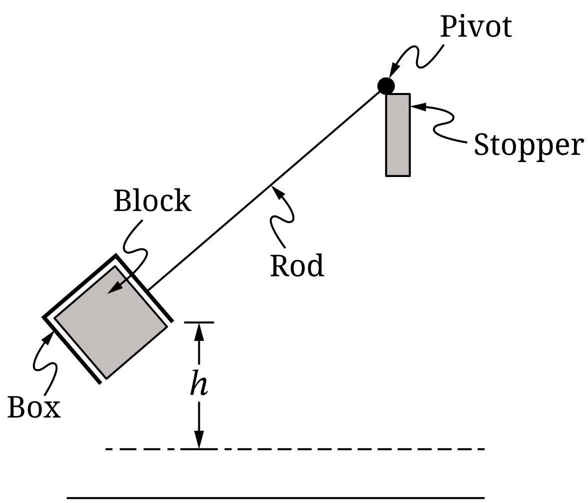


Figure 1

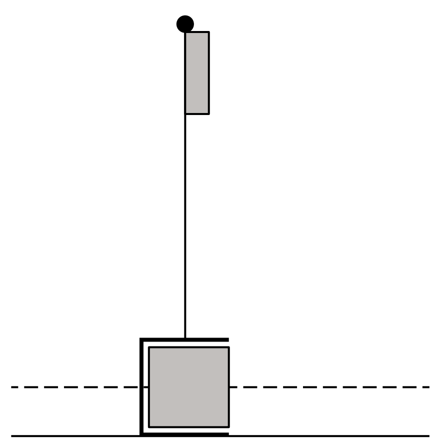


Figure 2

A. Students are asked to experimentally determine the acceleration due to gravity g using a linear graph. To determine g, the students are permitted to use measurements from only a meterstick and the motion sensor.

Describe an experimental procedure using the described setup to collect data that would allow the students to determine an experimental value of g using a linear graph. Include any steps necessary to reduce experimental uncertainty.

B. **Describe** how the data collected in part A could be graphed and how that graph would be analyzed to determine the value of g.

C. The experiment is repeated, but the horizontal surface on which the block slides is replaced with a new rough surface, as shown in Figure 3. The coefficient of kinetic friction between the block and the new surface is μ.

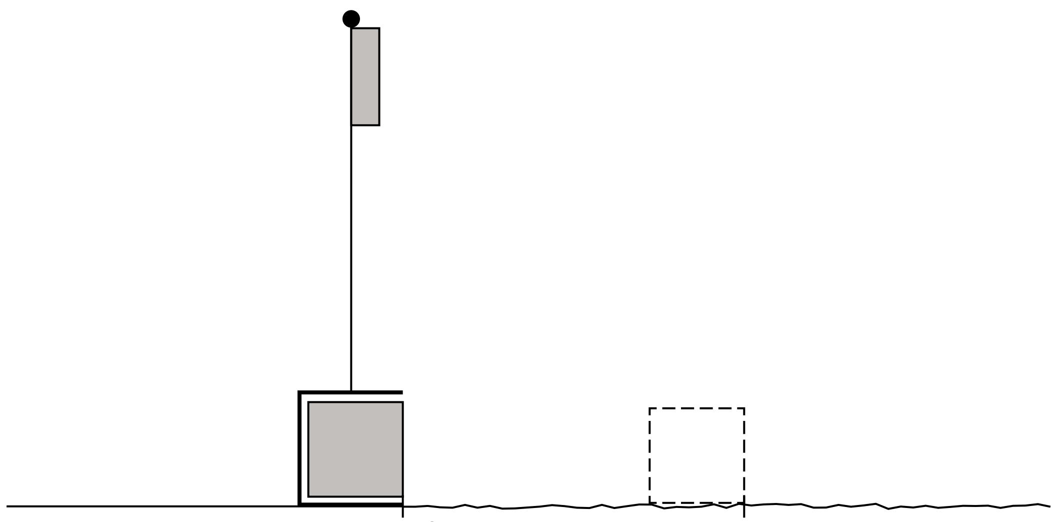


Figure 3

The block-box system is pulled aside so that the center of mass of the block is displaced various vertical distances h and then released from rest. For each vertical distance, students measure the position $x = x_{max}$ at which the block comes to rest.

The students' measurements of h and x_{max} are shown in Table 1.

Table 1

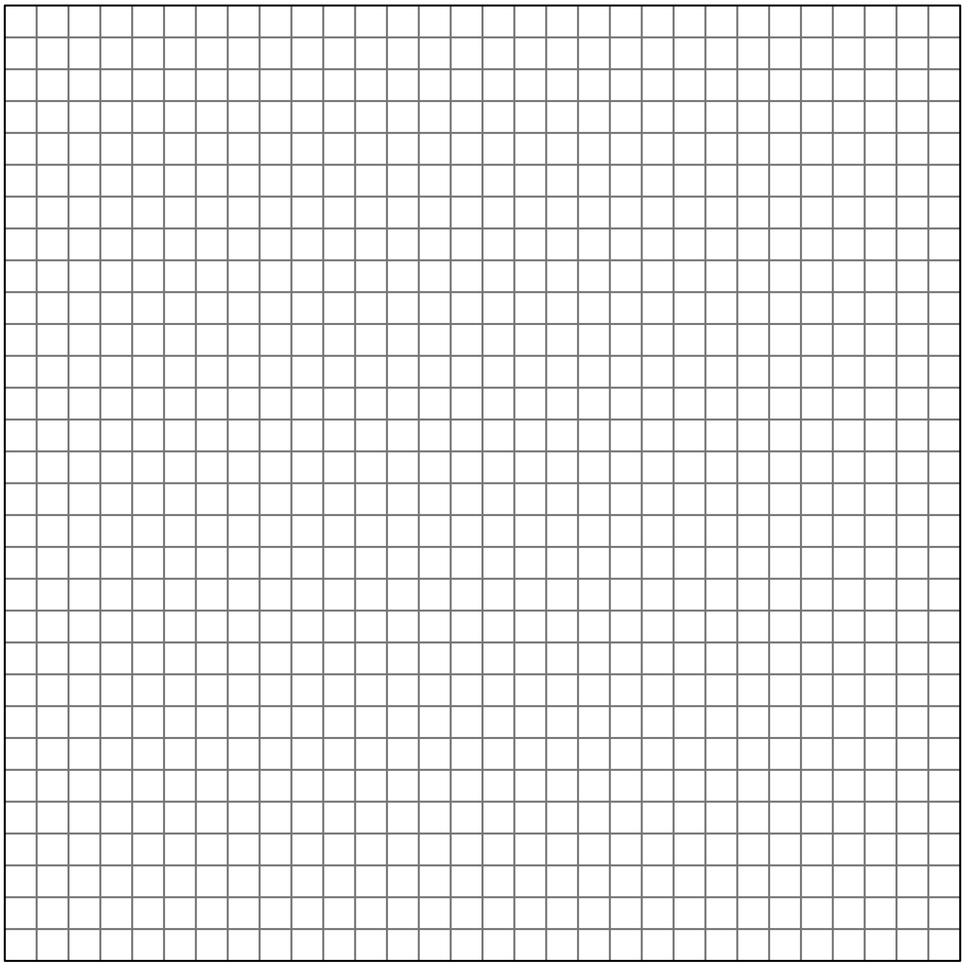
h (m)	x_{max} (m)
0.30	0.76
0.45	1.10
0.60	1.40
0.75	1.90
0.90	2.30

i. **Indicate** two quantities, either measured quantities from Table 1 or additional calculated quantities, that could be graphed to produce a straight line that could be used to determine μ.

Vertical axis: ______ Horizontal axis: ______

ii. On the grid provided, create a graph of the quantities indicated in part C (i).

- Use Table 2 to record the measured or calculated quantities that you will plot.
- Clearly **label** the axes, including units as appropriate.
- **Plot** the points you recorded in Table 2.



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

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

Question 3: Experimental Design and Analysis (LAB) — 10 points

A

For describing a procedure that includes measuring h and the speed of the block as the block moves across the surface — **Point A1**

For a procedure that indicates a reasonable method of reducing experimental uncertainty — **Point A2**

Examples of acceptable responses may include the following:

- Repeating the experiment multiple times for the same value of h
- Repeating the experiment for multiple values of h

Example Response

Measure the height h at which the block-box system is released. Measure the speed of the block as the block slides across the horizontal surface. Repeat the measurement of the speed of the block for varying release heights.

B

For describing a graph that has linear trend that can be used to find g — **Point B1**

Examples of acceptable responses include the following:

- v^2 vs. $2h$
- $\frac{1}{2}v^2$ vs. h
- v^2 vs. h
- v vs. $\sqrt{h}$

Scoring Notes:

- Reponses that include the reciprocals of the preceding examples, in addition to other equivalent graphs, also earn this point.
- This point may be earned independently of the response in part A.

For correctly relating the slope of the best-fit line to g — **Point B2**

Examples of acceptable responses include the following:

Graph	Analysis
v^2 vs. $2h$	slope $= g$
$\frac{1}{2}v^2$ vs. h	slope $= g$
v^2 vs. h	slope $= 2g$
v vs. $\sqrt{h}$	slope $= \sqrt{2g}$

Example Response

Plot v^2 on the vertical axis and $2h$ on the horizontal axis. The slope of the best-fit line is equal to g.