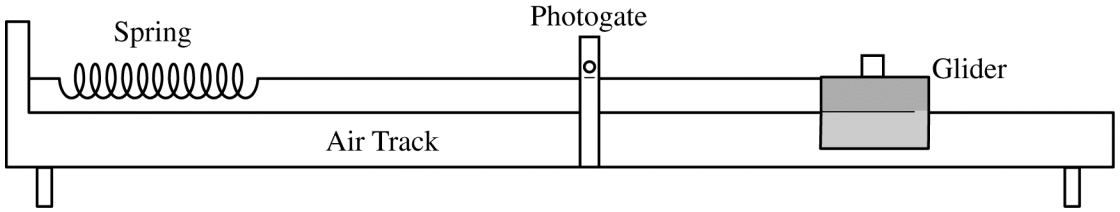


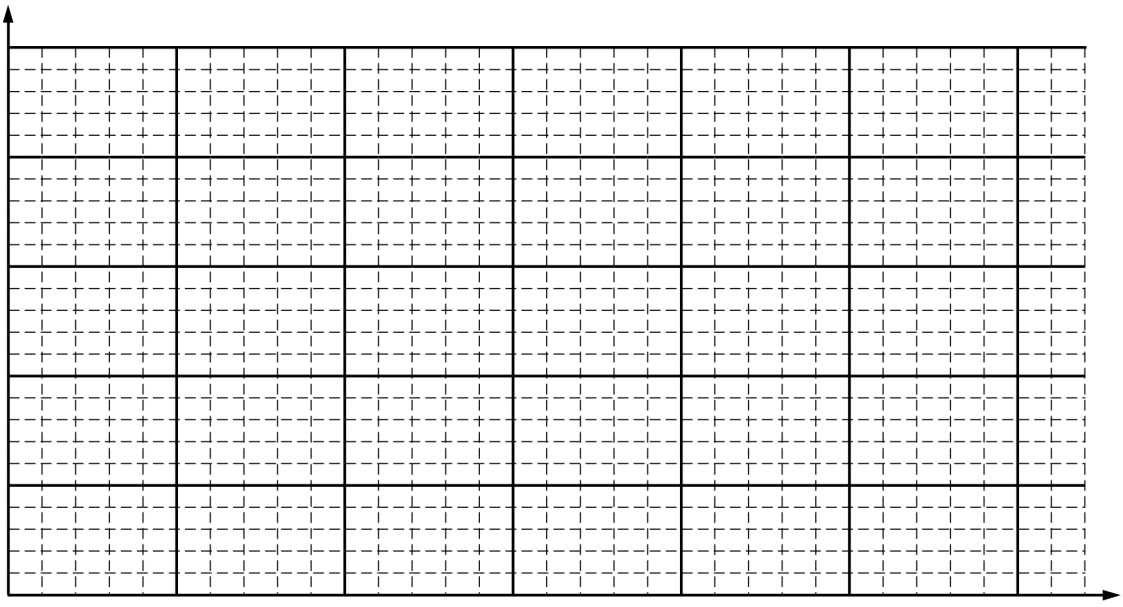
Mech. 3.

The apparatus above is used to study conservation of mechanical energy. A spring of force constant 40 N/m is held horizontal over a horizontal air track, with one end attached to the air track. A light string is attached to the other end of the spring and connects it to a glider of mass m. The glider is pulled to stretch the spring an amount x from equilibrium and then released. Before reaching the photogate, the glider attains its maximum speed and the string becomes slack. The photogate measures the time t that it takes the small block on top of the glider to pass through. Information about the distance x and the speed v of the glider as it passes through the photogate are given below.

Trial #	Extension of the Spring x (m)	Speed of Glider v (m/s)	Extension Squared x^2 $\left(\text{m}^2\right)$	Speed Squared v^2 $\left(\text{m}^2/\text{s}^2\right)$
1	0.30×10^{-1}	0.47	0.09×10^{-2}	0.22
2	0.60×10^{-1}	0.87	0.36×10^{-2}	0.76
3	0.90×10^{-1}	1.3	0.81×10^{-2}	1.7
4	1.2×10^{-1}	1.6	1.4×10^{-2}	2.6
5	1.5×10^{-1}	2.2	2.3×10^{-2}	4.8

(a) Assuming no energy is lost, write the equation for conservation of mechanical energy that would apply to this situation.

(b) On the grid below, plot v^2 versus x^2. Label the axes, including units and scale.

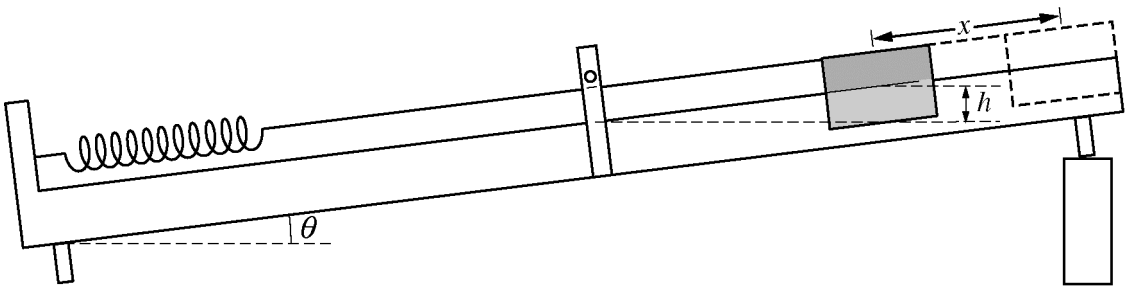


(c)

i. Draw a best-fit straight line through the data.

ii. Use the best-fit line to obtain the mass m of the glider.

(d) The track is now tilted at an angle θ as shown below. When the spring is unstretched, the center of the glider is a height h above the photogate. The experiment is repeated with a variety of values of x.



i. Assuming no energy is lost, write the new equation for conservation of mechanical energy that would apply to this situation.

ii. Will the graph of v^2 versus x^2 for this new experiment be a straight line?

_____ Yes _____ No

Justify your answer.

END OF EXAM

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Question 3

15 points total **Distribution of points**

(a) 2 points

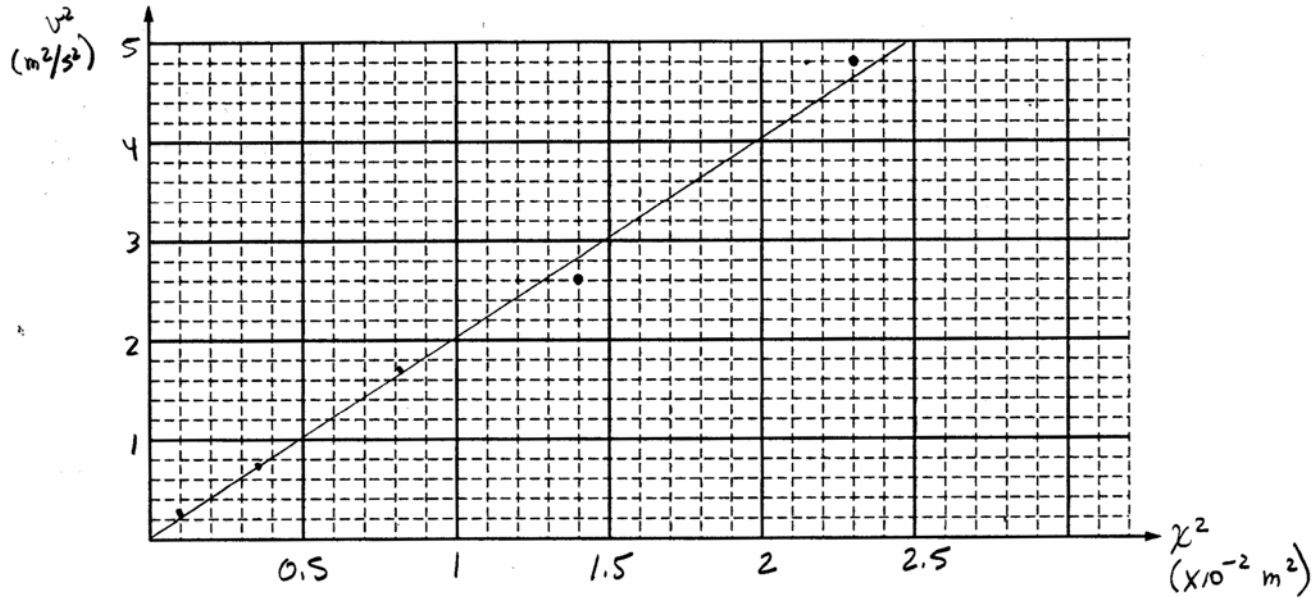
For a correct equation using conservation of energy 1 point

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

For a correct substitution of the numerical value of k in part (a) <u>or</u> in a subsequent part of the problem 1 point

$\frac{1}{2}mv^2 = \frac{1}{2}(40)x^2$

(b) and (c)



(b) 3 points

For correct axis labels and units on both axes 1 point

For correct linear scales on both axes 1 point

For plotting at least 4 of 5 points in the correct location 1 point

<u>Note:</u> Full credit was awarded if both axes were reversed from the graph shown above and everything else was correct.

Question 3 (continued)

Distribution of points

(c)

(i) 1 point

For a reasonable best-fit straight line — 1 point
Note: This point was awarded only if the axes had linear scales.

(ii) 3 points

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

$v^2 = \frac{k}{m}x^2$, so k/m is the slope of the graph of v^2 versus x^2

For use of a slope derived from the data — 1 point
For using two points in the calculation of the slope that are clearly on the best-fit line — 1 point
(Students using data points not on the line could not receive this second point.)

Example: Selecting the points (2.4×10^{-2}, 4.8) and (0.5×10^{-2}, 1.0), which are on the line shown in the graph

$$\text{Slope} = \frac{(4.8 - 1.0)\ \text{m}^2/\text{s}^2}{(2.4 - 0.5) \times 10^{-2}\ \text{m}^2} = 2.0 \times 10^2\ \text{s}^{-2} = \frac{k}{m}$$

$$m = \frac{k}{\text{slope}} = \frac{40\ \text{N/m}}{2.0 \times 10^2\ \text{s}^{-2}}$$

For a numerical answer in the range 0.18 kg to 0.22 kg — 1 point
$m = 0.20$ kg

(d)

(i) 4 points

For use of the correct energy types (K, U_g, and U_s) in a single equation — 1 point
For recognition that the difference in height is greater than h in the figure — 1 point
For a correct expression for U_g — 1 point
For substitution of U_g into a correct equation — 1 point

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 + mg(h + x\sin\theta)$

Note: Third and fourth points were awarded only if the first two points were awarded.

(ii) 2 points

For checking "No" — 1 point
For a clear justification explaining that v^2 varies with both x^2 and x. — 1 point