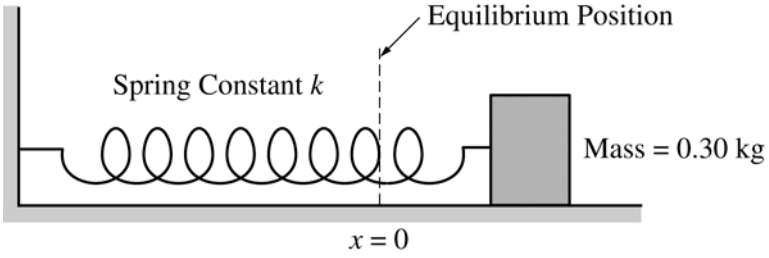
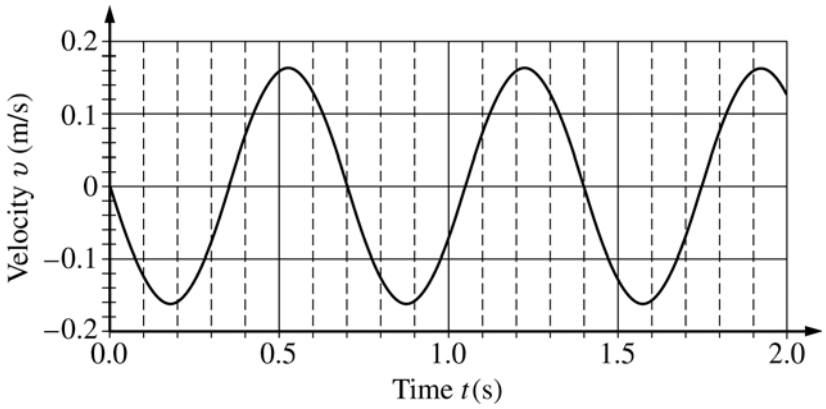
PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



Mech. 1.

Experiment 1. A block of mass 0.30 kg is placed on a frictionless table and is attached to one end of a horizontal spring of spring constant k, as shown above. The other end of the spring is attached to a fixed wall. The block is set into oscillatory motion by stretching the spring and releasing the block from rest at time $t = 0$. A motion detector is used to record the position of the block as it oscillates. The resulting graph of velocity v versus time t is shown below. The positive direction for all quantities is to the right.

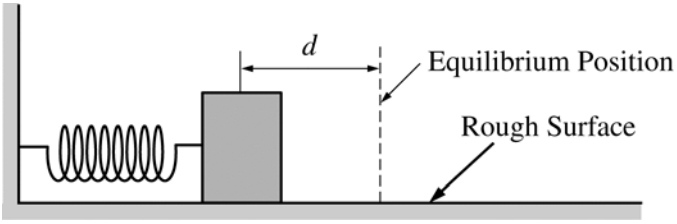


(a) Determine the equation for $v(t)$, including numerical values for all constants.

(b) Given that the equilibrium position is at $x = 0$, determine the equation for $x(t)$, including numerical values for all constants.

(c) Calculate the value of k.

Experiment 2. The block and spring arrangement is now placed on a rough surface, as shown below. The block is displaced so that the spring is compressed a distance d and released from rest.

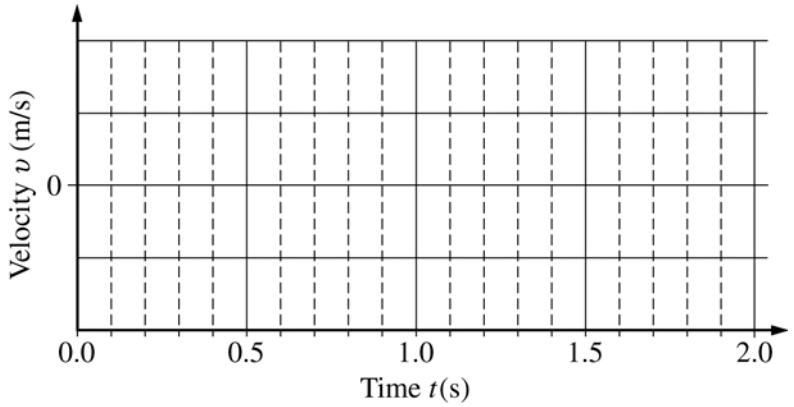


(d) On the dots below that represent the block, draw and label the forces (not components) that act on the block when the spring is compressed a distance $x = d/2$ and the block is moving in the direction indicated below each dot.

Toward the equilibrium position

Away from the equilibrium position

(e) Draw a sketch of v versus t in this case. Assume that there is a negligible change in the period and that the positive direction is still to the right.



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Question 1

15 points total | **Distribution of points**

(a) 4 points

For writing a correct trigonometric equation for velocity as a function of time, including the negative sign — 1 point

$v(t) = -v_{max}\sin(\omega t) = -v_{max}\sin(2\pi t/T)$

For using $\omega = 2\pi f$ or $\omega = \frac{2\pi}{T}$ to solve for ω — 1 point

For using the correct period of 0.70 s from the graph — 1 point

$\omega = \frac{2\pi}{0.70\text{s}} = 9.0 \text{ rad/s}$

For using the correct value of the maximum speed from the graph (acceptable range of values for v_{max}: 0.15 m/s to 0.17 m/s) — 1 point

$v(t) = (-0.16)\sin(9.0t)$

Note: One point is deducted if incorrect phase shift ϕ is used. Full credit is awarded for a correct answer with no work shown. Students are also given credit if the value of k from part (c) is used to calculate ω using $\omega = \sqrt{k/m}$.

(b) 2 points

Take the integral of the velocity determined in part (a)

$x(t) = \int v(t)dt = \int(-0.16 \text{ m/s})\sin((9.0 \text{ rad/s})t)dt$

For a correct trigonometric expression consistent with integrating the answer from part (a) — 1 point

For a correct x_{max} consistent with the integrating the answer from part (a) — 1 point

$x_{max} = (0.16 \text{ m/s})/(9.0 \text{ rad/s}) = 0.018 \text{ m}$

$x(t) = (0.018)\cos(9.0t)$

Question 1 (continued)

Distribution of points

(b) continued

Alternate solution — *Alternate points*

For solving for a maximum displacement consistent with the answer from part (a) — *1 point*

$v_{max} = x_{max}\omega$

$x_{max} = \frac{v_{max}}{\omega} = \frac{(0.16\ \text{m/s})}{(9.0\ \text{rad/s})}$

$x_{max} = 0.018\ \text{m}$

For a correct trigonometric expression consistent with the answer from part (a) — *1 point*

$x(t) = (0.018)\cos(9.0t)$

Note: Full credit is awarded for a correct answer with no work shown. One earned point is deducted for incorrect initial conditions (e.g., subtracting a constant from the cosine function).

(c) 2 points

For a correct relationship between the period and the spring constant — 1 point

$T = 2\pi\sqrt{\frac{m}{k}}$

For substituting correct values from previous parts into a correct expression — 1 point

$k = \frac{4\pi^2 m}{T^2} = \frac{\left(4\pi^2\right)(0.30\ \text{kg})}{(0.70\ \text{s})^2}$

$k = 24\ \text{N/m}$

Alternate solution #1 — *Alternate points*

For a correct expression relating angular frequency and the spring constant — *1 point*

$\omega = \sqrt{\frac{k}{m}}$

For substituting correct values from previous parts into a correct expression — *1 point*

$k = m\omega^2 = (0.30\ \text{kg})(9.0\ \text{rad/s})^2$

$k = 24\ \text{N/m}$

Question 1 (continued)

Distribution of points

(c) continued

Alternate solution #2 — *Alternate points*

For a correct statement of the conservation of energy, applied to the position of maximum displacement and the equilibrium position — *1 point*

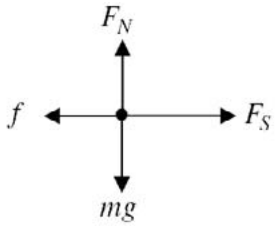
$$\frac{1}{2}kx_{\max}^2 = \frac{1}{2}mv_{\max}^2$$

For substituting correct values from previous parts into a correct expression — *1 point*

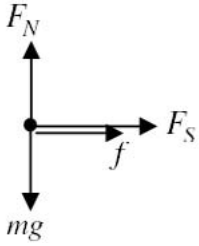
$$k = \frac{mv_{\max}^2}{x_{\max}^2} = \frac{(0.30\text{ kg})(0.16\text{ m/s})^2}{(0.018\text{ m})^2}$$

$$k = 24\text{ N/m}$$

(d) 4 points



Toward the equilibrium position



Away from the equilibrium position

For drawing and labeling F_N and mg correctly on both diagrams — 1 point

On diagram of the block moving toward the equilibrium position:

- For a correctly drawn and labeled spring force to the right — 1 point
- For a correctly drawn and labeled friction force to the left — 1 point

On diagram of the block moving away from the equilibrium position:

- For a correctly drawn and labeled spring force and friction force to the right — 1 point

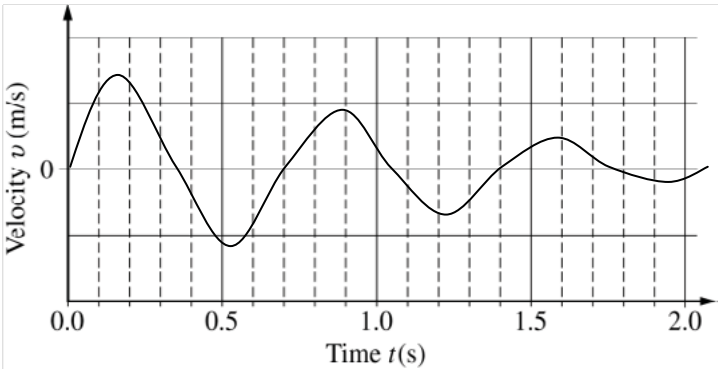
Notes

- Length of vectors is not considered, only direction.
- There is a 1-point maximum deduction for any vectors not touching (or at least almost touching) the dot or for any extraneous forces.Vectors can be drawn from the dot outward OR toward the dot, pointing inward and touching the dot.

Question 1 (continued)

Distribution of points

(e) 3 points



For a graph passing through equilibrium at 0.35 s intervals	1 point
For a graph displaying damped oscillations	1 point
For a graph that starts at zero with an increasing positive velocity	1 point