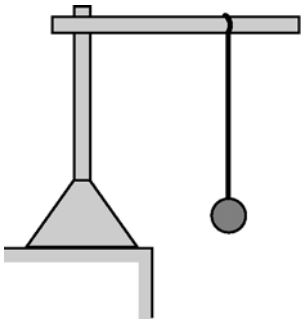
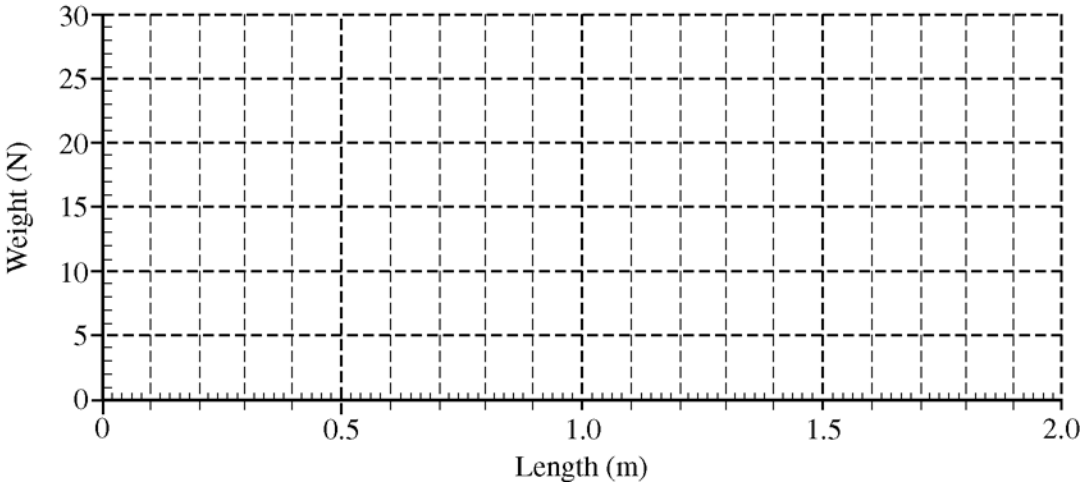


Mech. 3.

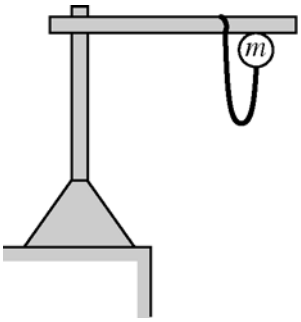
In an experiment to determine the spring constant of an elastic cord of length 0.60 m, a student hangs the cord from a rod as represented above and then attaches a variety of weights to the cord. For each weight, the student allows the weight to hang in equilibrium and then measures the entire length of the cord. The data are recorded in the table below:

Weight (N)	0	10	15	20	25
Length (m)	0.60	0.97	1.24	1.37	1.64

(a) Use the data to plot a graph of weight versus length on the axes below. Sketch a best-fit straight line through the data.



(b) Use the best-fit line you sketched in part (a) to determine an experimental value for the spring constant k of the cord.



The student now attaches an object of unknown mass m to the cord and holds the object adjacent to the point at which the top of the cord is tied to the rod, as represented above. When the object is released from rest, it falls 1.5 m before stopping and turning around. Assume that air resistance is negligible.

(c) Calculate the value of the unknown mass m of the object.

(d) i. Calculate how far down the object has fallen at the moment it attains its maximum speed.

ii. Explain why this is the point at which the object has its maximum speed.

iii. Calculate the maximum speed of the object.

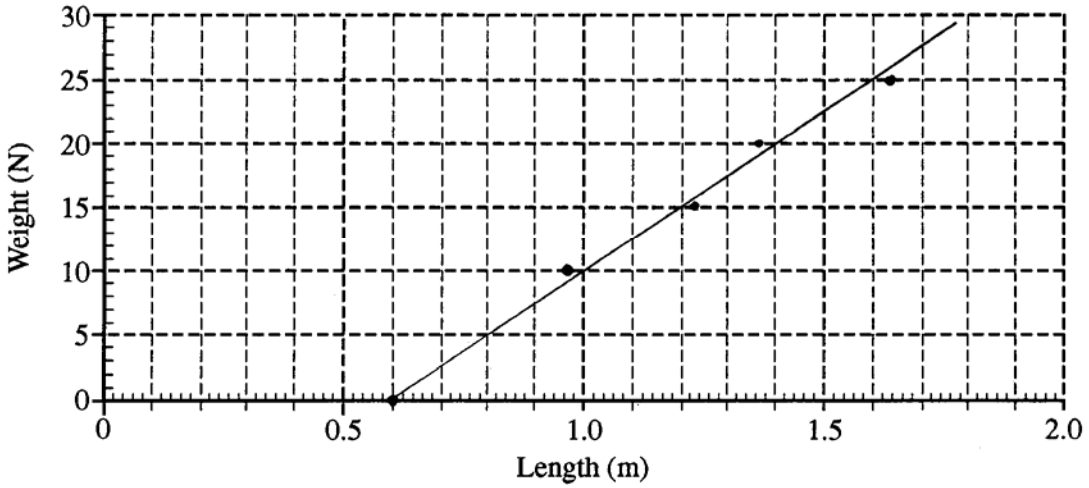
END OF EXAM

AP® PHYSICS C: MECHANICS
2008 SCORING GUIDELINES

Question 3

15 points total **Distribution of points**

(a) 2 points



For four or more correctly plotted points with no extraneous points — 1 point
For a straight line drawn with at least one point above and one point below the line — 1 point

(b) 3 points

For any indication that the slope is used, or $W = k(L - L_0)$ — 1 point

For a calculation using two points from the straight line — 1 point
For example, using the example graph above

$$k = \text{slope} = \frac{20 - 0}{1.4 - 0.60}\frac{\text{N}}{\text{m}}$$

For a numeric answer between 23 N/m and 27 N/m — 1 point

$k = 25$ N/m

Alternate solution

For an indication of a linear regression calculation using the student's calculator — *1 point*
For an indication that the slope is used to get k — *1 point*
For a numeric answer between 23 N/m *and* 27 N/m — *1 point*

Question 3 (continued)

Distribution of points

(c) 3 points

For an equation using the correct forms for gravitational and spring potential energies 1 point

$mgy_{\max} = \frac{1}{2}kx^2$

$m = kx^2/2gy_{\max}$

For a correct substitution of $y_{\max} = 1.5$ m and k from part (a) 1 point

For a correct numeric substitution of $x = (1.5\text{ m} - 0.60\text{ m}) = 0.90$ m 1 point

$m = \left(25\text{ kg/s}^2\right)(0.90\text{ m})^2 / 2\left(9.8\text{ m/s}^2\right)(1.5\text{ m})$

$m = 0.69$ kg (or 0.68 kg using $g = 10\text{ m/s}^2$)

Note: The second and third points are awarded only if the first point is awarded.

(d)

(i) 3 points

Maximum speed occurs when the net force is zero.

$\Sigma F = 0$

For a correct equation relating gravitational and spring forces 1 point

$mg = kx$

$x = \frac{mg}{k}$

For the correct numeric substitution of the mass obtained in part (c) and k obtained in part (a) 1 point

$x = \frac{(0.69\text{ kg})(9.8\text{ m/s}^2)}{25\text{ kg/s}^2}$

$x = 0.27$ m

For adding the unstretched cord length to the value of x calculated above 1 point

$y_{v\max} = 0.27\text{ m} + 0.60\text{ m}$

$y_{v\max} = 0.87$ m

Notes:

- The second and third points were awarded only if the first point was awarded.
- Full credit was awarded for a correct solution that takes the minimum of a potential function or the maximum of a kinetic energy function to determine $y_{v\max}$.

Question 3 (continued)

Distribution of points

(d) (continued)

(ii) 2 points

Note: These points could be awarded only if the first point in (d)(i) was awarded.

For a correct statement that acceleration is zero or switches from downwards to upwards at that point — 1 point

Note: This point was also awarded for stating that the potential energy is a minimum at that point, which implies that the kinetic energy and speed are at their maximum values.

For an additional correct statement and no incorrect statements regarding the motion — 1 point

Example: The acceleration is zero when the two forces are equal in magnitude. Since the acceleration switches from downward to upward (aligned with the velocity to opposing the velocity), the velocity changes from increasing to decreasing.

(iii) 2 points

For a correct energy expression — 1 point

$$mgy_{v\max} = \frac{1}{2}kx^2 + \frac{1}{2}mv_{\max}{}^2$$

$$\frac{1}{2}mv_{\max}{}^2 = mgy_{v\max} - \frac{1}{2}kx^2$$

$$v_{\max}{}^2 = 2gy_{v\max} - \frac{k}{m}x^2$$

For correct substitution of values previously obtained (especially those from part (d)(i)) — 1 point

$$v_{\max}{}^2 = 2(9.8\ \text{m/s}^2)(0.87\ \text{m}) - \frac{(25\ \text{N/m})}{(0.69\ \text{kg})}(0.27\ \text{m})^2$$

$$v_{\max}{}^2 = 14.4(\text{m/s})^2$$

$$v_{\max} = 3.8\ \text{m/s}$$