# AP® Physics C: Mechanics
# 2003 Scoring Guidelines



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## Question 1

| **15 points total** | **Distribution of points** |
|---|---|
| (a) 3 points | |
| For indicating speed as the time derivative of position | 1 point |
| $v = \frac{dx}{dt}$ | |
| For taking the correct derivative | 1 point |
| $v = 1.5t^2 + 2$ | |
| For finding the correct initial speed at $t = 0$ | 1 point |
| $v_0 = 2\ \text{m/s}$ | |
| (b) 6 points | |
| i. (1 point) | |
| $K = \frac{1}{2}mv^2$ | |
| For correctly substituting for the mass and the expression for $v$ found in (a) | 1 point |
| $K = \frac{1}{2}(100)(1.5t^2 + 2)^2 = 50(1.5t^2 + 2)^2$ | |
| ii. (3 points) | |
| $F_{net} = ma$ | |
| For indicating acceleration as the time derivative of the velocity | 1 point |
| $a = \frac{dv}{dt}$ | |
| For taking the correct derivative | 1 point |
| $a = 3t$ | |
| For the correct expression | 1 point |
| $F_{net} = (100)(3t) = 300t$ | |

**Question 1 (cont'd.)**

| | **Distribution of points** |
|---|---|
| iii. (2 points) | |
| For the correct equation relating power to force and velocity | 1 point |
| $P = F\upsilon$ | |
| For substituting expressions for $F$ and $\upsilon$ found in previous parts | 1 point |
| $P = (300t)(1.5t^2 + 2) = 450t^3 + 600t$ | |
| *Alternate method* | *Alternate points* |
| For indicating power as the time derivative of kinetic energy | *1 point* |
| $P = \dfrac{dK}{dt}$ | |
| For substituting the expression for kinetic energy from (b)i. | *1 point* |
| $P = \dfrac{d}{dt}\left(112.5t^4 + 300t^2 + 200\right) = 450t^3 + 600t$ | |

(c) 4 points

| | |
|---|---|
| For a statement that the work done on the box is equal to the change in its kinetic energy | 2 point |
| $W = \Delta K$ | |
| For finding $\upsilon$ at 2 seconds | 1 point |
| $\upsilon = (1.5)(2)^2 + 2 = 8$ m/s | |
| Substituting, using the value of $\upsilon_0$ from part (a): | |
| $W = \dfrac{1}{2}(100\text{ kg})\left((8\text{ m/s})^2 - (2\text{ m/s})^2\right)$ | |
| For the correct answer with correct unit | 1 point |
| $W = 3000$ J | |
| *Alternate method* | *Alternate points* |
| For a statement that the work done by the box is equal to the integral of power over time | *1 point* |
| $W = \int P\,dt$ | |
| For substituting the expression for power found in (b)iii | *2 points* |
| $W = \int_0^2 (450t^3 + 600t)\,dt$ | |
| $W = \dfrac{450}{4}\left(t^4\right)\Big\vert_0^2 + \dfrac{600}{2}\left(t^2\right)\Big\vert_0^2$ | |
| $W = 1800\text{ J} + 1200\text{ J}$ | |
| For the correct answer with unit | *1 point* |
| $W = 3000$ J | |

**Question 1 (cont'd.)**

| | | Distribution of points |
|---|---|---|
| (d) | 2 points | |
| | For checking the box that the work done by the student is greater than in part (c) | 1 point |
| | For a reasonable justification recognizing that the student had to perform work against friction, such as $W_{student} = \Delta KE + W_{friction}$ | 1 point |

## Question 2

**15 points total** | **Distribution of points**

(a) 2 points

For a statement of conservation of energy — 1 point

$MgH = \frac{1}{2}M\upsilon_c^2$

For the correct answer — 1 point

$\upsilon_c = \sqrt{2gH}$

*Alternate solution* — *Alternate points*

For use of correct kinematics equation $\upsilon_c^2 = \upsilon_0^2 + 2gH$, — *1 point*

OR the combination of $a = g$; $\upsilon_c = gt$; and $H = \frac{1}{2}gt^2$,

For the correct answer — *1 point*

$\upsilon_c = \sqrt{2gH}$

(b) 3 points

For recognition that momentum is conserved in the inelastic collision — 1 point

For use of the correct equation expressing conservation of momentum — 1 point

$M\upsilon_c = 2M\upsilon_p$

For the correct answer — 1 point

$\upsilon_p = \frac{1}{2}\sqrt{2gH}$

(c) 4 points

For use of the correct equation for the period of a mass on a spring — 1 point

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

For recognition that $m = 2M$ — 1 point

For correct calculation of $k$ using the force equation for the initial stretching of the spring — 1 point

$Mg = kD$, giving $k = \frac{Mg}{D}$

For the correct answer after substituting for $m$ and $k$ — 1 point

$T = 2\pi\sqrt{\frac{2D}{g}}$

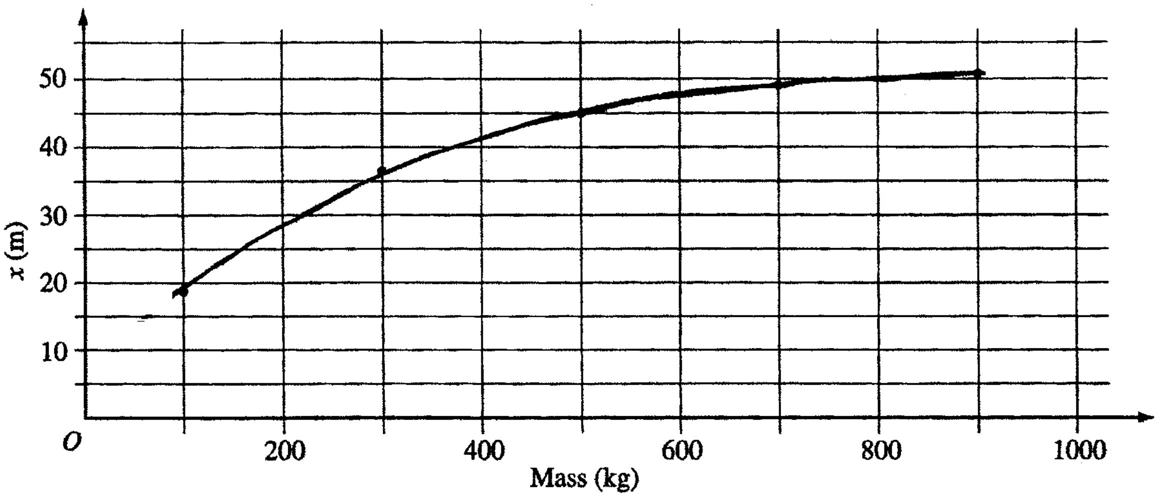
**Question 2 (cont'd.)**

| | Distribution of points |
|---|---|
| (d) 3 points | |
| For recognition that the speed $v$ is a maximum at the equilibrium point, which can be correctly described by one or more of the following statements: equilibrium point, $F = 0$, $a = 0$, kinetic energy is a maximum, midpoint of the oscillation, etc. | 1 point |
| For recognition that there is a new equilibrium point given by the following equation $kx = 2Mg$ , where $x$ is the distance the spring is stretched from its initial unstretched length | 1 point |
| Substituting the value of $k$ found in part (c) | |
| $\left(\frac{Mg}{D}\right)x = 2Mg$ | |
| For the correct answer | 1 point |
| $x = 2D$ | |
| For a correct answer, $x = 2D$ , but with no justification, only 1 point was awarded | |
| (e) 3 points | |
| For a check in the "Less than" space in part (c) | 1 point |
| For a correct justification that states that in the second case there is less mass oscillating than in part (c) and that the period decreases with decreasing mass, $T = 2\pi\sqrt{\frac{m}{k}}$ . | 2 points |
| (The formula is <u>not</u> necessary for full credit.) | |

## Question 3

**15 points total** **Distribution of points**

(a) 2 points




i. (1 point)

For a smooth concave downward curve in the region between the points, that passes near all the points. — 1 point

ii. (1 point)

For a reasonable interpolation of the value of $x$ when $M = 250$ kg, based on the graph that was drawn — 1 point

For example, using the above graph $x \approx 33$ m

(b) 10 points

i. (2 points)

For using correct kinematic equation(s) — 1 point

For example, the equation $y = (1/2)gt^2$ can be used to directly solve for the time

$t = \sqrt{2y/g} = \sqrt{2(15\text{ m})/9.8\text{ m/s}^2}$

For the correct answer — 1 point

$t = 1.75$ s (or 1.73 s using $g = 10\text{ m/s}^2$ )

ii. (3 points)

For determining the potential energy of both the load in the counterweight bucket and the projectile — 1 point

For the correct value of the potential energy of the bucket load — 1 point

$U_b = mgh = M(9.8)3 = 29.4M$

For the correct value of the potential energy of the projectile — 1 point

$U_p = mgh = (10)(9.8)3 = 294$

$U_{init} = U_b + U_p = 29.4M + 294$ (or $30M + 300$ using $g = 10\text{ m/s}^2$ )

**Question 3 (cont'd.)**

**Distribution of points**

(b) (continued)

iii. (5 points)

For a valid statement or equation indicating conservation of energy — 1 point

$U_{init} = U_{final} + K$

For the correct final potential energy of the bucket load — 1 point

For the correct final potential energy of the projectile — 1 point

$U_{final} = M(9.8)(1) + (10)(9.8)(15) = 9.8M + 1470$

For having terms for the final kinetic energy of both the bucket load and the projectile — 1 point

$K_p = (1/2)10\upsilon_x^2$ and $K_b = (1/2)M\upsilon_b^2$ OR $K_p = (1/2)(1440)\omega^2$ and $K_b = (1/2)(4M)\omega^2$

For using one of the following relationships to write all expressions in terms of $\upsilon_x$ — 1 point

$\upsilon_b = (1/6)\upsilon_x$ OR $\omega = \upsilon_x/12$

Substituting into the conservation of energy equation above and solving for $\upsilon_x$ :

$29.4M + 294 = 9.8M + 1470 + 5\upsilon_x^2 + (M/72)\upsilon_x^2$

$\upsilon_x = \sqrt{(19.6M - 1176)/(5 + (M/72))}$

(or $\sqrt{(20M - 1200)/(5 + (M/72))}$ using $g = 10\text{ m/s}^2$ )

*Alternate solution* — *Alternate points*

For an application of the equation for torque — *1 point*

$\sum \tau = I\alpha = I(d\omega/dt)$

For determining the torque applied by the bucket load — *1 point*

$\tau_b = Fr = Mgr\sin\theta = 19.6M\sin\theta$

For determining the torque applied by the projectile — *1 point*

$\tau_p = 10(9.8)\sin\theta(12) = 2940\sin\theta$

For determining the total rotational inertia — *1 point*

$I = 10(12)^2 + M(2)^2 = 1440 + 4M$

For using the proper relationship to change from a rotational to a linear solution — *1 point*

$\omega = (1/12)\upsilon_x$

Substituting:

$19.6M\sin\theta - 2940\sin\theta = (1/12)(1440 + 4M)(d\upsilon_x/dt)$

This equation can then be solved to obtain the expression for $\upsilon_x$

**Question 3 (cont'd.)**

**Distribution of points**

(c) 3 points

i. (1 point)
Using the given relationship for $x$
$x = v_x t$
For substituting the answers answer from parts (b) iii. and (b) i. — 1 point
$x = 1.75\sqrt{(19.6M - 1176)/(5 + (M/72))}$
(or $1.73\sqrt{(20M - 1200)/(5 + (M/72))}$ using $g = 10\ \text{m/s}^2$ )

ii. (2 points)
For using the equation from part (c) i. to predict $x_{theor}$ — 1 point
$x_{theo} = 1.75\sqrt{(19.6(300) - 1176)/(5 + (300/72))} = 39.7\ \text{m}$ (or 40.0 m using $g = 10\ \text{m/s}^2$ )
For a reasonable explanation for the fact that $x_{exp} < x_{theor}$ — 1 point
Examples: friction at the pivot, air resistance, neglected masses are not really negligible

One point was awarded if no equation is available from (c) i. to make a theoretical prediction but the student developed the reasonable explanation for $x_{exp} < x_{theor}$

One point was awarded for a reasonable explanation if evaluation of equation in part (c) resulted in $x_{exp} > x_{theor}$ .