AP® Physics C: Mechanics
2003 Scoring Guidelines

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AP® PHYSICS C: MECHANICS
2003 SCORING GUIDELINES

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

$v_0 = 2$ 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
$P = Fv$

For substituting expressions for F and v 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*
$P = \frac{dK}{dt}$

For substituting the expression for kinetic energy from (b)i. — *1 point*
$P = \frac{d}{dt}\left(112.5t^4 + 300t^2 + 200\right) = 450t^3 + 600t$

(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 v at 2 seconds — 1 point
$v = (1.5)(2)^2 + 2 = 8$ m/s

Substituting, using the value of v_0 from part (a):

$W = \frac{1}{2}(100 \text{ kg})\left((8 \text{ m/s})^2 - (2 \text{ m/s})^2\right)$

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*

$W = \int_0^2 (450t^3 + 600t)dt$

$W = \frac{450}{4}\left(t^4\right)\Big|_0^2 + \frac{600}{2}\left(t^2\right)\Big|_0^2$

$W = 1800 \text{ J} + 1200 \text{ J}$

For the correct answer with unit — *1 point*
$W = 3000$ J

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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

$MgH = \frac{1}{2}Mv_c^2$

For the correct answer — 1 point

$v_c = \sqrt{2gH}$

Alternate solution — *Alternate points*

For use of correct kinematics equation $v_c^2 = v_0^2 + 2gH$, — *1 point*

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

For the correct answer — *1 point*

$v_c = \sqrt{2gH}$

(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

$Mv_c = 2Mv_p$

For the correct answer — 1 point

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

(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

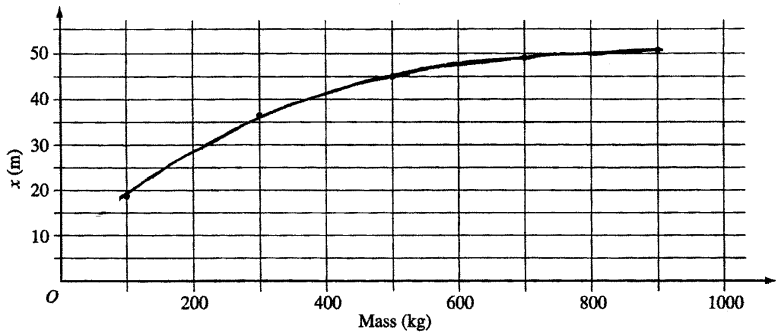
For a correct justification that states that in the second case there is less mass oscillating than in part (c) and that the period decreases with decreasing mass, $T = 2\pi\sqrt{\frac{m}{k}}$. — 2 points

(The formula is not 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
$K_p = (1/2)10v_x^2$ and $K_b = (1/2)Mv_b^2$ 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 v_x 1 point
$v_b = (1/6)v_x$ OR $\omega = v_x/12$
Substituting into the conservation of energy equation above and solving for v_x:
$29.4M + 294 = 9.8M + 1470 + 5v_x^2 + (M/72)v_x^2$
$v_x = \sqrt{(19.6M - 1176)/(5 + (M/72))}$
(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*
$\omega = (1/12)v_x$
Substituting:
$19.6M\sin\theta - 2940\sin\theta = (1/12)(1440 + 4M)(dv_x/dt)$
This equation can then be solved to obtain the expression for v_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 $x_{exp} > x_{theor}$.