AP Physics C: Mechanics
2000 Scoring Guidelines

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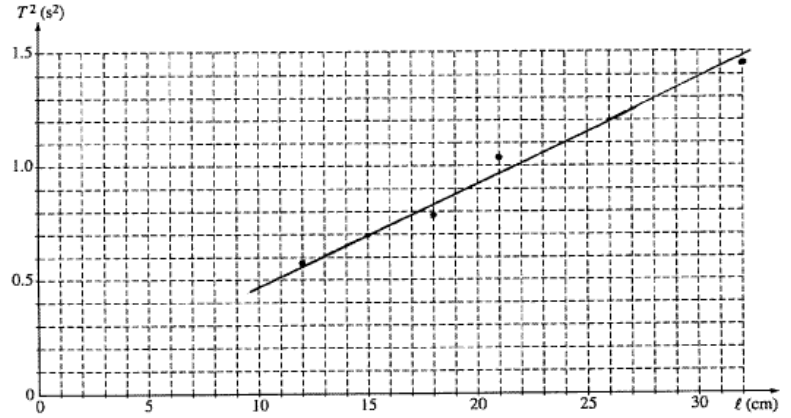
Mech. 1 (15 points)

(a) 4 points

ℓ (cm)	t_{10} (s)	T (s)	T^2 (s^2)
12	7.62	0.762	0.581
18	8.89	0.889	0.790
21	10.09	1.009	1.018
32	12.08	1.208	1.459

For correctly computing the period of each pendulum using the time for 10 oscillations — 1 point
For correctly computing the square of each period — 1 point
For expressing the periods and the squares of the periods to two or three decimal places — 1 point
For completing the data table — 1 point

(b) 3 points



For correctly plotting the square of the period as a function of the pendulum length — 1 point
For drawing a single straight line through the data points (could go through (0,0) but did not have to do so) — 1 point
For drawing this line to approximate a best fit with about an equal number of data points above and below the line — 1 point

Mech. 1 (continued)

(c) 4 points

For computing the slope of the straight line 1 point

slope $= \frac{\Delta T^2}{\Delta \ell}$

Credit was awarded for a calculated value that was consistent with the line drawn. A typical correct value was 4.50 s^2/m. Most values were between 4 and 5 s^2/m.

For recognizing that the motion of each pendulum is simple harmonic or for using the equation for the period of a simple pendulum 1 point

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

For using this relationship and the slope from the graph to determine g_{exp} 1 point

For example, the relation between T^2 and ℓ is given by $T^2 = \frac{4\pi^2}{g}\ell$, so slope $= \frac{4\pi^2}{g_{exp}}$

$g_{exp} = \frac{4\pi^2}{\text{slope}}$

Credit was awarded for a calculated value that was consistent with the slope determined above. For example, for a slope = 4.50 s^2/m, $g_{exp} = 8.77\ m/s^2$.

For using appropriate units for the computed acceleration 1 point

(d) 2 points

For correctly stating whether 9.8 m/s^2 is within ±4% of the experimental value g_{exp}. 1 point

Credit was awarded if the answer was consistent with the value obtained for g_{exp}. For example, for $g_{exp} = 8.77\ m/s^2$, the experimental value is not in agreement with g.

For justification, either by displaying the range of acceptable values within ±4% of the value of g_{exp} (e.g., approximately 8.42 m/s^2 to 9.12 m/s^2, for $g_{exp} = 8.77\ m/s^2$), OR by computing the percent difference between the g_{exp} and 9.80 m/s^2 (e.g., $\frac{9.80 - 8.77}{8.77} \times 100 = 11.7\%$, which is greater than 4%, for $g_{exp} = 8.77\ m/s^2$) 1 point

(e) 2 points

For correctly computing the acceleration of the elevator 1 point

From Newton's 2nd law for objects in the elevator:

$mg - N = ma$, where $N = mg_{exp}$, so $a = g - g_{exp}$

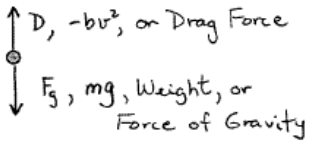
For correctly stating whether the acceleration of the elevator is upward or downward 1 point

Credit for magnitude and direction of acceleration given for answers consistent with g_{exp}. For example, for $g_{exp} = 8.77\ m/s^2$, $a = 9.80 - 8.77 = 1.03\ m/s^2$, directed downward.

2000 Physics C Solutions **Distribution of points**

Mech. 2 (15 points)

(a) 3 points



For a vector arrow pointing downward 1 point

For a vector arrow pointing upward 1 point

For correct force labels on both vectors 1 point

For any extra vectors drawn, deduct 1 point

(b) 3 points

For indicating that the acceleration decreases 1 point

For a correct explanation that includes a correct mention of forces. 2 points

For example, as the ball approaches terminal speed, the velocity increases, so the drag force increases and gets closer in magnitude to the gravitational force. The resultant force, which is the difference between the gravitational and drag forces, gets smaller, and since it is proportional to the acceleration, the acceleration decreases.

Partial credit of 1 point given for only a statement including a basic definition of terminal velocity (e.g., at terminal velocity v = constant, so a must decrease from 9.8 m/s^2 to zero)

(c) 2 points

For an expression for the resultant force on the ball 1 point

$F = mg - bv^2$

Since $F = ma = m\frac{dv}{dt}$, then $m\frac{dv}{dt} = mg - bv^2$

For a correct differential equation 1 point

$\frac{dv}{dt} = g - \frac{b}{m}v^2$

Students did not need to use the convention + and – for up and down, respectively, but they did have to be consistent in their sign notation for credit. The integral form of the differential equation was also acceptable.

Mech. 2 (continued)

(d) 3 points

For recognition that acceleration is zero at terminal speed — 1 point
For setting the drag force equal to the gravitational force — 1 point
$mg = bv_t^2$
For a correct solution for v_t — 1 point
$v_t = \sqrt{\frac{mg}{b}}$

Full credit also given for writing answer only with no other work shown

(e) 4 points

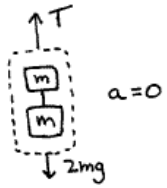
For a correct statement of work-energy, recognizing that the energy dissipated by the drag force is equal to the initial energy minus the final energy — 1 point
For correct recognition of both initial potential energy mgh and final kinetic energy $\frac{1}{2}mv_t^2$ — 1 point
$\Delta E = mgh - \frac{1}{2}mv_t^2$
For correct substitution of v_t from part (d) — 1 point
$\Delta E = mgh - \frac{1}{2}m\left(\frac{mg}{b}\right)$
For correct answer — 1 point
$\Delta E = mg\left(h - \frac{m}{2b}\right)$

Alternate partial solution (for maximum credit of 2 points) — (*Alternate points*)
For a correct integral for work — (*1 point*)
$W = \int P\,dt$ OR $W = \int F\,dx$
For correct substitutions for P or F — (*1 point*)
$W = \int bv^3\,dt$ OR $W = \int bv^2\,dx$ OR $W = \int kv^2\,dx$

2000 Physics C Solutions **Distribution of points**

Mech. 3 (15 points)

(a) 2 points

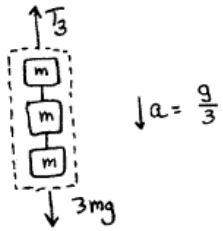


For a correct free-body diagram OR recognition that $a = 0$ OR correct use of Newton's second law — 1 point
$\Sigma F = ma$
$T - 2mg = 0$
For the correct answer — 1 point
$T = 2mg$

Full credit was also awarded for writing the correct answer with no other work shown.

(b)

i. 2 points

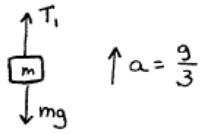


$\Sigma F = ma$
For correct substitutions into Newton's second law — 1 point
$3mg - T_3 = 3m\left(\frac{g}{3}\right)$
For a correct solution for T_3 — 1 point
$T_3 = 2mg$

Mech. 3 (continued)

(b) (continued)

ii. 2 points



$\Sigma F = ma$
For correct substitutions into Newton's second law — 1 point
$T_1 - mg = m\left(\frac{g}{3}\right)$
For a correct solution for T_1 — 1 point
$T_1 = \frac{4}{3}mg$

iii. 4 points

For $\tau = I_1\alpha$ — 1 point
For $\alpha = \frac{a}{R_1} = \frac{g}{3R_1}$ — 1 point
For $\tau = (T_3 - T_1)R_1$ — 1 point
For correct substitutions into $\tau = I_1\alpha$ and solution for I_1 — 1 point
$\left(2mg - \frac{4}{3}mg\right)R_1 = I_1\left(\frac{g}{3R_1}\right)$
$I_1 = 2mR_1^2$

Alternate Solution — *(alternate points)*
Use conservation of energy, $\Delta E = \Delta K + \Delta U = 0$
For $\Delta K = -\Delta U$ — *(1 point)*
For $\Delta K = \frac{1}{2}mv^2 + \frac{1}{2}(3m)v^2 + \frac{1}{2}I_1\omega^2$, where $\omega = \frac{v}{R_1}$ — *(1 point)*
For $\Delta U = mgh - 3mgh = -2mgh$, where $h = \frac{v^2}{2a} = \frac{3v^2}{2g}$ — *(1 point)*
For correct substitutions and solution for I_1 — *(1 point)*
$I_1 = 2mR_1^2$

2000 Physics C Solutions **Distribution of points**

Mech. 3 (continued)

(c)

i. 2 points

For recognition that the speed of the cord or the tangential speed of the pulleys is the same for both pulleys — 1 point
$\omega_1 R_1 = \omega_2 R_2 = \omega_2(2R_1)$
For the correct answer — 1 point
$\omega_2 = \frac{\omega_1}{2}$

ii. 1 point

For correct substitutions in $L = I\omega$ and correct solution — 1 point
$L_2 = (16I_1)\left(\frac{\omega_1}{2}\right)$
$L_2 = 8I_1\omega_1$

iii. 2 points

For a correct expression for the kinetic energy as the sum of the kinetic energies of the two pulleys — 1 point
$K = \frac{1}{2}I_1{\omega_1}^2 + \frac{1}{2}I_2{\omega_2}^2$
For correct substitutions and solution — 1 point
$K = \frac{1}{2}I_1{\omega_1}^2 + \frac{1}{2}(16I_1)\left(\frac{\omega_1}{2}\right)^2$
$K = \frac{5}{2}I_1{\omega_1}^2$