AP® Physics C
1989 Scoring Guidelines

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1989 Physics C — Distribution of points

Mech 1.

(a) 3 points

For any statement of conservation of energy — 1 point

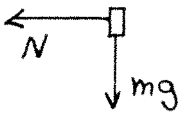
For an equation containing three correct terms:

$mgh = mgh_C + \frac{1}{2}mv_C^2$ — 1 point

$h = h_C + \frac{v_C^2}{2g} = 0.5\text{ m} + \frac{(4\text{ m/s})^2}{2(9.8\text{ m/s}^2)}$

$h = 1.3\text{ m}$ — 1 point

(b) 3 points



For one correct force — 2 points

For second correct force — 1 point

1 point was deducted if any extraneous forces were shown.

(c) 3 points

For centripetal force equation: $F_c = \frac{mv^2}{r}$ — 1 point

For recognition that $v_B = v_C = 4$ m/s — 1 point

$F_c = (0.1\text{ kg})(4\text{ m/s})^2/(0.5\text{ m}) = 3.2\text{ N}$ — 1 point

Only 2 points were awarded for a correct calculation of the net force, instead of the force exerted by the track.

(d) 3 points

For any statement of applicable equation: $v_f^2 - v_i^2 = 2a\,\Delta y$ — 1 point

For recognition that $v_i = v_C \sin 30° = 2$ m/s — 1 point

$\Delta y = -\frac{v_i^2}{2a} = \frac{v_i^2}{2g}$

$\Delta y = (2\text{ m/s})^2/2(9.8\text{ m/s}^2) = 0.2\text{ m}$ <u>or</u> $y = 0.7\text{ m}$ — 1 point

<u>Alternate Solution I</u> — (Alternate points)

$v_f = v_i - gt = 0$ — (1 point)

$v_i = v_C \sin 30° = 2$ m/s — (1 point)

$t = \frac{v_i}{g} = \frac{2\text{ m/s}}{9.8\text{ m/s}^2} = 0.2\text{ s}$

$y = y_i + v_i t - \frac{1}{2}gt^2$

$= 0.5\text{ m} + (2\text{ m/s})(0.2\text{ s}) - \frac{1}{2}(9.8\text{ m/s}^2)(0.2\text{ s})^2$

$y = 0.7\text{ m}$ <u>or</u> $\Delta y = 0.2\text{ m}$ — (1 point)

Mech 1. (continued)

Alternate Solution II

For conserving energy: $\frac{1}{2}m(v_{iy}^2 + v_{ix}^2) + mgh_C = mgy + \frac{1}{2}mv_{ix}^2$ (1 point)

$v_{iy} = v_C \sin 30° = 2$ m/s (1 point)

$\frac{1}{2}(2\text{ m/s})^2 + (9.8\text{ m/s}^2)(0.5\text{ m}) = (9.8\text{ m/s}^2)y$

$y = 0.7$ m (1 point)

If part (a) was solved correctly, conservation of energy is used to solve (d), and the answer obtained is y = 1.3 m, only 1 point was awarded for (d). If (a) was incorrect, this same solution to (d) was awarded 2 points.

(e) 3 points

For any indication that the work equals some change in energy — 1 point

$W = E_C - E_A = mgh_C + \frac{1}{2}mv_C^2 - mgh_A$ — 1 point

$W = (0.1\text{ kg})[(9.8\text{ m/s}^2)(0.5\text{ m}) + \frac{1}{2}(4\text{ m/s})^2 - (9.8\text{ m/s}^2)(2\text{ m})]$

$= -0.7$ J — 1 point

Alternate Solution (Alternate points)

$W = \Delta E$ (1 point)

$= mgh_{part(a)} - mgh_{part(e)}$ (1 point)

$W = (0.1\text{ kg})(9.8\text{ m/s}^2)[1.3\text{ m} - 2\text{ m}] = -0.7$ J (1 point)

Mech 2.

(a) 3 points

For Newton's 2nd Law: $\sum F = ma$ — 1 point

For applying Newton's 2nd Law to block A:

$\sum F = 2Mg - T_v$ — 1 point

$2Mg - T_v = 2Ma$

$T_v = 2M(g - a)$ or equivalent — 1 point

(b) 5 points

For relating torque to rotational motion: $\sum\tau = I\alpha$ — 1 point

For relating α to a: $a = \alpha R$ — 1 point

For relating torque to tension: $\tau = TR$ — 1 point

For calculating the net torque: $\sum\tau = T_vR - T_hR$ — 1 point

$T_vR - T_hR = I\frac{a}{R} = 3MRa$

$T_h = \frac{1}{R}(T_vR - 3MRa) = 2M(g - a) - 3Ma$

$T_h = 2Mg - 5Ma$ — 1 point

Mech. 2. (continued)

(c) 4 points

$f = \mu N$ — 1 point

For use of correct normal force: $N = 4Mg$ — 1 point

For correctly applying 2nd Law to block B:

$T_h - f = 3Ma$ — 1 point

$2Mg - 5Ma - 4\mu Mg = 3Ma$

$4\mu Mg = 2Mg - 8Ma$ — 1 point

$\mu = (2g - 8a)/4g$
$= [2(9.8\ m/s^2) - 8(2\ m/s^2)]/4(9.8\ m/s^2)$

$\mu = 0.1$

(d) 3 points

For including only the frictional force in 2nd Law: $f = ma_C$ — 1 point

For using $m = 4M$ — 1 point

$4M\mu g = 4Ma_C$

$a_C = \mu g = (0.1)(9.8\ m/s^2)$

$a_C = 1\ m/s^2$ — 1 point

Mech. 3

(a) 3 points

$mgh = \frac{1}{2}mv^2$

$v = \sqrt{2gh}$

For either or both equations — 1 point

For correct substitution: $v = \sqrt{2(9.8\ m/s^2)(0.45\ m)}$ — 1 point

$v = 3.0\ m/s$ — 1 point

Alternate Solution — (Alternate points)

$\Delta y = \frac{1}{2}gt^2$

$v = gt$

$v^2 = 2g\ \Delta y$ — (1 point)

For correct substitution — (1 point)

For correct answer — (1 point)

(b) 3 points

$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$ — 1 point

For correct substitution: $T = 2\pi\sqrt{\frac{2\ kg}{200\ N/m}}$ or $T = \frac{2\pi}{10\ Hz}$ — 1 point

$T = 0.63\ s$ — 1 point

Distribution of points

Mech. 3. (continued)

(c) 3 points

For any one of the following: — 1 point

1) $\sum F = 0$
2) Correct force diagram
3) $a = 0$ when v is maximum
4) $ky = mg$

For correct substitution into 4) above: $y = \dfrac{(2\text{ kg})(9.8\text{ m/s}^2)}{(200\text{ N/m})}$ — 1 point

$y = 0.098$ m or 0.1 m — 1 point

(d) 3 points

For use of conservation of energy — 1 point

For use of an appropriate reference level for potential energy — 1 point

For example:

$\frac{1}{2}ky^2 = mg(y + 0.45\text{ m})$ or $mgy + \frac{1}{2}mv^2$

For use of the quadratic formula to solve above equation — 1 point

$y = 0.41$ m or 0.42 m

(e) 2 points

For ony one of the following: — 1 point

1) An indication of subtracting the answer to (c) from the answer to (d)
2) Calculating both roots of the quadratic, and taking half their difference
3) Indication that in the quadratic solution $\alpha \pm \beta$, α is the equilibrium point and β is the amplitude

For correct answer: $A = 0.31$ m or 0.32 m — 1 point

(This answer must be the correct value - part (e) is where credit is earned for correct math in solving quadratic equation of part (d))

Additional 1 point awarded for correct use of units and no incorrect units — 1 point

Full credit for part (c) can be obtained by:
Solving (e) through second or third method
Indicating that maximum speed occurs at equilibrium
Finding the equilibrium point, using answer to (d) as necessary

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E & M 1.

(a) 2 points

$E = 0$ because the net charge is zero — 2 points

(b) 2 points

$V = 0$ because the net charge is zero — 2 points

Distribution of points

E & M 1. (continued)

(c) 5 points

For some statement of Gauss' Law: $\oint \vec{E}\cdot d\vec{A} = q/\epsilon_0$ — 1 point

For any attempt to calculate the portion of the negative charge within the radius r — 1 point

Portion of negative charge $= -Q\,\dfrac{(4/3)\pi r^3}{(4/3)\pi R^3} = \dfrac{-Qr^3}{R^3}$

Total charge inside r: $Q - \dfrac{Qr^3}{R^3}$ — 1 point

$A = 4\pi r^2$ — 1 point

$$E(4\pi r^2) = \frac{1}{\epsilon_0}\left[Q - \frac{Qr^3}{R^3}\right]$$

$E = \dfrac{Q}{4\pi\epsilon_0}\left(\dfrac{1}{r^2} - \dfrac{r}{R^3}\right)$ or equivalent — 1 point

(d) 6 points

$V = -\int_\infty^r \vec{E}\cdot d\vec{r}$ — 1 point

$$= -\int_\infty^R \vec{E}\cdot d\vec{r} - \int_R^r \vec{E}\cdot d\vec{r}$$

$$= 0 - \int_R^r \vec{E}\cdot d\vec{r}$$

For using correct limits, r and R, for non-zero contribution to V — 1 point

For correct substitution of E from part (c):

$V = -\dfrac{Q}{4\pi\epsilon_0}\left[\int_R^r \dfrac{1}{r^2}\,dr - \int_R^r \dfrac{r}{R^3}\,dr\right]$ — 1 point

For correct integrations:

$V = -\dfrac{Q}{4\pi\epsilon_0}\left[-\dfrac{1}{r} - \dfrac{r^2}{2R^3}\right]_R^r$ — 1 point

For correct substitution of limits:

$V = \dfrac{Q}{4\pi\epsilon_0}\left[\dfrac{1}{r} - \dfrac{1}{R} + \dfrac{r^2}{2R^3} - \dfrac{R^2}{2R^3}\right]$ — 1 point

$V = \dfrac{Q}{4\pi\epsilon_0}\left[\dfrac{1}{r} + \dfrac{r^2}{2R^3} - \dfrac{3}{2R}\right]$ — 1 point

If both (a) and (b) were wrong, and (c) and (d) were not attempted, points for Gauss' Law, correct area A etc. were awarded for (c) and (d) if they were written in (a) and (b).

E & M 1. (continued)

If no points were awarded for any of the above, the equations $E = kq/r^2$ and $V = kq/r$ were awarded 2 points each when present.

E & M 2.

(a)

i) 4 points

$\mathcal{E} = -\dfrac{d\Phi}{dt} = B\ell v$	1 point
For substitution of correct length: $\mathcal{E} = Bhv$	1 point
For a statement of Ohm's Law: $I = \mathcal{E}/R$	1 point
For correct answer: $I = Bhv/R$	1 point

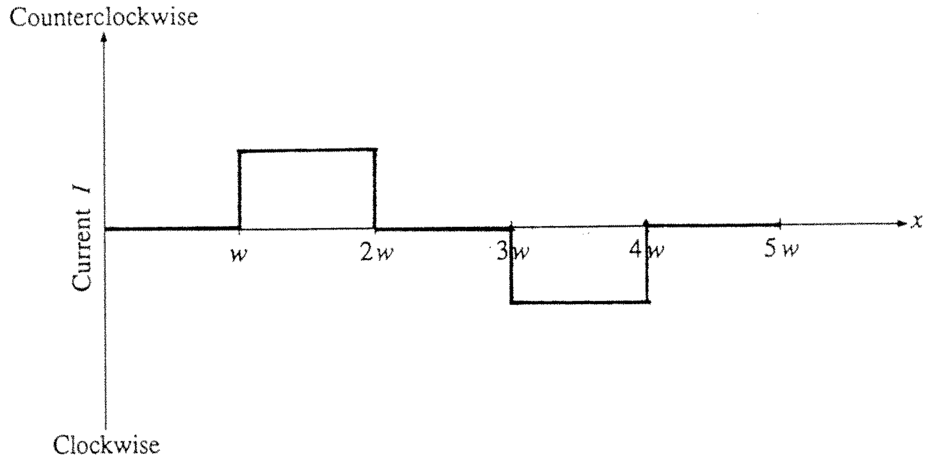
ii) 3 points

For $F_A = F_{field} = I\ell B$ (or qvB)	1 point
For correctly substituting I from i): $F_A = \left(\dfrac{Bhv}{R}\right)\ell B$	1 point
For substitution of correct length: $F_A = \left(\dfrac{Bhv}{R}\right) hB$	1 point

$$F_A = \frac{B^2h^2v}{R}$$

(b)

i) 4 points

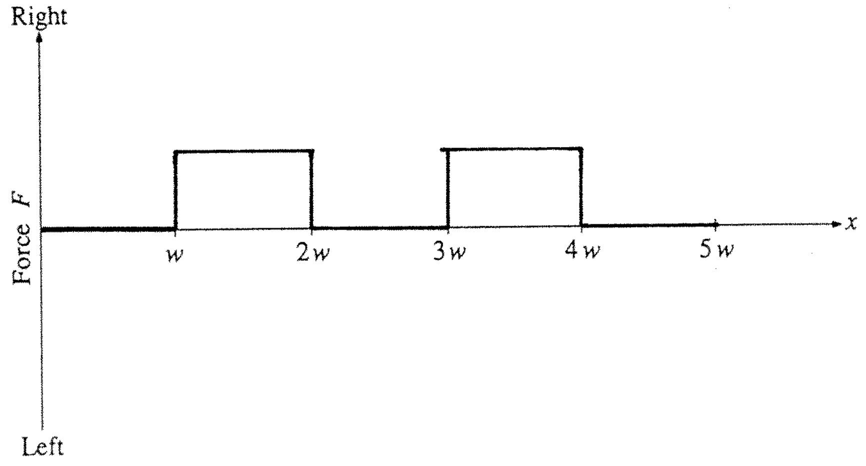


For correctly indicating ranges of x for which $I = 0$	1 point
For constant values of I when $w < x < 2w$ and $3w < x < 4w$	1 point
For positive I when $w < x < 2w$	1 point
For negative I when $3w < x < 4w$	1 point

Distribution of points

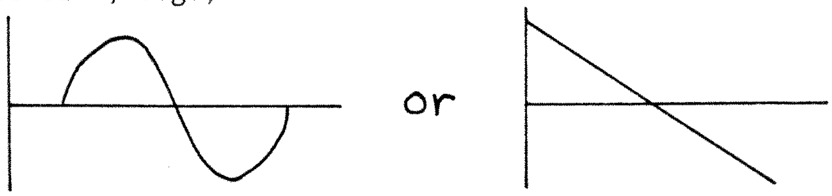
E & M 2. (continued)

ii) 4 points



For correctly indicating ranges of x for which $F = 0$ — 1 point
For constant value of F when $w < x < 2w$ and $3w < x < 4w$ — 1 point
For positive F when $w < x < 2w$ — 1 point
For positive F when $3w < x < 4w$ — 1 point

In both i) and ii), only 1 of the last 2 points was awarded if the graph did not contain characteristic "breaks" at multiples of w, e.g.,



Also, a total of 3 points was awarded for graphs that were perfect inversions of the correct graphs with respect to the x-axis.

E & M 3.

(a) 3 points

$U = \frac{1}{2}CV^2$ — 1 point

For substitution: $U = \frac{1}{2}(6\ \mu F)(20\ V)^2$ — 1 point

For correct answer: $U = 1200\ \mu J$ — 1 point

The last point was <u>not</u> awarded for an answer of just "1200." An indication of comprehension of the units "μF" was required by the presence of "μJ" or a numerical answer indicating the use of 6×10^{-6} F.

E & M 3. (continued)

(b) 4 points

For realization that the charge is constant: — 1 point
Q = constant or $CV = C'V'$

For an indication that the work equals the change in stored energy: $W = \Delta U$ — 1 point

For correct new capacitance: $C' = (1/4)C$ — 1 point

$$V' = \frac{CV}{C'} = 4V$$

$$W = \frac{1}{2}(C'V'^2 - CV^2) = \frac{1}{2}(4CV^2 - CV^2) = 3\left(\frac{1}{2}CV^2\right)$$

$W = 3600\ \mu J$ — 1 point

Alternate Solution I — (Alternate points)

$W = \int F \cdot dx = \int \frac{QE}{2}\, dx$ — (1 point)

For the factor of 1/2 — (1 point)

$E = V_0/x_0$ is constant, since $\frac{V}{x} = \frac{Q}{Cx} = \frac{Q}{\epsilon_0 A}$

$$W = \frac{Q}{2}\int_{x_0}^{4x_0} (V_0/x_0)\,dx$$

For correct limits — (1 point)

$$W = \frac{QV_0}{2x_0}(4x_0 - x_0) = \left(\frac{3}{2}QV_0\right) = 3\left(\frac{1}{2}C_0V_0^2\right)$$

$= 3(1200\ \mu J) = 3600\ \mu J$ — (1 point)

Alternate Solution II

$W = \int dU = \int \frac{Q}{2}\, dV$ — (1 point)

For the factor of 1/2 — (1 point)

$$V = \frac{Q}{C} \longrightarrow dV = -\frac{Q}{C^2}\, dC$$

$$W = -\frac{Q^2}{2}\int_{C_0}^{C_0/4} \frac{dC}{C^2}$$

For correct limits — (1 point)

$$W = \left(-\frac{Q^2}{2}\right)\left(-\frac{1}{C}\right)\Bigg|_{C_0}^{C_0/4} = \frac{Q^2}{2}\left(\frac{4}{C_0} - \frac{1}{C_0}\right) = \frac{3Q^2}{2C_0}$$

$W = 3\left(\frac{1}{2}C_0V_0^2\right) = 3(1200\ \mu J) = 3600\ \mu J$ — (1 point)

Distribution of points

E & M 3. (continued)

(c) 3 points

For Ohm's Law $V = IR$	1 point
Voltage across capacitor is $4V_0 = 80$ V	1 point
$I = V/R = (80\text{ V} - 20\text{ V})/300{,}000\ \Omega = 2 \times 10^{-4}$ A	1 point

Alternate Solution (Alternate points)

$V_{batt} = -IR + Q/C'$ (1 point)

$$I = \frac{Q}{C'R} - \frac{V}{R}$$ (1 point)

$$I = \frac{CV}{C'R} - \frac{V}{R}$$ (1 point)

$$= \frac{20\text{ V}}{300{,}000\ \Omega}(4 - 1)$$

$I = 2 \times 10^{-4}$ A (1 point)

(d) 3 points

$Q = CV$	1 point
$Q_i = (6\ \mu\text{F})(20\text{ V}) = 120\ \mu\text{C}$	
For either value	1 point
$Q_f = \left(\frac{6}{4}\ \mu\text{F}\right)(20\text{ V}) = 30\ \mu\text{C}$	
$\Delta Q = 120\ \mu\text{C} - 30\ \mu\text{C} = 90\ \mu\text{C}$	1 point

Alternate Solution (Alternate points)

$\Delta Q = \int I\, dt$ (1 point)

$I = I_0\, e^{-t/RC}$

For correct integration: $\Delta Q = I_0 \int_0^\infty e^{-t/RC}\, dt = I_0 RC$ (1 point)

$\Delta Q = (2 \times 10^{-4}\text{ A})(300{,}000\ \Omega)\left(\frac{3}{2}\ \mu\text{F}\right) = 90\ \mu\text{C}$ (1 point)

(e) 2 points

$\Delta E = \Delta Q\, V_{batt}$	1 point
$\Delta E = (90\ \mu\text{C})(20\text{ V}) = 1800\ \mu\text{J}$	1 point