AP® Physics C
1987 Scoring Guidelines

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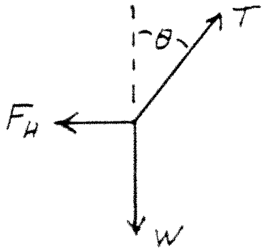
1987 Physics C — Distribution of Points

Mech. 1.

(a) and (b) 7 points



If vector diagram shown, 1 point was awarded for each vector correctly drawn and labeled. — 3 points

Summation of forces equal to zero. Taking components:

(1) in y-direction: $T \cos\theta - W = 0$
(2) in x-direction: $T \sin\theta - F_H = 0$
(3) in direction of T:
$T - W \cos\theta - F_H \sin\theta = 0$

For correctly obtaining any two of these three equations — 2 points

(If vector diagram not shown, 5 points awarded for two of the 3 equations)

For correct simultaneous solution for T and F_H of any two of the equations (1), (2), or (3) — 2 points

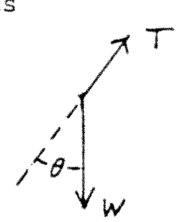
Example: from (1) $T = \dfrac{W}{\cos\theta}$

Substituting into (2) $\dfrac{W}{\cos\theta} \sin\theta - F_H = 0$

$$F_H = W \tan\theta$$

(-1 point for using wrong functions, -1 point for answers not in terms of W and θ)

(c) 3 points



For vector diagram — 1 point

Summation of forces in direction of T equals zero — 1 point

$T = W \cos\theta$ — 1 point

(Full 3-point credit given for simply stating the correct answer)

Mech. 1 (continued)

(d) 5 points

$a_c = \frac{v^2}{R}$ 1 point

$T - W = ma_c$

(1) $T - W = m\frac{v^2}{L}$ 1 point

From conservation of energy,

(2) $\underbrace{mgL(1 - \cos\theta)}_{\text{1 point}} = \underbrace{\frac{1}{2}mv^2}_{\text{1 point}}$ 2 points

Letting $mg = W$, and solving (1) and (2) for T, gives
$T = W(3 - 2\cos\theta)$ 1 point

Mech. 2.

(a) 3 points

Points of equilibrium are:

$x_E = 2$ m 1 point

$x_E = 5$ m 1 point

No extraneous points indicated 1 point

(b) 3 points

$E_{tot} = K + U = 4$ J 1 point

At x = 2.0 m: $K = 4 - U(2) = 4 - 1 = 3$ J 1 point

At x = 4.0 m: $K = 4 - U(4) = 4 - 3 = 1$ J 1 point

(c) 2 points

No, the particle cannot reach x = 0.5 m 1 point

The total energy is insufficient. 1 point

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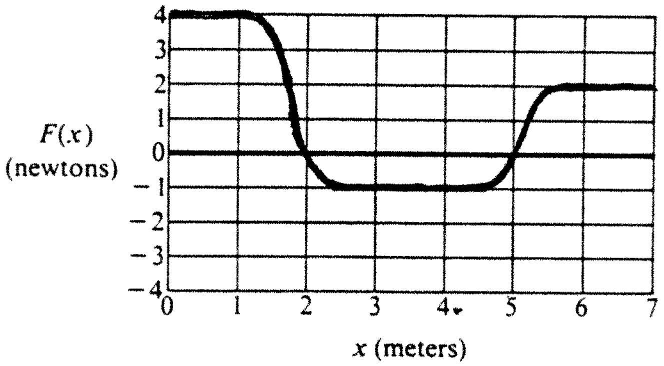
Mech. 2 (continued)

(d) 2 points

Yes, the particle can reach $x = 5.0$ m. 1 point

The total energy is sufficient 1 point

(e) 5 points



For rough slopes, or a shape indicating change between positive and negative values at 2 places 1 point

For having signs correct (i.e., positive values of F, then negative values, then positive values again) 1 point

For correct placement of zeros at $x = 2$ m and $x = 5$ m 1 point

For constant values (zero slopes) at appropriate places 1 point

For correct numerical values of F for regions of zero slope 1 point

(If no graph, +1 point was awarded for $F = dU/dx$, or +2 points were awarded for $F = -dU/dx$)

Mech. 3.

(a) 4 points

K.E. of rod at bottom of swing = P.E. of rod at top

$\frac{1}{2}I\omega^2 = mgh$ 1 point

$\frac{1}{2}\left(\frac{m\ell^2}{3}\right)\omega^2 = Mg\left(\frac{\ell}{2}\right)$ 1 point

$$\omega^2 = \frac{3g}{\ell} = \frac{(3)(10)}{1.2} = 25$$

$\omega = 5\ \frac{\text{radians}}{\text{sec}}$ 2 points

(1 point for numerical answer, 1 point for units of radians/second or seconds^{-1})

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Mech. 3 (continued)

(b) 4 points

K.E. before collision = K.E. after collision

$$\underbrace{\frac{1}{2}m_0 v_0{}^2}_{1\text{ pt.}} = \underbrace{\frac{1}{2}m_0 v^2}_{1\text{ pt.}} + \underbrace{\frac{1}{2}I\omega^2}_{1\text{ pt.}}$$ 3 points

$$\frac{1}{2}(1)(10)^2 = \frac{1}{2}(1)v^2 + \frac{1}{2}\left(\frac{3(1.2)^2}{3}\right)(5)^2$$

$$50 = \frac{1}{2}v^2 + 18$$

$$v^2 = 64$$

$v = 8$ m/s 1 point

(c) 4 points

$L = mvr \sin\theta$ <u>or</u> $L = mvr$ <u>or</u> $\vec{L} = \vec{r} \times \vec{P}$ 2 points

$L = (1)(10)(1.2)$

$L = 12\ \text{kg}\cdot\text{m}^2/\text{s}$ 2 points

(1 point for numerical answer, 1 point for correct units)

(d) 3 points

Angular momentum is conserved during collision, so

L (before) = L (after) 1 point

$m_0 v_0 \ell = m_0(v\cos\theta)\ell + I\omega$ 1 point

$12 = (1)(8)(1.2)\cos\theta + (1.44)(5)$

$12 = 9.6\cos\theta + 7.2$

$\cos\theta = 0.5$

$\theta = 60°$ 1 point

<u>Alternately</u>, angular momentum of ball after collision may be written $m_0 v\ell \sin\phi$, where ϕ is the angle between v and ℓ. The solution yields $\phi = 30°$, but $\theta = 90° - \phi = 90° - 30° = 60°$.

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E & M 1.

(a) 4 points

Gauss's law for $r > R$

$\int \vec{E} \cdot \vec{dA} = Q/\epsilon_0$	1 point
$E \int dA = Q/\epsilon_0$	1 point
$E(4\pi r^2) = Q/\epsilon_0$	1 point
$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$	1 point

(-1 point for answer in terms of R, -3 points for answer only without showing details)

(b) 5 points

Show or mention Gaussian surface as inside sphere with radius r. — 1 point

Charge enclosed by Gaussian surface

$$Q = \underbrace{\left(\frac{Q}{\frac{4}{3}\pi R^3}\right)}_{1\text{ pt.}} \underbrace{\left(\frac{4}{3}\pi r^3\right)}_{1\text{ pt.}} = \frac{Qr^3}{R^3} \qquad \text{2 points}$$

From Gauss's law,

$E(4\pi r^2) = \frac{q}{\epsilon_0} = \frac{Q}{\epsilon_0}\frac{r^3}{R^3}$	1 point
$E = \frac{Q}{4\pi\epsilon_0}\frac{r}{R^3}$	1 point

<u>Alternate solution</u> in terms of density ρ	(Alternate Points)
Show or mention Gaussian surface as above	(1 point)
$\rho = \frac{Q}{\frac{4}{3}\pi R^3}$	(1 point)
$q = \rho V = \rho\left(\frac{4}{3}\pi r^3\right)$	(1 point)
$E(4\pi r^2) = \frac{q}{\epsilon_0} = \frac{\rho}{\epsilon_0}\left(\frac{4}{3}\pi r^3\right)$	(1 point)
$E = \frac{\rho r}{3\epsilon_0}$	(1 point)

(-1 point for using ρ without defining it, -3 points for answer only without showing details)

E & M 1 (continued)

(c) 2 points

$V = \dfrac{Q}{4\pi\epsilon_0 R}$ — 2 points

(-1 point for answer in terms of r)

(d) 4 points

$V_{center} = V_{surface} + \underbrace{\int_R^0 \vec{E}\cdot\vec{dr}}_{1\ pt.}$ (1 point for sum) — 2 points

$= \dfrac{Q}{4\pi\epsilon_0 R} + \dfrac{Q}{4\pi\epsilon_0 R^3}\left[-\dfrac{r^2}{2}\right]_R^0$ — 1 point

$= \dfrac{Q}{4\pi\epsilon_0 R} + \dfrac{Q}{8\pi\epsilon_0 R} = \dfrac{3Q}{8\pi\epsilon_0 R}$ — 1 point

E & M 2.

(a) 4 points

$\Phi = BA$ (or $\Phi = \int\vec{B}\cdot d\vec{A}$ or $\Phi = \int\vec{B}\cdot d\vec{s}$) — 1 point

$\Phi = \underbrace{(2e^{-4t})}_{1\ pt.}\underbrace{(.09)}_{1\ pt.}$ — 2 points

$\Phi = 0.18e^{-4t}$ — 1 point

(However, no points were awarded for going from $\int\vec{B}\cdot d\vec{A}$ to a time integral such as $\int e^{-4t}\,dt$)

(b) 1 point

For statement or arrows indicating counterclockwise direction — 1 point

(c) 4 points

$\mathcal{E} = -\dfrac{d\Phi}{dt}$ — 1 point

$= 0.72e^{-4t}$ — 1 point

$i = \dfrac{\mathcal{E}}{R}$ — 1 point

$i = 0.12e^{-4t}$ — 1 point

E & M 2 (continued)

(d) 6 points

$P = i^2R$ (<u>or</u> $P = \mathcal{E}^2/R$ <u>or</u> $P = i\mathcal{E}$) 1 point

$W = \int_0^\infty i^2R\,dt$ (+1 point for indication of integral. If integral is shown, then +1 point for correct limits) 2 points

$W = \int_0^\infty 0.864\ e^{-8t}dt$ 1 point

$= 0.108\ e^{-8t} \Big|_0^\infty$ 1 point

$W = 0.108$ J 1 point

E & M 3.

(a) 3 points

Immediately after the switch is closed, there is no current in the inductor; its impedance is infinite.

$R_{tot} = 10 + 90 = 100\ \Omega$ 1 point

$i = \dfrac{\mathcal{E}}{R_{tot}} = \dfrac{20}{100} = 0.2$ A 1 point

The potential difference across the 90-ohm resistor, V_{90}, is given by

$V_{90} = iR = (0.2)(90) = 18$ V 1 point

(b) 3 points

$\mathcal{E} = -L\dfrac{di}{dt}$ 1 point

$\mathcal{E} = V_{90} = 18$ V 1 point

$\left|\dfrac{di}{dt}\right| = \dfrac{\mathcal{E}}{L} = \dfrac{18}{0.5} = 36$ A/s 1 point

(Students who used the emf of the battery, 20 V, and obtained $di/dt = 40$ A/s received 2 points)

E & M 3 (continued)

(c) 2 points

After a long time, the inductor acts as a short circuit

$R_{tot} = 10\ \Omega$ — 1 point

$i = \frac{\mathcal{E}}{R_{tot}} = \frac{20}{10} = 2\ \text{A}$ — 1 point

(d) 2 points

$\text{Energy} = \frac{1}{2}i^2L$ — 1 point

$= \frac{1}{2}(4)(0.5) = 1.0\ \text{J}$ — 1 point

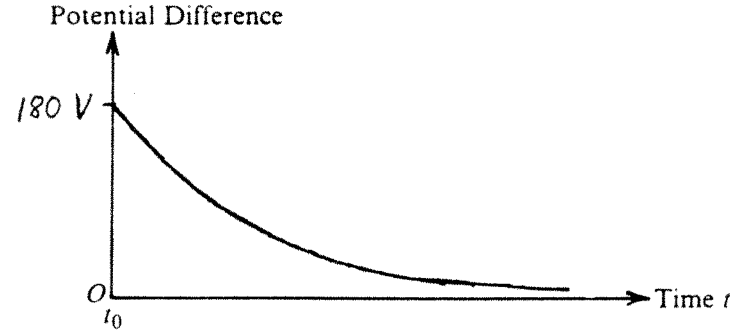
(e) 2 points

Immediately after the switch is opened, the current in the inductor is the same as in part (c). All the current must go through the 90-ohm resistor.

$V_{90} = V_{inductor} = iR = (2)(90)$ — 1 point

$= 180\ \text{V}$ — 1 point

(f) 2 points



For curve decreasing in value and concave upward — 1 point

For 180 V starting point or any carefully derived answer to part (e) — 1 point

Extra 1 point

For obtaining three out of five correct units for answers to parts (a) and (e) — 1 point