AP® Physics C
1984 Scoring Guidelines

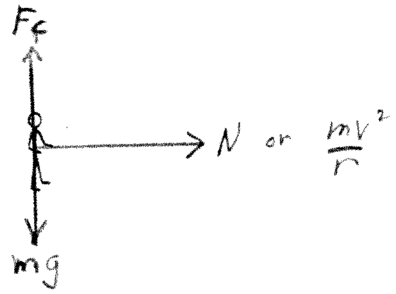
DRAFT

1984 Physics C

SOLUTION

Distribution of Points

Mech. 1. (a) 4 points



1 point for each of the three correctly identified forces	3 points
For no extraneous horizontal forces	1 point

(b) 5 points

$F = \frac{mv^2}{r}$ (1 point) and $v = r\omega$ (1 point) <u>or</u> $F = mr\omega^2$	2 points
$F = 50 \cdot 5 \cdot (2)^2 = 1000$ N (1 point for magnitude, 1 point for units)	2 points
The centripetal force is provided by the normal force.	1 point

(c) 4 points

$\Sigma F_y = 0$, therefore $F_f = mg$	2 points
$F_f = (50)(9.8) = 490$ N	1 point
The upward force is provided by friction	1 point

(d) 2 points

No	1 point
For correct justification involving recalculation with m replaced by 2m <u>or</u> by arguing that m cancels in appropriate equations, e.g., $\mu \cancel{m} r\omega^2 \geq \cancel{m} g$	1 point

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SOLUTION

Distribution of Points

Mech. 2 (a) 5 points

$$F_{grav} = G\frac{m_1 m_2}{R^2}$$ 1 point

$$a_{cent} = \frac{v_o^2}{R}$$ 1 point

$$G\frac{m_1 m_2}{R^2} = \frac{m_2 v_o^2}{R}$$ 1 point

$\therefore v_o^2 = \frac{GM}{R}$; but $R = 2R_E$ 1 point

$\therefore v_o = \sqrt{\frac{GM_E}{2R_E}}$ (i.e., for correct algebra) 1 point

(b) 4 points

Using conservation of momentum,

$(3m)v_o - (m)v_o = (4m)v$ 3 points

(2 points for correct values of momentums, and 1 point for minus sign. One point if only $p = mv$ given) 1 point

$\therefore v = \frac{1}{2}v_o$ (i.e., for correct algebra) 1 point

(c) 6 points

$$E_{mech} = \frac{1}{2}(4m)\left(\frac{1}{2}v_o\right)^2 - G\frac{(M_E)(4m)}{2R_E}$$ 5 points

Points in this equation include

1 point for knowing it's the sum of two energies

1 point for knowing the energies are kinetic and potential

1 point for correct substitution of 4m for mass

1 point for correct substitution of $2R_E$ for radius

1 point for the minus sign

$E_{mech} = -\frac{7}{4}\frac{GmM_E}{R_E}$ (i.e., for correct algebra) 1 point

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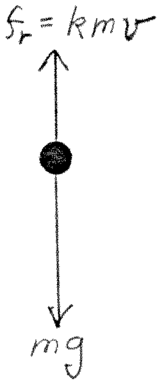
SOLUTION

Distribution of Points

Mech. 3. (a) 3 points



1 point for each of the correctly identified forces	2 points
For having f_r up, opposite to mg	1 point

(b) 4 points

$$\frac{dv}{dt} = g - kv$$ 4 points

Points in this equation include

1 point for knowing to use F = ma

1 point for using derivative $a = \frac{dv}{dt}$

1 point for F = mg - kmv (signs reversed if use up as +)

1 point for putting together properly

(c) 3 points

$$\left.\begin{aligned} &F = 0 \\ &mg = kmv_T \\ &v_T = \frac{g}{k} \end{aligned}\right\} \quad \underline{\text{or}} \quad \left\{\begin{aligned} &a = 0 \quad (\text{or } v = \text{const}) \\ &g = kv_T \\ &v_T = \frac{g}{k} \end{aligned}\right.$$

2 points (for the first two lines)

1 point (for the last line)

Answer also commonly obtained after part (d) by letting $t \to \infty$. This approach also awarded full credit.

SOLUTION

Distribution of Points

(d) 3 points

$\int \frac{dv}{g-kv} = \int dt$ (i.e., for any correct integral set up) — 1 point

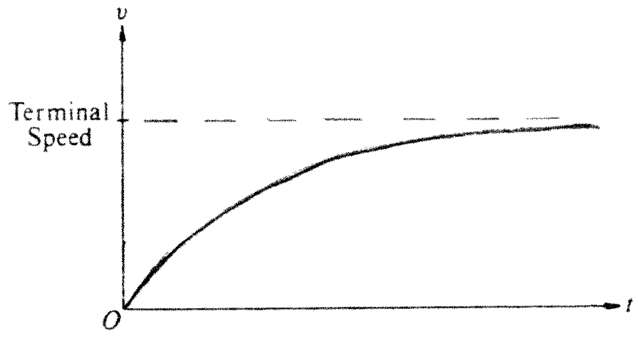
$-\frac{1}{k}\ln(g-kv) = t + C$ — 1 point

(i.e., for constant of integration, correct limits on integral, or matching initial condition)

$$\left.\begin{aligned} &t = 0 \text{ implies } v = 0 \\ &\therefore C = -\tfrac{1}{k}\ln g \\ &-\tfrac{1}{k}\ln(g-kv) = t - \tfrac{1}{k}\ln g \\ &v = \tfrac{g}{k}\left(1-e^{-kt}\right) \end{aligned}\right\} \text{ or } \left\{ \begin{aligned} &\text{Correct evaluation of} \\ &\int_0^v \frac{dv}{g-kv} = \int_0^t dt \end{aligned}\right.$$

1 point

(e) 3 points



For curve having v = 0 at t = 0 — 1 point

For curve being concave downward all the way — 1 point

For curve being asymptotic to v_T — 1 point

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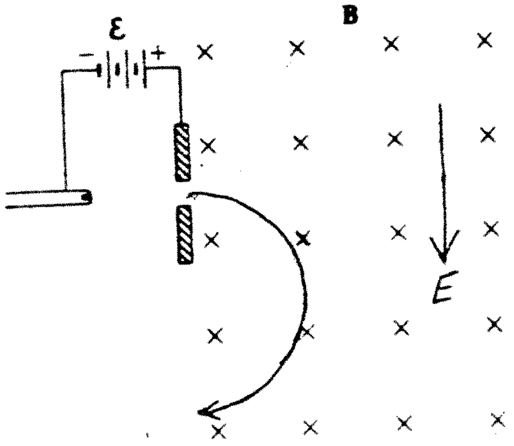
SOLUTION



Distribution of Points

E&M 1. (a) 3 points

$\underbrace{\frac{1}{2}mv^2}_{1\ point} = \underbrace{\mathcal{E}q}_{1\ point}$ — 2 points

$\mathcal{E} = \frac{mv^2}{2e}$ — 1 point

(b) 3 points

For curved path — 1 point

For downward path — 1 point

For correct curve beginning immediately upon leaving slit, i.e., not — 1 point

(c) 4 points

$\underbrace{qvB}_{1\ point} = \underbrace{\frac{mv^2}{r}}_{2\ points}$ (1 point for recognition of centripetal force, 1 point for correct form) — 3 points

$r = \frac{mv}{Be}$ — 1 point

(d) 5 points

i. $\underbrace{-qE}_{1\ point} = \underbrace{qvB}_{1\ point}$ — 2 points

$E = vB$ — 1 point

ii. For $\vec{E}$ vertical — 1 point

For $\vec{E}$ in the same direction as deflection due to $\vec{B}$ — 1 point

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SOLUTION

Distribution of Points

E&M 2. (a) 3 points

$V_1 = E_1 a$ and $V_2 = E_2 b$	1 point
$V_1 = V_2$, so $E_1 a = E_2 b$	1 point
$\therefore \frac{E_1}{E_2} = \frac{b}{a}$	1 point

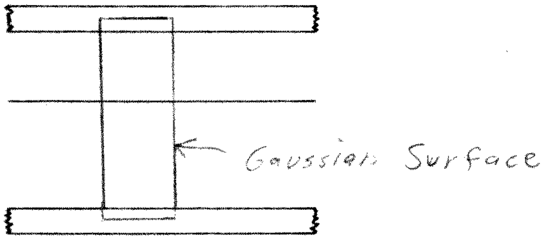
(b) 5 points

$\oint \vec{E}\cdot d\vec{A} = q_{in}/\epsilon_0$ (i.e., for correct statement of Gauss's law)	1 point
$\oint \vec{E}\cdot d\vec{A} = E_1 A + E_2 A$	2 points

(i.e., 1 point for no flux on the sides and 1 point for recognizing two fields involved)

$q_{in} = \sigma A$	1 point
$\therefore E_1 A + E_2 A = \sigma A/\epsilon_0$	
$E_1 + E_2 = \sigma/\epsilon_0$	1 point

(c) 4 points



Correct Gaussian surface	1 point
$\vec{E} = 0$ in a conductor	1 point
Since $\oint \vec{E}\cdot d\vec{A} = 0$, $q_{in} = 0$	1 point
$\therefore \oint \vec{E}\cdot d\vec{A} = \sigma_1 A + \sigma_2 A + \sigma A = 0$	
$\sigma_1 + \sigma_2 = -\sigma$	1 point

<u>or</u>

Since there was some ambiguity about whether the σ's included the sign or meant just absolute value, full credit also given for *obtaining* $\sigma_1 + \sigma_2 = \sigma$

SOLUTION

Distribution of Points

(d) 3 points

$E_1 a = E_2 b$, $E_1 + E_2 = \sigma/\epsilon_0$ (i.e., to assemble these equations) — 1 point

$E_1 = \dfrac{\sigma b}{\epsilon_0 (a+b)}$ or $E_2 = \dfrac{\sigma a}{\epsilon_0 (a+b)}$ (i.e., to find a field) — 1 point

$V = E_1 a$ or $V = E_2 b$

$\therefore V = \dfrac{\sigma a b}{\epsilon_0 (a+b)}$ — 1 point

Alternate Solutions to (d) - Also worth full credit

1) $E_1 + E_2 = \sigma/\epsilon_0$

$E_1 = V/a$, $E_2 = V/b$

$\therefore \dfrac{V}{a} + \dfrac{V}{b} = \dfrac{\sigma}{\epsilon_0}$

$V = \dfrac{\sigma a b}{\epsilon_0 (a+b)}$

2) This situation is the same as two parallel-plate capacitors in parallel, so

$C = C_1 + C_2 = \dfrac{\epsilon_0 A}{a} + \dfrac{\epsilon_0 A}{b}$, where A is the plate area

But $C = \dfrac{Q}{V} = \dfrac{\sigma A}{V}$

$\therefore \dfrac{\sigma A}{V} = \epsilon_0 A \left(\dfrac{1}{a} + \dfrac{1}{b} \right)$

$V = \dfrac{\sigma a b}{\epsilon_0 (a+b)}$

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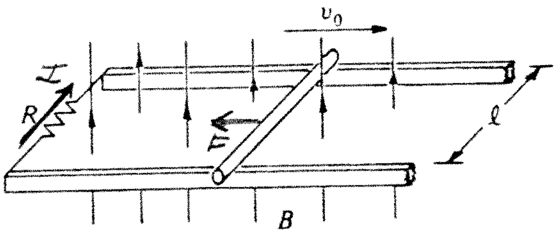
SOLUTION

Distribution of Points



E&M 3. (a) 2 points

For correct identification of current in diagram — 2 points

(b) 4 points

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

$$= -\frac{d(BA)}{dt} = -B\frac{d(\ell x)}{dt}$$

$$\mathcal{E} = -B\ell v_0$$

(2 points also awarded for beginning with $E = B\ell v_0$, without derivation) — 1 point

$$IR = -B\ell v_0$$ — 1 point

$$I = -\frac{B\ell v_0}{R}$$ — 1 point

However, sign was ignored in grading. In essence it was $|I| = \frac{B\ell v_0}{R}$ that was looked for. Full credit also given for using v instead of v_0.

(c) 2 points

For correct identification of force to left on diagram — 2 points

(d) 2 points

$$F = I\ell B$$

$$= \left(\frac{B\ell v_0}{R}\right)\ell B$$ — 1 point

$$F = \frac{B^2\ell^2 v_0}{R}$$ — 1 point

SOLUTION

Distribution of Points

Alternate Solution — Alternate points

$F = ma = m\frac{dv}{dt}$

$F(t) = m\frac{d}{dt}\left(v_0 e^{-\frac{B^2\ell^2 t}{Rm}}\right) = m\left(-\frac{B^2\ell^2 v_0}{R} e^{-\frac{B^2\ell^2 t}{Rm}}\right)$ (1 point)

$F(0) = -\frac{B^2\ell^2 v_0}{R}$ (1 point)

If the answer was left as F(t), rather than F(0), full credit was still awarded.

(e) 3 points

$P = I^2R$ — 1 point

$I = \frac{B\ell v}{R}$ (from part (b), except cannot use v_0)

$\therefore P = \left(\frac{B\ell v}{R}\right)^2 R$ — 1 point

$P = \frac{B^2\ell^2}{R}\left(v_0 e^{-\frac{B^2\ell^2 t}{mR}}\right)^2 = \frac{B^2\ell^2 v_0^2}{R} e^{-\frac{2B^2\ell^2 t}{mR}}$ — 1 point

Either form of the last two steps was acceptable.

Alternate solutions — Alternate points

1) $P = Fv$

$P = \left(\frac{B^2\ell^2 v}{R}\right)v$ or $P = (I\ell B)v = \left(\frac{B\ell v}{R}\right)\ell B v$ (1 point)

$P = \frac{B^2\ell^2 v^2}{R}$ (1 point)

$P = \frac{B^2\ell^2}{R}\left(v_0 e^{-\frac{B^2\ell^2 t}{mR}}\right)^2 = \frac{B^2\ell^2 v_0^2}{R} e^{-\frac{2B^2\ell^2 t}{mR}}$ (1 point)

Again either form of the last two steps was acceptable. If $F = \frac{B^2\ell^2 v_0}{R}$ was substituted at 2nd step, a maximum of 2 points given, because it meant that a factor of 2 was missing from the exponent.

SOLUTION

Distribution of Points

2) $P = \frac{dW}{dt} = \frac{d}{dt}\left(\frac{1}{2}mv^2\right)$ (1 point)

$= mv\frac{dv}{dt} = mv\left(-\frac{B^2\ell^2}{mR}v\right)$ (1 point)

$= -\frac{B^2\ell^2}{R}v^2$

(rest of solution as in previous alternate; minus sign was ignored) (1 point)

(f) 2 points

$P = \frac{dW}{dt}$ or $W = \int_0^\infty P(t)\,dt$ 1 point

$W = \int_0^\infty \frac{B^2\ell^2 v_0^2}{R} e^{-\frac{2B^2\ell^2 t}{mR}} dt$

$W = \frac{1}{2}mv_0^2$ 1 point

If student used a form for P(t) missing the factor of 2 in the exponent, full credit was given for answer of mv_0^2 (correct calculation), but only 1 point was given for $\frac{1}{2}mv_0^2$ (incorrect calculation, or "forcing" the answer).