AP® Physics C
1978 Scoring Guidelines

The materials included in these files are intended for use by AP teachers for course and exam preparation in the classroom; permission for any other use must be sought from the Advanced Placement Program®. Teachers may reproduce them, in whole or in part, in limited quantities, for face-to-face teaching purposes but may not mass distribute the materials, electronically or otherwise. These materials and any copies made of them may not be resold, and the copyright notices must be retained as they appear here. This permission does not apply to any third-party copyrights contained herein.

78C

b) Partial credit:

Nodes at either end of a system (can be pictorial) leads to	3

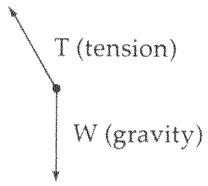
$$L = \frac{n}{2}\lambda$$

$$\lambda = \frac{2L}{n}$$

1978 C: Mech.-1

Solution	*Distribution of Points*

a) 3 points



Each force with correct direction	1
If no extraneous forces were shown	1

b) 7 points

$T \cos\theta = mg$	2
(1 point for any use of $F = ma$)	
$T \sin\theta = ma$	1
$= m\omega^2 r$	1
$= m\omega^2 (A + \ell \sin\theta)$	1
$mg \tan\theta = m\omega^2 (A + \ell \sin\theta)$	1
$\omega = \sqrt{\dfrac{g \tan\theta}{A + \ell \sin\theta}}$	1

Alternate:

$\tan\theta = \dfrac{m\omega^2 r}{mg} = \dfrac{\omega^2 r}{g}$	4
$g \tan\theta = \omega^2 (A + \ell \sin\theta)$	2
etc.	

c) 5 points

$W = \Delta E$ (or any mention of work-energy theorem)	1
$\Delta E = \Delta K + \Delta U$	1
$\Delta K = \frac{1}{2} mv^2$ per rider	1
$\Delta U = mg\ell (1 - \cos\theta)$ per rider	1
$W = 6 (\frac{1}{2} mv^2 + mg\ell (1 - \cos\theta))$	1

1978 C: Mech.-2

Solution	*Distribution of Points*
a) 4 points	
$L_{\text{before collision}} = L_{\text{after collision}}$	1
$L_{\text{before}} = I\omega = (\frac{1}{3} M_1 \ell^2)\,\omega$	1
$L_{\text{after}} = \ell M_2 v$	1
$v = M_1 \ell\omega / 3M_2$	1
b) 3 points	
Most common solution employed the concept of center of mass:	
$P_{CM} = M_1 v_{CM} = M_1 (\omega\ell/2) = P_{\text{system}}$	3
Full credit also given for direct integration:	

$$\left[\begin{array}{l} P = \int v\, dM, \text{ where } dM = \rho\, dV = \rho A\, dr \\ \text{and } v = r\omega \text{ thus} \\ P = \int_0^{\ell} r\omega\, \rho A\, dr = \omega\rho A \int_0^{\ell} r\, dr = \omega\rho A\, \ell^2/2 \\ \text{Thus, since } M_1 = \rho A l,\ P = \omega\ell M_1/2 \end{array}\right]$$

c) 2 points	
$P_{\text{after}} = M_2 v_{\text{after}}$	2
where from part a, $v_{\text{after}} = M_1\ell\omega/3M_2$ $= \frac{\omega M_1 \ell}{3}$	
d) There is a net external force acting on the system at the pivot P. Hence, the linear momentum is *not* conserved.	3
e) Since the net external force in the plane of rotation acts at the pivot P, the net torque about the pivot P is zero. Hence, angular momentum is conserved.	3

1978 C: Mech.-3

Solution	*Distribution of Points*
a) 4 points	
$F = -kx$	1
$x = L\theta$ (or $\sin\theta$)	1
$F = -kL\theta$ Torque $= FL$ ($\cos\theta$ or 1)	1
Torque $= -kL^2\theta$ (or $\sin\theta \times \cos\theta$)	1

b) 4 points

Torque $= I\alpha$	2
$I = 2mL^2$	2
$\alpha = \dfrac{T}{I} = -\dfrac{k}{2m}\theta$	

c) 3 points

$\alpha = \dfrac{d^2\theta}{dt^2}$	1
Thus, $\dfrac{d^2\theta}{dt^2} = -\dfrac{k}{2m}\theta$	2

d) 4 points

$\theta = \theta_0 \cos\left(\sqrt{\dfrac{k}{2m}}\, t\right)$	4

or any equivalent solutions with appropriate constants

1978 C: E & M-1

Solution	*Distribution of Points*
a) 4 points	
From energy consideration	
$\Delta PE = \Delta KE$	
$eV_g = \frac{1}{2} mv_e^2$	3
$v_e = \sqrt{2eV_g/m}$	1
b) 5 points	
Again from energy consideration	
Total energy upon entering = total energy at y_{max}	
$\frac{1}{2} mv_e^2 = \frac{1}{2} mv_e^2 \cos^2\theta + e\dfrac{V_p}{d} y_{max}$	3
Thus, $y_{max} = d\dfrac{V_g}{V_p}\sin^2\theta$	2
(Full credit also given for alternate correct solution, e.g., using Newton's Laws or a modified work-ΔKE attack)	

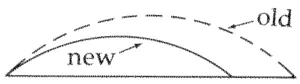
c) 3 points

The speed at impact is unchanged. 1

The magnetic force is always at 90° to the displacement (velocity) and thus does no work. 2

Hence, the speed depends only on height y.

d) 3 points



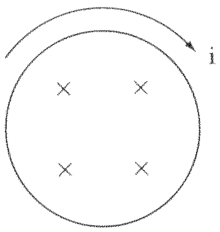
2

Along the old path, the magnetic force on an electron always has a downward component; thus y_{max} is lower and the time of flight shorter. Further, since the magnetic force has a positive component in the x direction during the first half and a negative component during the second half, the range is shorter because the time of flight is shorter. 1

1978 C: E & M-2

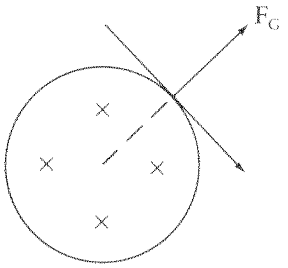
	Solution	*Distribution of Points*

a) 3 points



Since the magnetic flux through the loop is decreasing, Lenz's Law states that the flux associated with the induced current will be increasing through the loop. Hence, a clockwise current. 2 1

b) 3 points



Expand 1

At every point the force is outward since 2

$$F_G = i\vec{\ell} \times \vec{B}$$

c) 4 points

$$Q = \int_0^\infty I\,dt = \int_0^\infty \frac{V}{R}\,dt$$ 1

$$V = -\frac{d\theta}{dt} = -A\frac{dB}{dt} = \alpha A B_0 e^{-\alpha t}$$ 2

$$\text{Thus, } Q = \frac{\alpha B_0 A}{R}\int_0^\infty e^{-\alpha t}\,dt = \frac{AB_0}{R}$$ 1

d) 5 points

$H = \int_0^\infty I^2R\,dt = \int_0^\infty \frac{V^2}{R}\,dt$	2
From c) $V = \alpha AB_0e^{-\alpha t}$	1
Thus, $H = \frac{A^2\alpha^2B_0^2}{R}\int_0^\infty e^{-2\alpha t}\,dt$	1
or	
$H = A^2B_0^2\alpha/2R$	1

1978 C: E & M-3

Solution	*Distribution of Points*
a) 3 points	
$\int\vec{E}\cdot d\vec{s} = Q/\epsilon_0$	1
$\int\vec{E}\cdot d\vec{s} = E_0 \cdot$ area of sphere	1
$Q = \epsilon_0 \cdot E_0 \cdot 4\pi a^2$	1
(Only 1 point was awarded if Gauss's Law was not used.)	
b) 3 points	
$E = E_0\,a^2/r^2$	
$1/r^2$ dependence	1
$E = E_0$ when $r = a$	1
Expression in terms of E_0 a and r	1
No work was required, but partial credit was awarded when some correct work was shown.	
c) 3 points	
$V = E_0a^2\left(\frac{1}{a} - \frac{1}{b}\right)$	
No work was required.	
1 point off for wrong sign	
1 point off for not expressing answer in terms of E_0, a, and b	
d) 3 points	
$U = \frac{1}{2}QV$ or $U = \frac{1}{2}CV^2$ and $C = Q/V$	1
Substitution for Q or V from above	1
Answer expressed in terms of E_0, a, and b	1
$U = \frac{1}{2}\epsilon_0 E_0 4\pi a^2 \cdot E_0a^2\left(\frac{1}{a} - \frac{1}{b}\right) = 2\pi\epsilon_0E_0^2\left(a^3 - \frac{a^4}{b}\right)$	

e) 3 points

dU/da = 0	1
Correct differentiation	1
Correct algebra and answer	1

$$3a^2 - \frac{4a^3}{b} = 0 \Longrightarrow a = \tfrac{3}{4}\, b$$