



AP[®] Physics C 1982 Scoring Guidelines

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*Solution**Distribution
of Points*

1. a) 5 points

During the slide, mechanical energy is conserved,

1 point

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

2 points

Substituting $H = L \cdot \sin \theta = 3$ meters gives

1 point

$$v = \sqrt{60} \text{ m/s}$$

1 point

b) 6 points

Between release and bottom stopping point,
 $\Delta K = K_f - K_o = 0$. Thus $\Delta U = 0$

$$\Delta U_g + \Delta U_{\text{spring}} = 0 \text{ or } |\Delta U_g| = |\Delta U_{\text{spring}}| \quad 1 \text{ point}$$

$$|\Delta U_g| = mgh = mg\ell \sin \theta \text{ with } \ell = x + 6 \quad 2 \text{ points}$$

$$\Delta U_{\text{spring}} = \frac{1}{2}kx^2 \quad 2 \text{ points}$$

Substitute and solve to get $100(x + 6) = 100x^2$
 or $x^2 - x - 6 = 0$ whose positive root is $x = 3$ meters 1 point

c) 4 points

No; at contact, the spring does not exert any force. 1 point

As the spring compression is increased, the spring force increases. 1 point

v will be maximum when the acceleration is zero. This occurs when the net force is zero. 1 point

Equating the component of gravity and the spring force: $mg \sin \theta = kx$

Solving for x gives $x = \frac{1}{2} \text{ m}$ 1 point

Total 15 points

2. a) 5 points

The kinetic energy is given by $K = \frac{1}{2}Mv^2$ 1 point

Substituting $v = \sqrt{v_0^2 - \frac{Rt}{M}}$ gives $K = \frac{1}{2}M(v_0^2 - \frac{Rt}{M})$ 1 point

To find the time rate of change of kinetic energy, we differentiate, getting $\frac{dK}{dt}$ 1 point

$$\frac{dK}{dt} = \frac{1}{2}M(0 - \frac{R}{M}) = -\frac{R}{2} \quad 2 \text{ points}$$

b) 3 points

Setting v (or K) equal to zero: 1 point

$$v_0^2 = \frac{RT}{M} \text{ . Solving for } T \quad 1 \text{ point}$$

$$\text{gives } T = \frac{Mv_0^2}{R} \quad 1 \text{ point}$$

c) 4 points

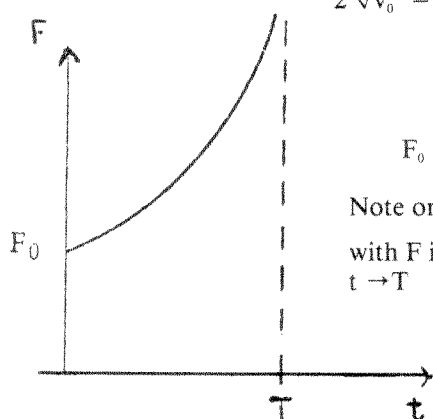
Since $a = \frac{dv}{dt}$, we differentiate to get 2 points

$$a = \frac{1}{2}(v_0^2 - \frac{Rt}{M})^{-\frac{1}{2}}(-\frac{R}{M}) \quad 2 \text{ points}$$

d) 3 points

Since $F = Ma$, we have $F = \frac{-R}{2\sqrt{v_0^2 - Rt/M}}$

1 point



$$F_0 = \frac{R}{2v_0}$$

Note or label nonzero F_0 at $t = 0$
with F increasing without limit as
 $t \rightarrow T$

1 point

1 point

Total 15 points

82 M 3. a) 5 points

Using $L = I\omega$

2 points

with $I = \sum mr^2 = (2m)\ell^2 + m(2\ell)^2$

1 point

$$= 6m\ell^2$$

1 point

we substitute to get $L = 6m\ell^2\omega_0$

1 point

b) 5 points

The frictional force will be found by $f = \mu mg$

1 point

and the torque will be given by $\Gamma = \sum \mathbf{R} \times \mathbf{f}$

2 points

Combining gives $\Gamma = -[\ell(\mu \cdot 2mg) + 2\ell(\mu \cdot mg)]$

1 point

$$= -4\mu mg\ell$$

1 point

c) 5 points

Because the frictional torque is constant, the angular acceleration is constant and

$$\omega = \omega_0 + \alpha t$$

1 point

Since $\Gamma = I\alpha$

1 point

$$\alpha = \frac{\Gamma}{I} = \frac{-4\mu mg\ell}{6m\ell^2} = -\frac{2\mu g}{3\ell}$$

1 point

Setting ω equal to zero and solving for time

1 point

gives $t = -\frac{\omega_0}{\alpha} = \frac{3\omega_0\ell}{2\mu g}$

1 point

Total 15 points

1982 C: E&M

1. a) 5 points

The potential V due to a point charge is $V = kq/R$

1 point

Because potential adds as a scalar quantity, the total $V = V_1 + V_2 + V_3$

1 point

$$= \frac{2kq}{\sqrt{a^2 + x^2}} - \frac{kq}{x}$$

1 point

To find the point where $V = 0$, solve and find

$$\frac{1}{x} = \frac{2}{\sqrt{a^2 + x^2}}$$

1 point

$$a^2 + x^2 = 4x^2$$

$$\therefore x = \pm a/\sqrt{3}$$

1 point

b) 7 points

In general, $|\vec{E}| = E = kq/R^2$ for a point charge.

1 point

By symmetry, $E_y = 0$

2 points

$$E_x = E \cos \theta$$

1 point

$$\text{with } \cos \theta = x/\sqrt{a^2 + x^2}$$

1 point

$$\therefore E_x = E_{1x} + E_{2x} + E_{3x}$$

1 point

$$= \frac{2kq x}{(a^2 + x^2)^{3/2}} - \frac{kq}{x^2}$$

1 point

c) 3 points

By definition, $\phi_E = \oint \vec{E} \cdot d\vec{A}$ and $\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\epsilon_0}$ using Gauss's law.

2 points

In this situation, $Q_{\text{enclosed}} = +q + q - q = q$

$$\therefore \phi_E = q/\epsilon_0 = 4\pi kq$$

1 point

Total 15 points

2. a) 3 points

Ampere's Law states that for any closed path, $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 i_{\text{enclosed}}$

1 point

For a circular path of radius r , centered on the wire, $\oint \vec{B} \cdot d\vec{\ell} = B \cdot 2\pi r$

1 point

$$\text{Solving for } B \text{ gives } B = \frac{\mu_0 i}{2\pi r}$$

1 point

b) 6 points

Since B is not constant, the flux must be calculated by integration over the loop, using

$$\Phi_B = \oint \vec{B} \cdot d\vec{A}$$

2 points

The integral can be evaluated by dividing the loop into narrow strips, all of width ℓ , and integrating over r :

$$\Phi_B = \int_a^{a+b} B(r)\ell \, dr$$

1 point

$$\text{Substituting } B = \frac{\mu_0 i}{2\pi r} \text{ gives } \Phi_B = \frac{\mu_0 i \ell}{2\pi} \int_a^{a+b} \frac{dr}{r}$$

1 point

$$\text{Evaluating the integral gives } \Phi_B = \frac{\mu_0 i \ell}{2\pi} \ln r \Big|_a^{a+b}$$

1 point

and substituting the limits gives

$$\Phi_B = \frac{\mu_0 i \ell}{2\pi} \ln \frac{a+b}{a}$$

1 point

c) 6 points

By Lenz's Law, the induced current i must oppose the change that produced it.

1 point

Since at time $t = \pi/\omega$, the current in the long wire is produced by a field through the loop that is changing from out of the page to into the page, the induced current must cause a field through the loop that is directed out of the page: it must be a counter-clockwise current.

1 point

The induced emf follows from Faraday's Law:

$$\mathcal{E} = -d\Phi_B/dt$$

1 point

From part b), $\Phi_B = \frac{\mu_0 \ell}{2\pi} \ln \frac{a+b}{a} i_m \sin \omega t$

1 point

and so $-\frac{d\Phi_B}{dt} = -\frac{\mu_0 \ell}{2\pi} \ln \frac{a+b}{a} i_m \cos \omega t$

1 point

When $t = \pi/\omega$, $\cos \omega t = \cos \pi = -1$

and so

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = \frac{\mu_0 i_m \ell \omega}{2\pi} \ln \frac{a+b}{a}$$

1 point

Total 15 points

3. a) 3 points

After the switch has been closed for a long time, the current will have ceased changing, so the inductor voltage $V_L = L \frac{di}{dt} = 0$. Therefore, the inductor can be ignored in this part of the problem.

1 point

The current can be calculated by using Ohm's Law, $V = iR$

1 point

Since the total resistance is just R , $i_A = \mathcal{E}/R$

1 point

b) 2 points

After the switch is opened, the two resistors are in series, and their combined resistance is $2R$.

1 point

The current is $i_B = \mathcal{E}/2R$

1 point

c) 3 points

When $t = 0$, the current is $i_A = \mathcal{E}/R$

It decreases after the switch has been opened.

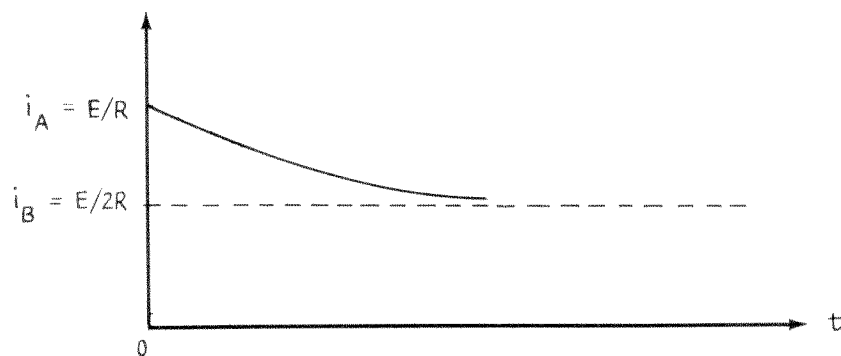
1 point

Eventually it approaches the limiting value $i_B = \mathcal{E}/2R$

1 point

The decrease is exponential, as shown below.

1 point



Solution

*Distribution
of Points*

d) 4 points

The battery emf must equal the sum of the potential differences across the inductor:

$$\mathcal{E} = V_R + V_L.$$

1 point

The sum of the potential differences across the resistors is $V_R = 2Ri$

1 point

The potential difference across the inductance is $V_L = L \frac{di}{dt}$

1 point

The differential equation for the current is

$$\text{therefore } \mathcal{E} = 2Ri + L \frac{di}{dt}$$

1 point

e) 3 points

The expression for $i(t)$ must involve an exponential function of the form $e^{-t/T}$

1 point

The time constant $T = L/2R$

1 point

The solution must be the sum of a constant and a term involving $e^{-2Rt/L}$. It must satisfy the boundary conditions $i(0) = \mathcal{E}/R$, and $i(t) \rightarrow \mathcal{E}/2R$ as $t \rightarrow \infty$

$$\text{By inspection, } i(t) = \frac{\mathcal{E}}{2R} (1 + e^{-2Rt/L})$$

1 point

Total 15 points