



AP[®] Physics C 1983 Scoring Guidelines

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1983 Physics C Solutions

Mechanics

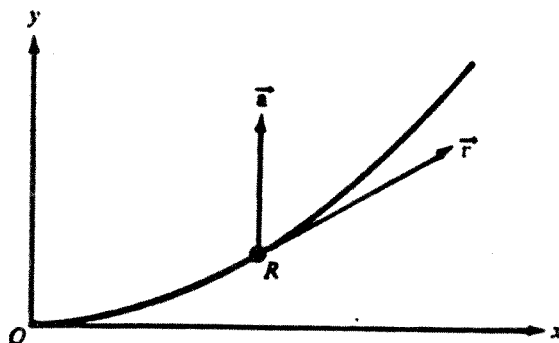
Mech. 1. (a) 9 points

i. The velocity vector is tangent to the path.

Since $r_x = \text{constant}$, $a_x = 0$, and the acceleration vector has only a positive y -component as shown below.

1 point

2 points



ii. The y -component of velocity is $v_y = \frac{dy}{dt}$

1 point

By the chain rule, $\frac{dy}{dt} = \frac{dy}{dx} \frac{dx}{dt}$

1 point

Since $y = \frac{1}{2}x^2$, $\frac{dy}{dx} = x$

1 point

and $v_y = x \frac{dx}{dt} = Cx$

1 point

iii. The acceleration is given by $a_y = \frac{dv_y}{dt}$

1 point

so $a_y = C \frac{dx}{dt} = C^2$

1 point

Alternate solution for ii and iii:

(Alternate points)

ii. Since $y = \frac{1}{2}x^2$ and $x = Ct$, $y = \frac{1}{2}C^2t^2$

(1 point)

Thus $v_y = \frac{dy}{dt} = C^2t$

(2 points)

Since $Ct = x$, $v_y = Cx$

(1 point)

iii. $a_y = \frac{dv_y}{dt} = \frac{d}{dt}(C^2t) = C^2$

(2 points)

Distribution
of points

(b) 6 points

i. The speed is given by $v = \sqrt{v_x^2 + v_y^2}$ 1 pointBy the chain rule, $v_y = \frac{dy}{dt} = \frac{dy}{dx} \frac{dx}{dt} = x v_x$ 1 point

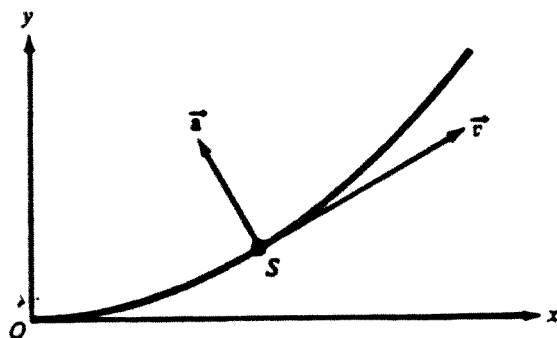
$$\text{So } v = \sqrt{v_x^2(1+x^2)} = \sqrt{\frac{C^2}{1+x^2}(1+x^2)} = C$$

1 point

ii. Again the velocity vector is tangent to the path. Since the speed is constant, there is no component of \vec{a} along the path, so \vec{a} is centripetal, perpendicular to \vec{v} as shown.

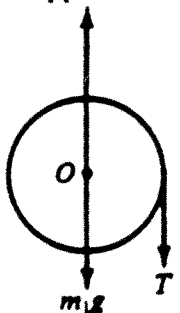
1 point

2 points



Mech. 2. (a) 4 points

Support Force



On the block, the forces are weight = m_2g and tension T

1 point

1 point

On the disk, there are tension T and the pair: m_1g and supporting force

1 point

1 point

(b) i. and ii. 8 points

On the disk, torque = $\Gamma = I\alpha = \frac{1}{2}m_1R^2\alpha$

1 point

with $\Gamma = T \cdot R$ and

1 point

acceleration of the block = $a = R\alpha$, so $\alpha = a/R$

1 point

For the block, $F_{\text{net}} = m_2a$

1 point

with $F_{\text{net}} = m_2g - T$

1 point

Solving simultaneously gives

1 point

$$a = \frac{2m_2g}{2m_2 + m_1} \text{ and}$$

1 point

$$T = \frac{m_1m_2g}{2m_2 + m_1}$$

1 point

(b) iii. 3 points

By definition, angular momentum $L = I\omega$

1 point

Angular velocity $\omega = \alpha t$

1 point

Since $I = \frac{1}{2} m_1 R^2$ and $\alpha = \frac{a}{R}$,

$$L = \frac{1}{2} m_1 R^2 \cdot \frac{a}{R} \cdot t = \frac{1}{2} m_1 a R t$$

Substituting the expression for a from part (b) gives

$$L = \frac{m_1 m_2 g R t}{2m_2 + m_1}$$

1 point

Mech. 3. (a) 11 points

i. Energy is conserved as the particle slides down the sphere, so

$$K + U = \text{constant},$$

2 points

where gravitational potential energy $U = mgh$.

1 point

If h is measured from the center of this sphere,

$$0 + mgR = K + mgR \cos \theta$$

1 point

so that

$$K = mgR(1 - \cos \theta).$$

1 point

ii. The centripetal acceleration is

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

1 point

From part i:

$$\frac{1}{2} m v^2 = mgR(1 - \cos \theta)$$

1 point

$$\text{so } a_c = \frac{v^2}{R} = 2g(1 - \cos \theta)$$

1 point

iii. The only force with a tangential component is the gravitational force mg . As the diagram shows, its tangential component is $mg \sin \theta$

By Newton's second law, $ma_T = mg \sin \theta$, so

$$a_T = g \sin \theta$$

1 point

(b) 4 points

The particle leaves the sphere when the normal force N has decreased to zero.

2 points

At that point the radial component of the weight provides the centripetal acceleration, so

$$mg \cos \theta = ma_c$$

1 point

$$\text{Therefore } g \cos \theta = a_c = 2g(1 - \cos \theta)$$

$$\text{and } \cos \theta = \frac{2}{3}$$

$$\text{or } \theta = \arccos \frac{2}{3}$$

1 point

1983 Physics C Solutions

Electricity and Magnetism

Distribution
of points

E&M 1. (a) 6 points

Gauss's Law states that

$$\Phi = \oint \vec{E} \cdot d\vec{A} = \frac{q(\text{enclosed})}{\epsilon_0}$$

2 points

Apply it to a sphere of radius r ($a < r < b$).

Since \vec{E} is uniform and directed outward,

$$\oint \vec{E} \cdot d\vec{A} = E \cdot (\text{area of sphere}) = E \cdot 4\pi r^2$$

2 points

The enclosed charge is Q .

1 point

$$\text{Therefore } E = \frac{Q}{4\pi\epsilon_0 r^2}$$

1 point

(b) 5 points

The potential V_0 equals the potential difference between the spheres, which may be expressed as

$$\int \vec{E} \cdot d\vec{r}$$

1 point

$$\text{Therefore } V_0 = \frac{Q}{4\pi\epsilon_0} \int_a^b \frac{dr}{r^2}$$

1 point

Evaluating the integral gives

$$V_0 = \frac{Q}{4\pi\epsilon_0} \left[-\frac{1}{r} \right]_a^b$$

2 points

$$\text{or } V_0 = \frac{Q}{4\pi\epsilon_0} \left(\frac{1}{a} - \frac{1}{b} \right) = \frac{Q}{4\pi\epsilon_0} \cdot \frac{b-a}{ab}$$

1 point

(c) 4 points

By definition

$$C = \frac{Q}{V_0}$$

2 points

Substitution of the expression for V_0 from part (b) gives

$$C = \frac{Q}{\frac{Q}{4\pi\epsilon_0} \cdot \frac{b-a}{ab}} = \frac{4\pi\epsilon_0 ab}{b-a}$$

2 points

E&M 2. (a) 4 points

Initially there is no potential drop across the capacitor, so

$$\mathcal{E} = i_0 R$$

2 points

$$\text{and } \mathcal{E} = 10(10^{-6})(2 \times 10^6) = 20 \text{ volts}$$

2 points

Distribution
of points

(b) 5 points

Current i and charge Q are related by

$$i = \frac{dQ}{dt} \text{ or } Q = \int i dt$$

1 point

$$\text{so that } Q = \int i_0 e^{\left(\frac{-t}{6}\right)} dt$$

1 point

Evaluation of the antiderivative gives

$$Q = -6i_0 e^{\left(\frac{-t}{6}\right)} + C$$

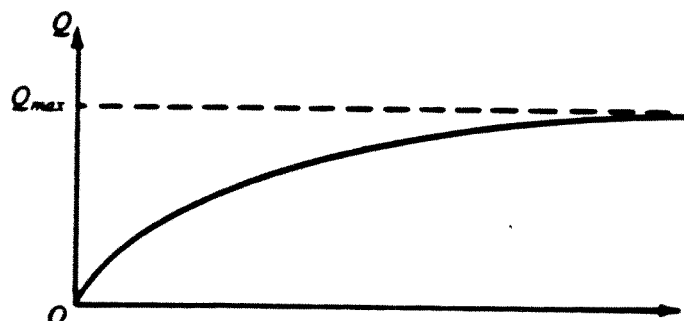
2 points

Since $Q = 0$ when $t = 0$, the constant of integration C must equal $6i_0$, and

$$Q = 6i_0 \left(1 - e^{\left(\frac{-t}{6}\right)}\right)$$

1 point

(c) 3 points



$$Q = 0 \text{ at } t = 0$$

1 point

$$\text{As } t \rightarrow \infty, Q \rightarrow Q_{\max}$$

1 point

Exponential shape

1 point

(d) 3 points

For a charging or discharging capacitor, the time constant is RC .

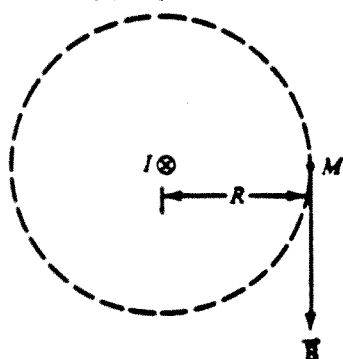
1 point

Here, the numerical value of the time constant is 6 seconds, so

$$C = \frac{6}{R} = \frac{6}{2 \times 10^6} = 3 \times 10^{-6} \text{ farads}$$

2 points

E&M 3. (a) 6 points



The field at M is down.
 The path of integration
 is a circle around I .
 Ampere's Law states that
 $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$
 Applied to the circular
 path, it gives
 $B \cdot 2\pi R = \mu_0 I$
 so that $B = \frac{\mu_0 I}{2\pi R}$

Distribution
of points

1 point

1 point

2 points

1 point

1 point

(b) 9 points

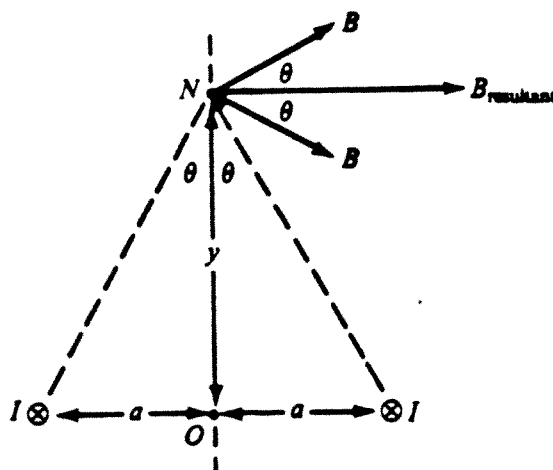
i. 3 points

At point O , the B field is zero
 because the field caused by
 the right current cancels the
 field caused by the left current.

2 points

1 point

ii. 6 points



Each current contributes a field vector of magnitude

$$B = \frac{\mu_0 I}{2\pi \sqrt{a^2 + y^2}}$$

1 point

The vector sum of the two is directed to the right.

1 point

$$B_{\text{resultant}} = 2 \cdot B_x$$

1 point

$$= 2 \cdot B \cdot \cos \theta$$

1 point

$$= 2 \cdot B \cdot \left(\frac{y}{\sqrt{a^2 + y^2}} \right), \text{ giving the final result}$$

1 point

$$B_{\text{resultant}} = \frac{\mu_0 I y}{\pi (a^2 + y^2)}, \text{ directed to the right.}$$

1 point