AP® Physics B
2002 Sample Student Responses
Form B

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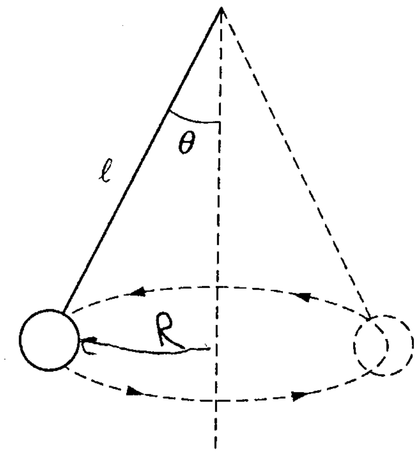
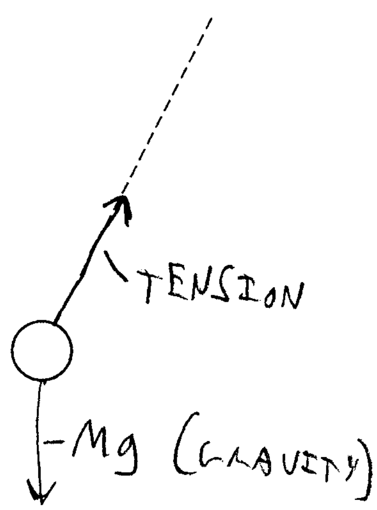


2. (15 points)

A ball attached to a string of length ℓ swings in a horizontal circle, as shown above, with a constant speed. The string makes an angle θ with the vertical, and T is the magnitude of the tension in the string. Express your answers to the following in terms of the given quantities and fundamental constants.

(a) On the figure below, draw and label vectors to represent all the forces acting on the ball when it is at the position shown in the diagram. The lengths of the vectors should be consistent with the relative magnitudes of the forces.



(b) Determine the mass of the ball.

TENSION = ↗ = (T cos θ), T sin θ

Since the ball experiences no vertical acceleration, $T\cos\theta = Mg$, $\boxed{M = \frac{T\cos\theta}{g}\ \text{kg}}$

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(c) Determine the speed of the ball.

THE NET FORCE ON THE BALL IS $T\sin\alpha$. HOWEVER, SINCE THE MOTION IS CENTRIPEDAL, THE FORCE IS ALSO $\frac{MV^2}{R}$ OR, SINCE $R = l\sin\alpha$, $\frac{MV^2}{l\sin\alpha}$.

SO $T\sin\alpha = \frac{MV^2}{l\sin\alpha}$; $V^2 = \frac{Tl\sin^2\alpha}{M}$; $V^2 = \frac{Tl\sin^2\alpha}{\left(\frac{T\cos\alpha}{g}\right)} = gl\sin\alpha\tan\alpha$.

$V = \sqrt{gl\sin\alpha\tan\alpha}$ M/S

(d) Determine the frequency of revolution of the ball.

$\omega = \frac{V}{R} = \frac{\sqrt{gl\sin\alpha\tan\alpha}}{l\sin\alpha} = \sqrt{\frac{g}{l\cos\alpha}}$. $F = \frac{1}{2\pi}\omega = \frac{1}{2\pi}\sqrt{\frac{g}{l\cos\alpha}}$ HERTZ

(e) Suppose that the string breaks as the ball swings in its circular path. Qualitatively describe the trajectory of the ball after the string breaks but before it hits the ground.

IT WILL CONTINUE AT A CONSTANT SPEED IN THE COMPONENT OF VELOCITY TANGENT TO THE CURVE AT THE POINT OF BREAKAGE, BUT WILL EXPERIENCE A CONSTANT DOWNWARD ACCELERATION, AND SO WOULD CUT A PARABOLIC SHAPE THROUGH SPACE.

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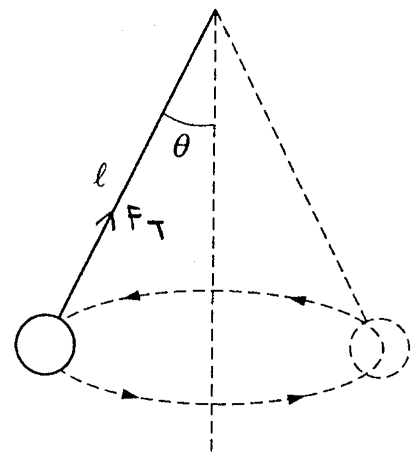

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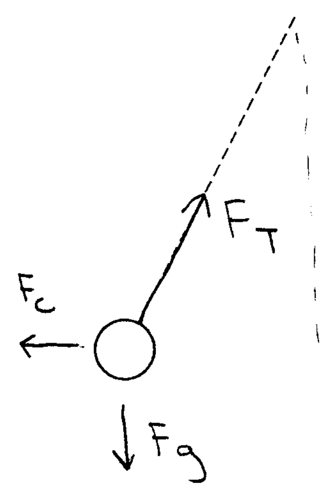

(b) Determine the mass of the ball.

$$T = \frac{2\pi r}{v}$$

$$T\cos\theta = mg$$

$$m\frac{v^2}{r} = T\sin\theta$$

$$T = \frac{mg}{\cos\theta}$$

$$\boxed{m = \frac{T\cos\theta}{g}}$$

$$m\frac{v^2}{r}$$

$$m\frac{v^2}{\ell\sin\theta} = T\sin\theta$$

$$v^2 = \frac{\cancel{T}\,\ell\sin^2\theta\, g}{\cancel{T}\cos}$$

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$v^2 = g\frac{T\cancel{v}}{2\pi}\tan\theta$

(c) Determine the speed of the ball.

$T = \frac{2\pi r}{v}$ $\frac{mv^2}{r} = T\sin\theta$ $\boxed{v = \frac{gT\tan\theta}{2\pi}}$

$r = \frac{Tv}{2\pi}$ $m = \frac{T\cos\theta}{g}$

$\frac{\cancel{T}\cos\theta\, v^2}{gr} = \cancel{T}\sin\theta$ $\boxed{v = \sqrt{\frac{g\ell\sin^2\theta}{\cos\theta}}}$

$r = \ell\sin\theta$

$v^2 = gr\tan\theta$

(d) Determine the frequency of revolution of the ball.

$\cancel{\text{Period} = \frac{2\pi r}{v}}$ $T = \frac{2\pi r}{v}$ $f = \frac{v}{2\pi\ell\sin\theta}$ $f = \left(\frac{gT\tan\theta}{2\pi}\right)\left(\frac{1}{2\pi\ell\sin\theta}\right)$

$\cancel{f = \frac{v}{2\pi r}}$ $= \left(\frac{gT\tan\theta}{2\pi}\right)\left(\frac{1}{2\pi r}\right)$ $f = \frac{\sqrt{\frac{g\ell\sin^2\theta}{\cos\theta}}}{2\pi\ell\sin\theta} = \boxed{\frac{\sin\theta\sqrt{\frac{g\ell}{\cos\theta}}}{2\pi\ell}}$

$= \frac{gT\tan\theta}{2\pi}\left(\frac{1}{2\pi r}\right) =$

(e) Suppose that the string breaks as the ball swings in its circular path. Qualitatively describe the trajectory of the ball after the string breaks but before it hits the ground.

At the moment the string broke, the ball would fly along a tangent from the circle it was originally traveling in. It would then follow a parabolic path to the ground

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