Phys. 807 — Statistical Mechanics

Solution.

(a)

Suppose the wheel moves with velocity v to the right and consider the point on the rim which was passing origin at $t = 0$. At time t the wheel rotates at the angle $\theta = \omega t = \frac{v}{a}t$ clockwise so in wheel's frame the coordinates of the point would be

$$x' = -a\sin\omega t, \qquad y' = a(1 - \cos\omega t)$$

However, during time t the center of the wheel shifts to the right at $x_0 = vt = \omega a$ so the coordinates of the point in rest frame are

$$x = x' + \omega t = x' = -\omega t - a\sin\omega t, \qquad y' = a(1 - \cos\omega t)$$

Eliminating t in favor of $\theta = \omega t$ we get

$$x = a(\theta - \sin\theta), \qquad y = a(1 - \cos\theta)$$

The cycloid turned upside down is

$$x = a(\theta - \sin\theta), \qquad y = a(-1 + \cos\theta) = -2a\sin^2\frac{\theta}{2} \qquad (1)$$

Next, using

$$dx = a(1 - \cos\theta)d\theta = 2a\sin^2\frac{\theta}{2}d\theta$$

$$dy = -a\sin\theta = -2a\sin\frac{\theta}{2}\cos\frac{\theta}{2}d\theta$$

we get the element of the length of the cycloid

$$ds = \sqrt{dx^2 + dy^2} = 2a\sin\frac{\theta}{2}d\theta$$

so the distance measured along the cycloid from the lowest point is

$$s = \int_0^s ds' = 2a\int_0^\theta d\theta'\sin\frac{\theta'}{2} = 4a\cos\frac{\theta}{2} \qquad (2)$$

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Statistical Mechanics Solution

Konstantin K. Likharev

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