5-4 For this force the PE is

$$U = -\int F\,dx = mk^2 \int \frac{dx}{x^3} = -\frac{mk^2}{2x^2}$$

Then

$$TME = \frac{1}{2}m\dot{x}^2 - \frac{1}{2}m\frac{k^2}{x^2} = -\frac{1}{2}m\frac{k^2}{d^2}$$

so

$$\left(\frac{dx}{dt}\right)^2 = \frac{k^2}{x^2} - \frac{k^2}{d^2} = k^2\left(\frac{1}{x^2} - \frac{1}{d^2}\right)$$

This differential equation is separable

$$\frac{dx}{dt} = \pm k\sqrt{\frac{1}{x^2} - \frac{1}{d^2}} \qquad \text{so}$$

$$dt = \frac{dx}{\pm k\sqrt{\frac{1}{x^2} - \frac{1}{d^2}}}$$

Now we must choose the sign on the rhs. In this problem, when x decreases, t increases. $\therefore$ we must chose the minus sign because as x decreases the denominator increases so t decreases unless we choose the minus sign.

$$\therefore \int_0^t dt = t = -\frac{1}{k}\int_d^0 \frac{dx}{\sqrt{\frac{d^2 - x^2}{x^2 d^2}}}$$

$$= \frac{1}{2}\frac{d}{k}\int_0^d \frac{2x\,dx}{\sqrt{d^2 - x^2}}$$

$$= \frac{d}{k}\,\frac{1}{2}\,\frac{(d^2 - x^2)^{1/2}}{1/2}\Big|_0^d$$

$$= d^2/k$$