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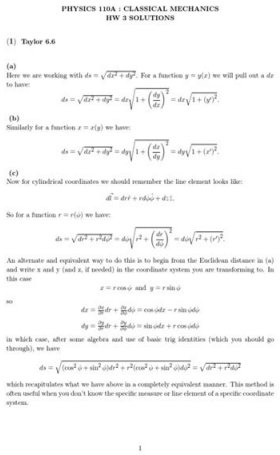

PHYSICS 110A : CLASSICAL MECHANICS
HW 3 SOLUTIONS

(1) **Taylor 6.6**

(a)
Here we are working with $ds = \sqrt{dx^2 + dy^2}$. For a function $y = y(x)$ we will pull out a dx to have:

$$ds = \sqrt{dx^2 + dy^2} = dx\sqrt{1 + \left(\frac{dy}{dx}\right)^2} = dx\sqrt{1 + (y')^2}.$$

(b)
Similarly for a function $x = x(y)$ we have:

$$ds = \sqrt{dx^2 + dy^2} = dy\sqrt{1 + \left(\frac{dx}{dy}\right)^2} = dy\sqrt{1 + (x')^2}.$$

(c)
Now for cylindrical coordinates we should remember the line element looks like:

$$d\vec{s} = dr\hat{r} + rd\phi\hat{\phi} + dz\hat{z}.$$

So for a function $r = r(\phi)$ we have:

$$ds = \sqrt{dr^2 + r^2 d\phi^2} = d\phi\sqrt{r^2 + \left(\frac{dr}{d\phi}\right)^2} = d\phi\sqrt{r^2 + (r')^2}.$$

An alternate and equivalent way to do this is to begin from the Euclidean distance in (a) and write x and y (and z, if needed) in the coordinate system you are transforming to. In this case

$$x = r\cos\phi \quad \text{and} \quad y = r\sin\phi$$

so

$$dx = \frac{\partial x}{\partial r}dr + \frac{\partial x}{\partial \phi}d\phi = \cos\phi dx - r\sin\phi d\phi$$
$$dy = \frac{\partial y}{\partial r}dr + \frac{\partial y}{\partial \phi}d\phi = \sin\phi dx + r\cos\phi d\phi$$

in which case, after some algebra and use of basic trig identities (which you should go through), we have

$$ds = \sqrt{(\cos^2\phi + \sin^2\phi)dr^2 + r^2(\cos^2\phi + \sin^2\phi)d\phi^2} = \sqrt{dr^2 + r^2 d\phi^2}$$

which recapitulates what we have above in a completely equivalent manner. This method is often useful when you don't know the specific measure or line element of a specific coordinate system.

1

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