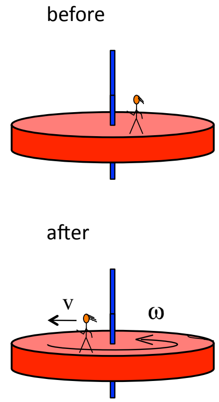
Problem 11.35

A girl begins to walk clockwise (as viewed from above) on a stationary disk that is free to wheel. As she begins to walk, the wheel begins to rotate counterclockwise.

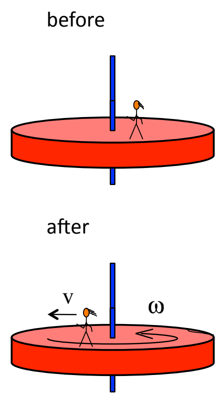
a.) Is *mechanical energy* conserved?

No. If for no other reason than the fact that the system started out stationary and ended up not stationary, *mechanical energy* is not conserved. Beyond that, the girl burns chemical energy as she exercises her muscles. As this does not produce a force that is conserved (walking *to the right* burns chemical energy; walking *to the left* does not restore that chemical energy), there are non-conservative forces acting in the system, so *mechanical energy* is not conserved!



b.) Is *momentum* conserved?

No. *The temptation* might be to say that because there is no motion to start with but motion to end with, there is no *momentum* conservation (this is similar to the legitimate *no mechanical-energy conservation* argument). Right answer, WRONG REASON. Because *momentum* is a vector, it is quite possible to have two individuals on ice skates, say, push one another with one going one way and the other the other, and because the forces acting are *internal* to the system, *momentum will be conserved*. That isn't what is happen here. Yes, the disk is rotating as a consequence of the girl walking, but it is not physically translating as a consequence because there is a force acting at its pin to keep it from moving translationally. In short, *momentum* is *not conserved* here.

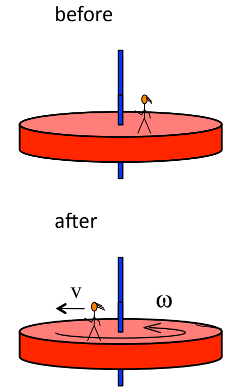


c.) Is *angular momentum* conserved?

Yes. All the torques acting in the system, the one that makes her change motion and the one that makes the disk change motion, are *internal* to the system. As such, *angular momentum* is conserved.

d.) In what direction and with what *angular speed* does the disk end up turning?

This is a *conservation of angular momentum* with zero *angular momentum* in the system to start with and with two objects, each ending up with *angular momentum*, whose *angular momentum* vectors are in opposite directions. I'm writing all of this because there isn't room below to do the problem, hence it has to be done on the next page, and I didn't want to leave all this space empty. Let's hear it for bureaucrats.



Conservation of angular momentum yields:

$$\sum L_1 + \sum \cancel{\Gamma_{external}}^{\,0} \Delta t = \sum L_2$$

$$\Rightarrow \quad 0 = I_{disk}\omega - \vec{r}_{toGirl} \times \left(m_{girl}\vec{v}\right)$$

$$\Rightarrow \quad I_{disk}\omega = mvR\sin 90^\circ$$

$$\Rightarrow \quad \omega = \frac{mvR}{I_{disk}}$$

$$= \frac{(60.0\text{ kg})(1.50\text{ m/s})(2.00\text{ m})}{(500.\text{ kg}\bullet\text{m}^2)}$$

$$= .360\text{ rad/s}$$

e.) How much chemical energy does the woman burn in making things move?

$$KE_{initial} + W_{ext} = KE_{final}$$

$$\Rightarrow \quad W_{chemBurn} = \frac{1}{2}I_{disk}\omega^2 - \frac{1}{2}m_{girl}v^2$$

$$= \frac{1}{2}\left(500.\text{ kg}\bullet\text{m}^2\right)\left(.360\text{ rad/s}^2\right)^2 + \frac{1}{2}(60.0\text{ kg})(1.50\text{ m/s})^2$$

$$= 99.9\text{ J}$$