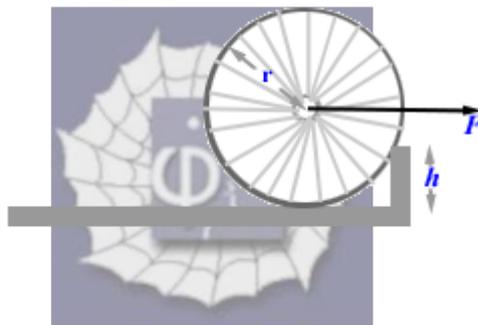


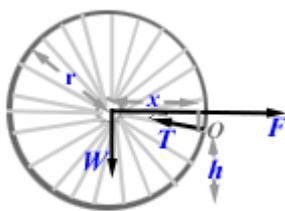
46.

**Problem 13.29P (HRW)**

*A force  $F$  is applied horizontally at the axle of a wheel for raising the wheel over an obstacle of height  $h$ . We have to find the force  $F$  necessary for raising the wheel over the obstacle. We can take  $r$  as the radius of the wheel and  $W$  as its weight.*



**Solution:**



When the wheel is just about to rise over the obstacle there will be no normal force from the ground. In addition to the weight  $W$  and force  $F$  the wheel will experience a normal force  $T$  exerted by the edge of the obstacle, indicated by  $O$  in the free-body diagram of the wheel. Let  $x$  be the moment arm of the

force  $W$  about the point  $O$ . From geometry we have the relation

$$\sqrt{(r^2 - x^2)} + h = r,$$

or,

$$x = (2rh - h^2)^{1/2}.$$

We calculate the torque about the point  $O$ . Condition for equilibrium is that net torque has to be zero. This gives the condition

$$F(r - h) = W(2rh - h^2)^{1/2},$$

or,

$$F = \frac{W(2rh - h^2)^{1/2}}{(r - h)}.$$

