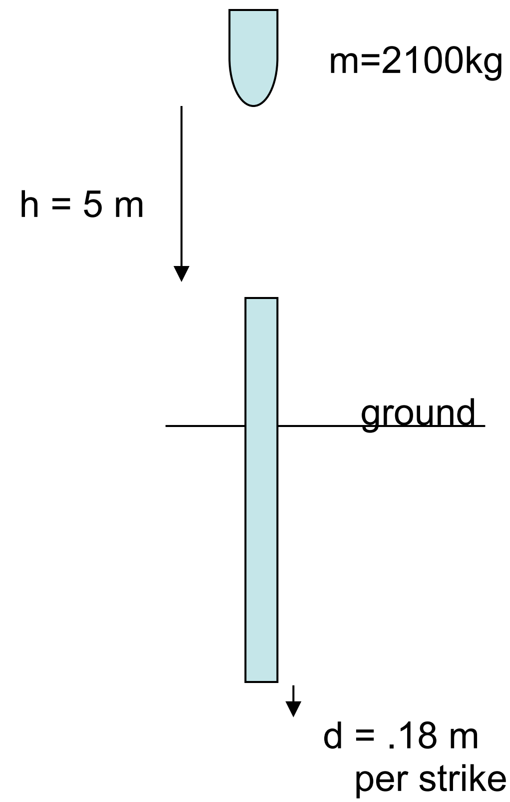
Problem 5.23

A 2100 kg pile driver drops from a height of 5 meters before striking a vertical I-beam. It drives the beam 18 cm into the ground. ASSUMING 3000 joules of energy was lost during the collision, use energy considerations to determine the average force the driver exerts on the beam. (You may also assume that the change of the beam's gravitational potential energy is negligible).



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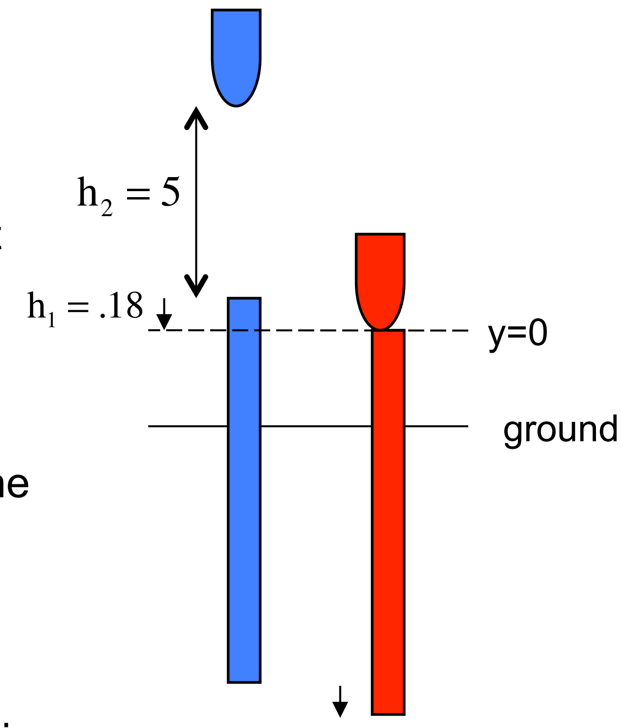

The temptation is to assume that energy considerations have to be exercised over the entire system—both the driver and the beam. If that had been the case, we would have had to take into account the fact that a gravitational potential energy change occurred for both the driver AND the beam (the beam did change vertical position during the contact). As we don't know the mass of the beam, we can't do that. An alternative is to use energy considerations on just the driver. In that case, along with potential and kinetic energy considerations, there is also work done by the force the beam exerts on the driver as the driver is brought to rest (in fact, that is the very force we are trying to determine) and the energy loss due to the actual collision. Putting it all together yields:

$$\cancelto{0}{\sum KE_1} + \sum U_1 + \sum W_{extraneous} = \cancelto{0}{\sum KE_2} + \sum U_2$$

$$\left(KE_{driver,1}\right) + \left(U_{grav,driver,1}\right) + \left(W_{loss} + W_{collision}\right) = \left(KE_{driver,2}\right) + \left(U_{grav,driver,2}\right)$$

$$\Rightarrow \left(U_{grav,driver,1}\right) + \left(W_{loss} + W_{collision}\right) = \left(U_{grav,driver,2}\right)$$

Putting in the numbers in we get:

$$\left(U_{grav,driver,1}\right) + \left(W_{loss} + W_{collision}\right) = \left(U_{grav,driver,2}\right)$$

$$\left(m_d g\left(h_1 + h_2\right)\right) + \left(\left(-3000\right) + Fh_2 \cos 180^o\right) = (0)$$

$$\left(m_d g\left(h_1 + h_2\right)\right) + \left(\left(-3000\right) - Fh_2\right) = 0$$

$$\Rightarrow \quad F = \frac{\left(\left(-3000\right) + m_d g\left(h_1 + h_2\right)\right)}{h_2}$$

$$\Rightarrow \quad F = \frac{\left(\left(-3000\right) + (2100 \text{ kg})\left(9.8 \text{ m/s}^2\right)(5 + .18 \text{ m})\right)}{(.18 \text{ m})}$$

$$\Rightarrow \quad F = 5.76\text{x}10^5 \text{ nts}$$