1 Selected Ch 7 Problems

1. How much power, in units of horsepower, would a 1000kg speedboat need to go from rest to 20.0m/s in 5.00s if water exerts a constant drag force $f_d = 500N$. You may assume acceleration is constant.
Ans) The power here is provided by the engine, which is a non-conservative force. We know that the work done by the engine and the work subtracted by the drag force will be equal to our change in energy.

$$W_{net} = W_{engine} - W_{drag} = \Delta KE = 1/2mv^2$$

The drag force is given by $W_{drag} = f_d * \Delta x$. Our problem is to now find Δx. We know the final and initial velocities of the boat and the time it takes to get there, so we can find both the acceleration and the distance covered.

$$\begin{aligned} v_f &= v_0 + at \\ 20m/s &= a(5.00s) \\ a &= 4.00m/s \\ v_f^2 &= v_0^2 + 2a\Delta x \\ (20.0m/s)^2 &= 0^2 + 2(4.00m/s^2)\Delta x \\ x &= 50.0m \end{aligned}$$

Knowing this we find that $W_{drag} = -f_d\Delta x = -500N(50.0m) = -2.5 * 10^4 J$. We can now solve for the work done by the engine, and thus the power it uses.

$$\begin{aligned} W_{engine} &= 1/2mv^2 - W_{drag} \\ W_{engine} &= 2.25 * 10^5 J \\ P_{engine} &= \frac{W_{engine}}{\Delta t} \\ P_{engine} &= 4.50 * 10^4 W = 60.3hp \end{aligned}$$

2. A box, attached to a spring which has one end attached to a wall, is slowly stretched out from x=0m to x=4m. The box weighs 100N and there is a coefficient of friction of $\mu = 0.25$. How much work must you do on the spring to stretch it if it has a spring constant of 80N/m?
Ans) The forces in the y-direction are gravity and the Normal force, and there is no acceleration in this direction. Therefore the normal force while just be equal to gravity and we get $N = W = 100N$. We know that the object is moving so we can find the friction as $f = \mu N = 25N$. Armed with this information we can now find the work done on the spring with our energy equation.

$$\begin{aligned} \Sigma W = W_{stretch} - W_{spring} - W_{friction} &= 0 \\ W_{stretch} &= \frac{1}{2}kx^2 + f_f\Delta x \\ W_{stretch} = \frac{1}{2}80N/m * (4m)^2 + 25N(4m) \\ W_{stretch} &= 740J \end{aligned}$$

3. Consider a game of tug of war where the two teams are completely evenly matched. There is no movement of the teams or the rope. If this is the case, is any work done on the rope? The pullers? The ground? Is work done on anything?
Ans) Since there is no motion there is no work, as $W = F\Delta x$. There is no work done on the rope, the pullers, or the ground. Remember, work is only in the direction of motion in most cases. The only time this might not be true is if you held something in the same spot but moved the whole earth, then it would take work to hold that thing because the force due to gravity would be changing.

4. Consider the discussion of conservative forces on page 215 of your book. We know that gravity is a conservative force, meaning that it is path independent. Considering this to be the case, why then do you feel more tired after running up and down a hill than when you just run straight?
Ans) In this case you have to consider that your body does not move you up the hill or down the hill perfectly. You have to do work against gravity while going up the hill to continuously push yourself up, and you must do work against gravity going down the hill to keep yourself from going too quickly downhill, lest you fall. Because of this you are working against gravity both up and down the hill. If you were some sort of perfect sphere then rolling up the hill and rolling down the hill would not take such motion into account and it would take equal amounts of energy to either do this or go on a straight path. Remember that while doing these problems we make plenty of assumptions about what is going on in order to always get a model that is 'good enough' to be a fairly accurate description of reality.

5. Do this problem two ways. If you throw a ball into the air with vertical velocity of 12m/s, how high does the ball go? Assume a constant force of air resistance of 3N and a ball mass of 1kg.
Ans) We can do this problem using either kinematics or conservation of energy, and the whole point is that you will typically be able to do problems in multiple ways so you should always choose the easiest way. Using kinematics requires that we use forces to find the total downward acceleration. This will be affected both by gravity and also by the drag force. We can do this as follows:

$$\begin{aligned} F_d + F_g &= ma \\ 3N + 9.8N &= 1kg * a \\ a = 12.8m/s^2 v_f^2 &= v_0^2 + 2a\Delta x \\ 0 &= (12m/s)^2 + 2(-12.8m/s^2)\Delta x \\ \Delta x &= 5.6m \end{aligned}$$

We can also do this by looking at conservation of energy. If we do this we need only consider that initially the ball has only kinetic energy (on the ground but moving up) and at its max height it has only potential energy (in the air but not moving). We also must subtract off the work done by the drag force.

$$
\begin{aligned}
E_i &= E_f \\
KE_i &= PE_f + W_{drag} \\
1/2mv^2 &= mgh + f_d h \\
h &= \frac{1/2mv^2}{mg + f_d} \\
h &= 5.6m
\end{aligned}
$$

The height we find must be the same regardless of how we do the problem, and it is. Here, I would probably use conservation of energy to solve this problem because it is only one equation, versus the multiple ones used considering forces and kinematics. Another important note is that energy is a scalar whereas forces are vectors. This means that you don't have to break energy up into x and y components, so therefore with problems strectching into 2 dimensions (x and y) energy is typically easier to deal with.