Solutions for Worksheet 6:

1. **Real System Design**
   - **a)** The first step is to calculate the total energy needed and assume a certain amount of buffer, in this case 30%.
     $$E_{Total} = 1.3 \times E_{consume} = 1.3 \times (4 \times 18 + 4 \times 75 + 8 \times 60)Wh = 1107.6Wh$$
   - **b)** Here it is assumed that the whole energy is provided in the time interval PSH (3h). With this we can calculate the power needed from the system:
     $$P = \frac{E_{Total}}{PSH} = 369.2W$$
     Assuming that a solar panel can provide 190 W, one needs 2 panels.
   - **c)** Since the used battery has a voltage of 12 V then input voltage for the inverter should have it too. Another, information is the power needed from the consumers. The efficiency is $\eta = 90\%$, so:
     $$P_{Inverter} = 153 \times 1.1\ W = 168.3W$$
   - **d)** A battery is an energy storage, which can provide energy in times where there is no sun. The question is, how many days of autonomy (DoA) are needed? In our case we assumed 3 days. Another important fact is the energy conversion efficiency during discharge which is most likely $\eta = 85\%$. The last restriction is the depth of discharge (DoD) which shouldn't be lower than 50% for lead acid batteries.
     $$C = T_{DoA}\frac{E_{consume}}{\eta \times DoD \times V_{battery}} = 501Ah$$
   - **e)** The last part of our system is the charge controller. The charge controller uses the energy provided by the solar panel to charge the battery. That means, that the input quantities must be transformed into the output quantities. Another, fact to think of is that the charge controller should be able of handling the maximum values for voltage and current provided by the solar panel (here V_{OC} and I_{SC}).
   - **f)** Here one needs to think of what is directly provided with energy from the PV during the day time. This is the Inverter and the dimension of the solar panels.

2. **Concept of MPPT**

   The most general strategy is to find a maximum of the power output:
   $$P = UI$$
   $$\frac{dP}{dI} = 0 = U + I\frac{dU}{dI} \Rightarrow -\frac{dU}{dI} = \frac{U}{I}$$
   This condition means the maximum power output is at a point where the equation:
   $$-\frac{dU}{dI} = \frac{U}{I}$$
   is correct.

3. **Li-Ion and LA Batteries**

   a) From the diagram one can conclude that the best way of operating a LA battery is by keeping it at high SoC. So usually during the day time, where it is most likely charged.

   b) The best way of operating a Li-Ion battery is to keep it at a lower SoC. So during the night, when the energy is needed.

c) see a) and b)
d) conclusion from a) and b)