Chapter 4 Question #5

An electric motor draws 3 A from the 12 V battery shown below. After 50 seconds of operation the 100 kg piston is raised a distance of 0.1 m. The area of the piston, which can be considered to move without friction, is 0.05 m, and the atmospheric pressure $p_{atm} = 10^5$ N/m$^2$.

During the 50s period what is the relationship between the
- work input to the gas from the motor $W_i$
- work to raise the piston $W_p$
- work done against the pressure of the atmosphere $W_a$
- work done by the gas in the chamber $W_g$?

1) $W_g > W_i > W_p > W_a$
2) $W_g > W_a > W_i > W_p$
3) $W_i > W_g > W_p > W_a$
4) $W_i > W_g > W_a > W_p$
5) $W_a > W_g > W_p > W_i$
6) $W_a > W_g > W_i > W_p$
Chapter 4 Question 5 Answer:

(4) Wi > Wg > Wa > Wp

Work input from the motor, Wi:

\[
\text{Power input} = 3\text{A} \times (12\text{V}) = 36 \text{ J/s, Time} = 50 \text{ s}
\]

\[
\text{Wi} = 36 \text{ J/s (50s)} = 1800 \text{ J}
\]

Work to raise the piston, Wp:

\[
\text{Wp} = \text{Force (distance)} = 100\text{kg} \times (9.8\text{m/s}^2) \times 0.1\text{m} = 98 \text{ J}
\]

Work to push against the atmosphere, Wa:

\[
\text{Wa} = \text{Force (distance)} = 105 \text{ N/m}^2 \times (0.05 \text{ m}^2) \times 0.1\text{m} = 500 \text{ J}
\]

Work done by the gas, Wg:

\[
\text{Wg} = \text{Wp} + \text{Wa} = 598 \text{ J}
\]

(The net work of the system = 598 J - 1800 J = -1202 J, thus in sum work is done on the system.)

Therefore Wi > Wg > Wa > Wp

It is possible to arrive at a different answer if you put a negative sign in front of the work done by the motor. This is a very minor error. Technically, I asked for the work input, so the sign was specified by the word "input", so you shouldn't put a negative in front of it.