Lecture 3

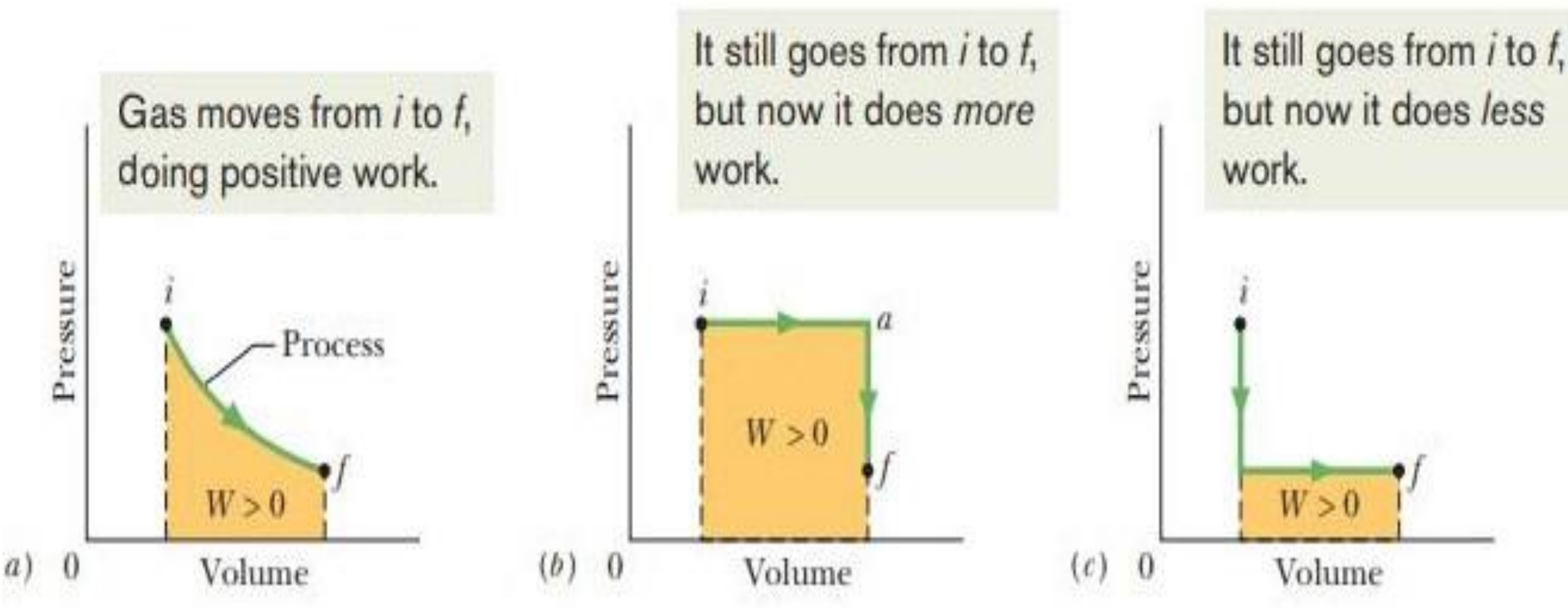
Chapter 18: Temperature, heat and the first law of thermodynamics

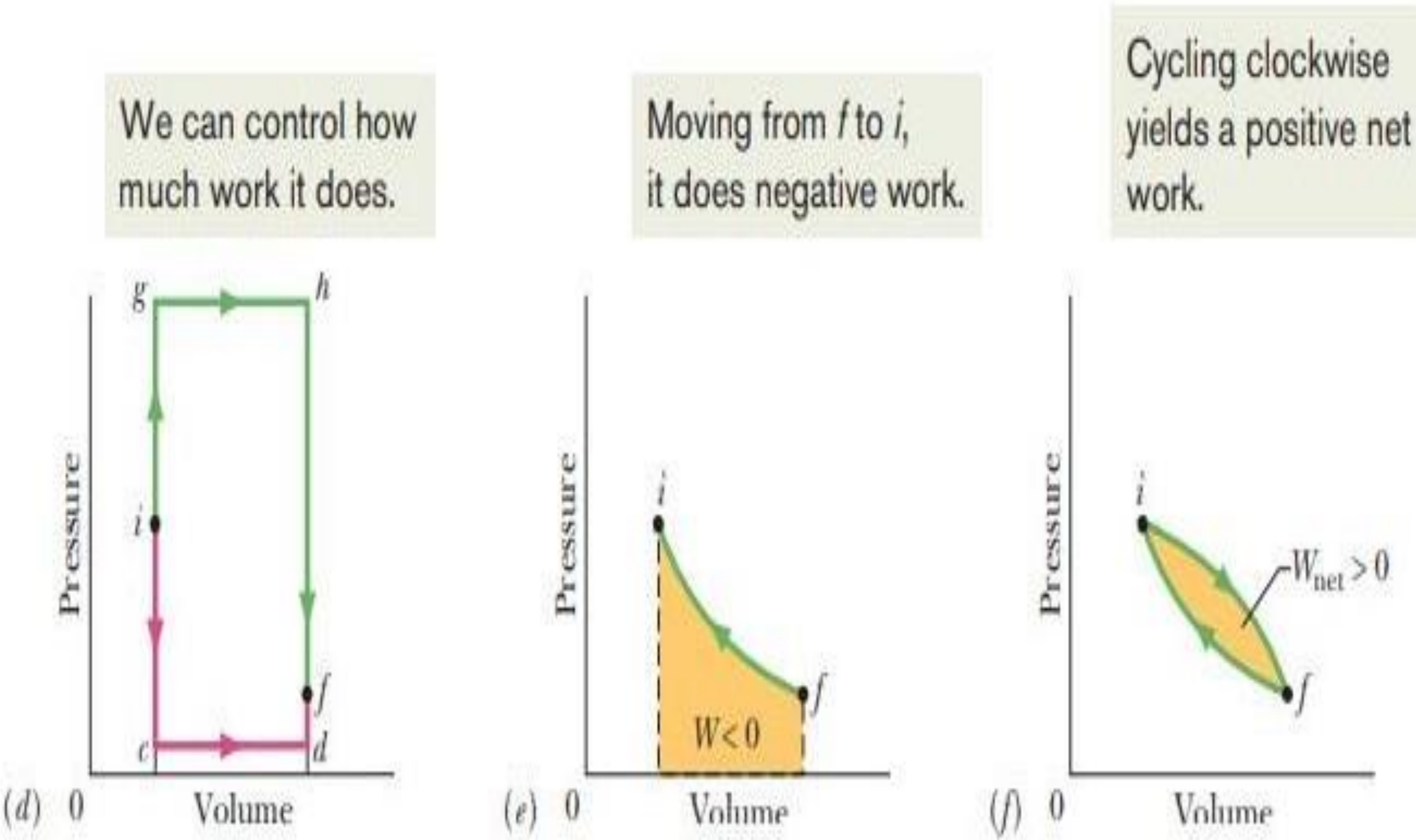
18.5: Path dependent work done in terms of p-V diagram:

Work done is always area under the p-V curve:

$W = \int_{V_i}^{V_f} p\, dV = p(V_f - V_i) = p\Delta V$

The amount of work depends on path.




We can control how much work it does.
Moving from f to i, it does negative work.
Cycling clockwise yields a positive net work.
g
h
i
f
c
d
Pressure
Volume
(d)
0
W < 0
(e)
W_net > 0
(f)

18.5: The First Law of Thermodynamics

When a system changes from a given initial state to a given final state, both the work W and the heat Q depend on the nature of the process but the quantity Q - W is the same for all processes. It depends only on the initial and final states and does not depend at all on how the system gets from one to the other. All other combinations of Q and W, including Q alone, W alone, Q +W, and Q - 2W, are path dependent; only the quantity Q - W is not. The quantity Q - W must represent a change in some intrinsic property of the system. We call this property the internal energy E_{int} and we write

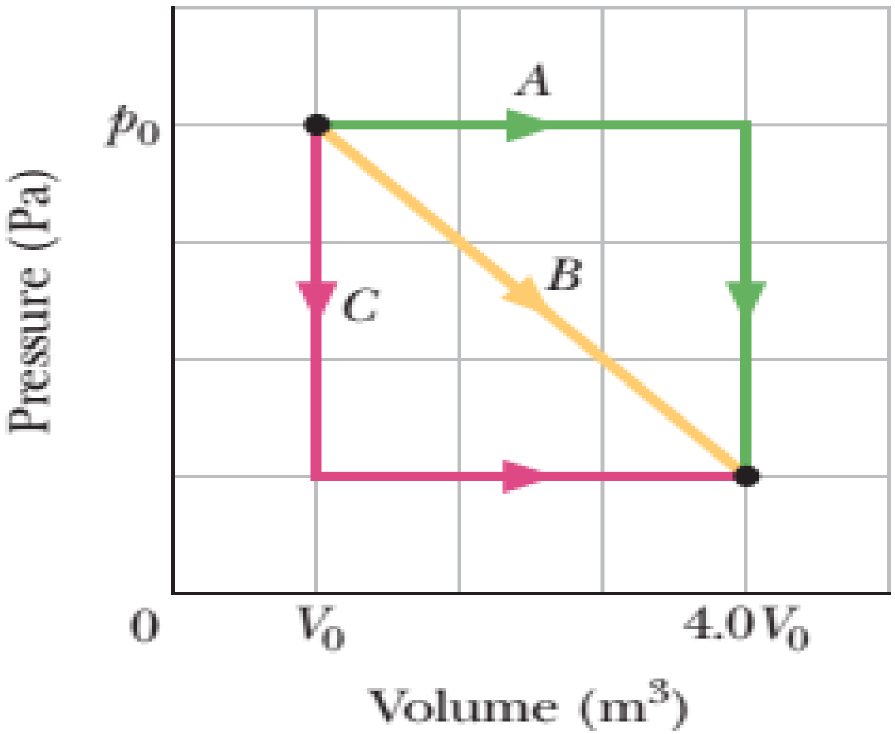
$$\Delta E_{int} = E_{int,f} - E_{int,i} = Q - W$$

The equation known as the first law of thermodynamics.

If the thermodynamic system undergoes only a differential change, we can write the first law as

$$dE_{int} = dQ - dW$$

43. In Fig., a gas sample expands from V_0 to $4.0V_0$ while its pressure decreases from p_0 to $p_0/4.0$. If $V_0 = 1.0\ m^3$ and $p_0 = 40$ Pa, how much work is done by the gas if its pressure changes with volume via (a) path A, (b) path B, and (c) path C?



Solution of 43

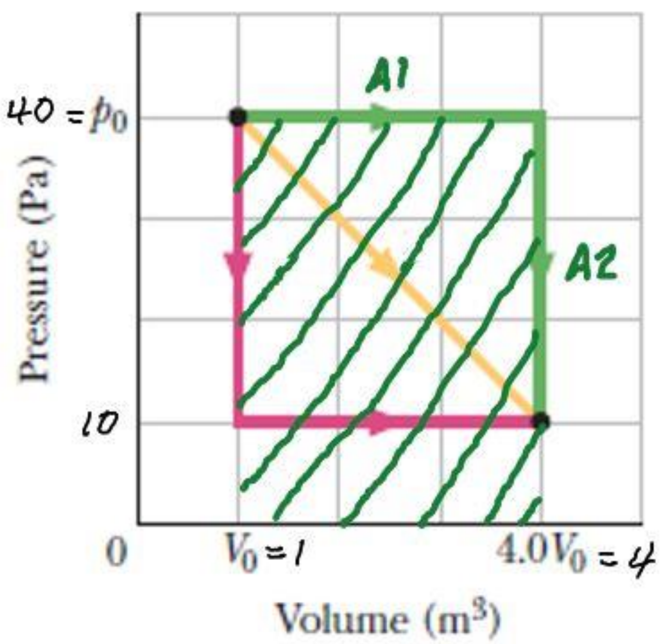
The volume increases through the three paths , so the work done by the gas is always positive.

W $=\int dW$ = $\int_{Vi}^{Vf} pdV$ = Area under the curve of p-V

(a) $W_A = W_{A1} + W_{A2}$

W_{A1} = 40 (4-1) = +120 J

(constant pressure)



W_{A2} = 0 (constant volume)

W_A = 120 +0 = +120 J

or

[W = pΔV = p($V_f - V_i$)= (40-0)(4-1)

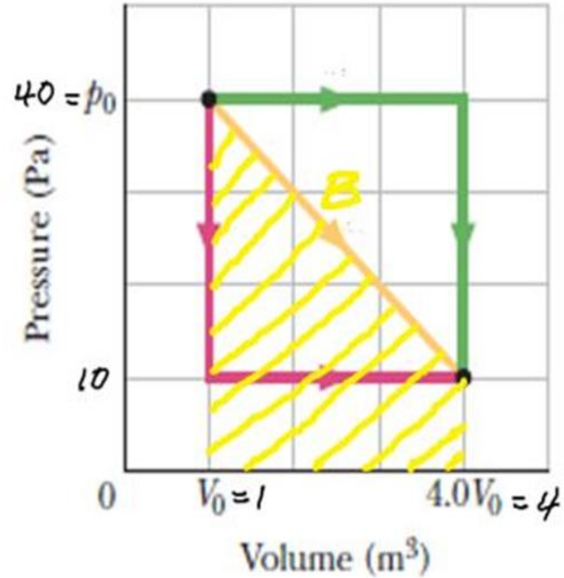
W=40(3) = +120 J]

(b) The work done by the gas is the area under the curve (yellow line)

$W_B = \frac{1}{2} \times (4 - 1)(40 - 10) + (4 - 1)(10 - 0)$

$= (45 + 30)$ J

$= +75$ J

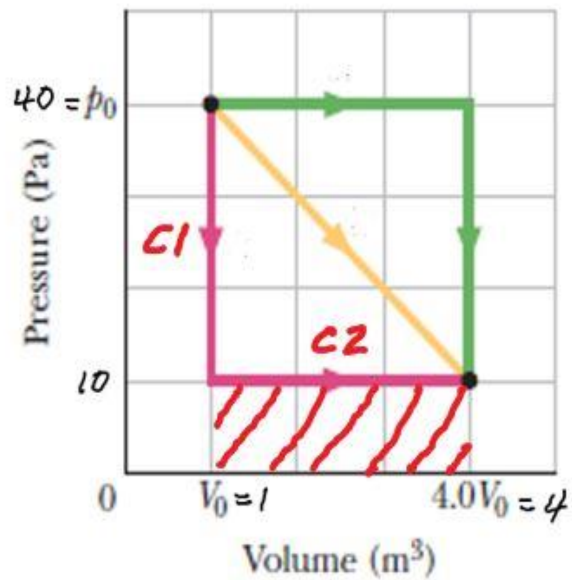


(c) $W_C = W_{C1} + W_{C2}$

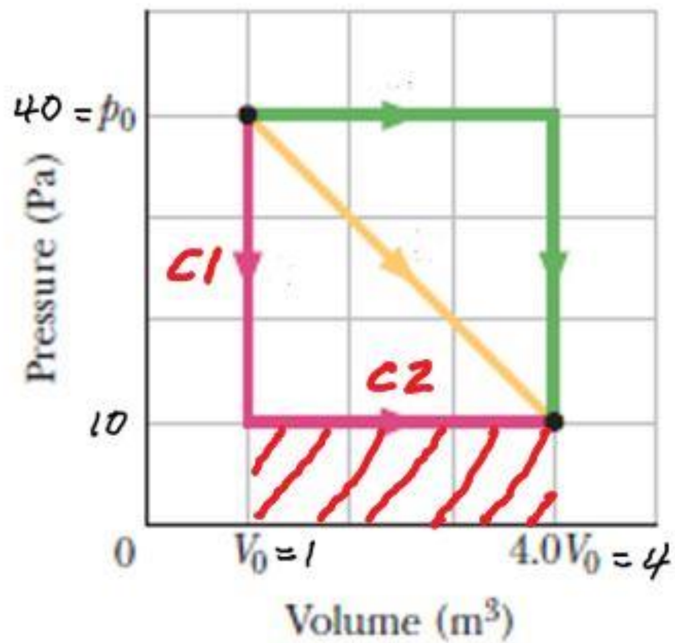
$W_{C1} = 0$ (constant volume)

$W_{C2} = (4-1)(10-0) = 30$ J

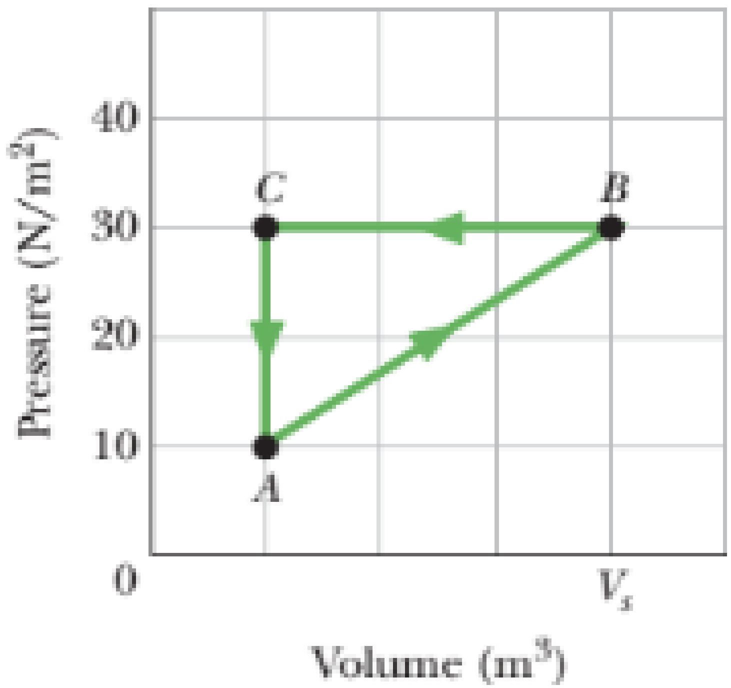
$W_C = 0 + 30 = +30$ J



- (c) $W_C = W_{C1} + W_{C2}$
- $W_{C1} = 0$ (constant volume)
- $W_{C2} = (4-1)(10-0) = 30$ J
- $W_C = 0 + 30 = +30$ J



45. A gas within a closed chamber undergoes the cycle shown in the *p-V* diagram of Fig. The horizontal scale is set by $V_s = 4.0\ m^3$. Calculate the net energy added to the system as heat during one complete cycle.



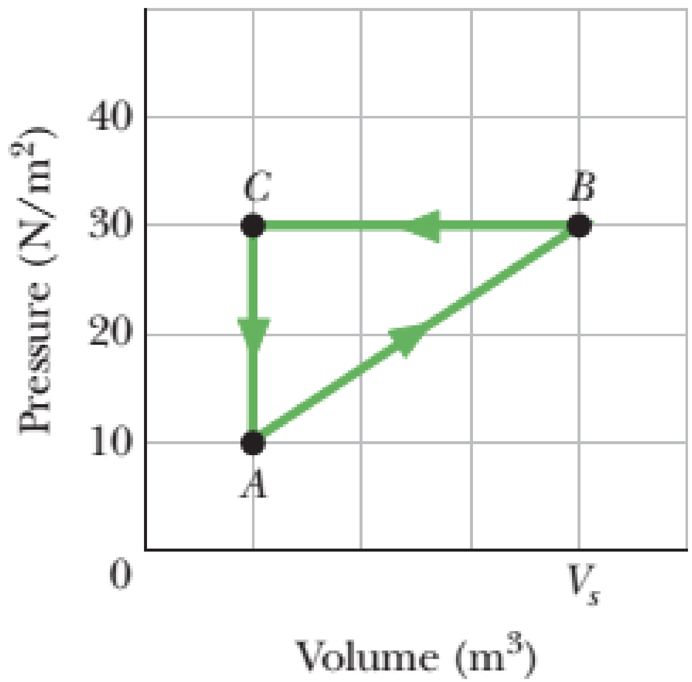
Solution:

Since for a closed cycle, $\Delta E_{int} = E - E = 0$

1^{st} law of thermodynamics, $\Delta E_{int} = Q - W$

$$0 = Q - W$$

$$Q = W$$



The work done in a complete cycle is given by the area inside the loop (triangle)

$W_{net} = \frac{1}{2} \times (4-1)(30-10) = 30$ J

Area under the curve B to C (compression) Is greater than the area under the curve A to B (expansion). So the net work done is negative.

$W_{net} = -30$ J

[or $W_{net} = \frac{1}{2} \times (V_f - V_i)(30-10) = \frac{1}{2} \times (1-4)(30-10) = -30$ J]

$Q = W = -30$ J

The gas (system) loses heat.