GIVEN

* Piston-cylinder
  - » initially $P_0 = P_{atm} = 100\ kPa$
  - » initial vol $V_0 = 32\ cm^3 = 32 \times 10^{-6}\ m^3$
  - » spring attached to piston
  - » Area A of piston $A = 0.0004\ m^2 = 4.00\ cm^2$
  - » $\dot{Q}$ to gas moves piston up distance $x = 2.0\ cm = 0.02\ m$
  - » spring constant $k = 20\ N/cm = 2000\ N/m$

FIND

(a) final absolute pressure (kPa) of gas
(b) final vol of gas (cm^3)
(c) show expansion process on P-V diagram
(d) calculate expansion process

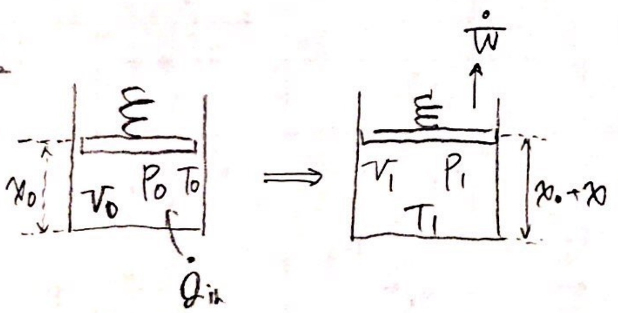
EQUATION

$PV = nRT$, $W = \frac{1}{2}kx^2$
$F = kx$, $\Delta U = Q - W$

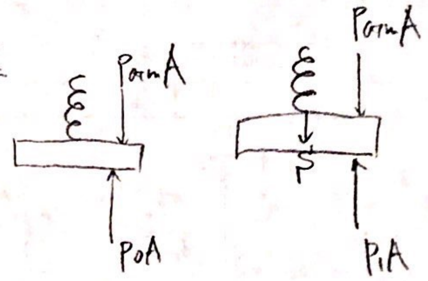
ASSUMPTION

- ideal gas
- Quasiequilibrium
- steady state
- closed system

EFD



FBD



SOLN

(a) $P_1 A = P_0 A + kx$

$$P_1 = P_0 + \frac{kx}{A} = 100\ kPa + \left(\frac{20\ N}{cm}\right)(2\ cm)\left(\frac{1}{0.0004\ m^2}\right)$$

$$= 100\ kPa + 100000\ Pa = \boxed{200\ kPa}$$

(b) $$V_1 = V_0 + xA = 32\ cm^3 + (2.0\ cm)(4.00\ cm^2)$$

$$= \boxed{40\ cm^3}$$

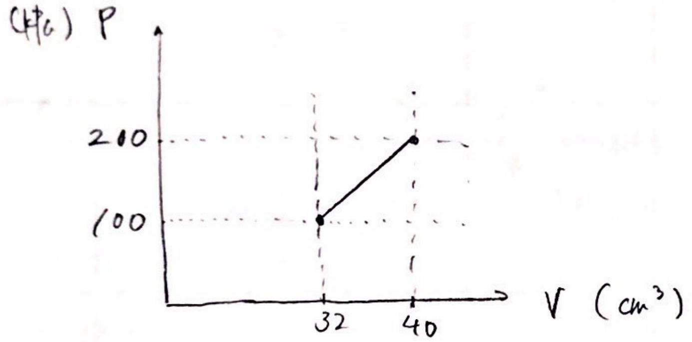
(c) $\begin{cases} P(x) = P_0 + \frac{k}{A}x \cdots ① \\ V(x) = V_0 + Ax \cdots ② \end{cases}$ thus, $\Rightarrow x = \frac{V - V_0}{A}$ plug into ①

$P = P_0 + \frac{k}{A}\frac{V-V_0}{A} = P_0 + \frac{k}{A^2}(V - V_0)$

$P = \frac{k}{A^2}V + P_0 - \frac{kV_0}{A^2}$

$P = \left(\frac{20N}{cm}\right)\left(\frac{1}{4.0^2\ cm^4}\right)V + 100kPa - \left(\frac{20N}{cm}\right)(32\ cm^3)\left(\frac{1}{4.0^2\ cm^4}\right)$

$P = 12.5\ V - 300$: P (kPa), V (cm³)



(d) kPa $\rightarrow$ Pa & cm³ $\rightarrow$ m³

$P = 1.25 \times 10^{10}\, V - 300000$

$W = \int_{V_0}^{V_1} P(V)\, dV$

$= \int_{32\times10^{-6}}^{40\times10^{-6}} (1.25\times10^{10}\, V - 3\times10^{5})\, dV$

$= \left[0.625\times10^{10}\, V^2 - 3\times10^{5}\, V\right]_{32\times10^{-6}}^{40\times10^{-6}}$

$= 3.6 - 2.4 = \boxed{1.2\ J}$