1. (a) $-H = -nC\Delta T$ (call lost heat negative)

$n = \#$ moles ; $m = \rho V = 9 \times 1 = 9$ gm

$$n = \frac{m}{A} = \frac{9}{63.5} = 0.14 \text{ moles}$$

$C =$ molar heat capacity
$= 3R$ (monatomic solids)
$= 3 \times 8.3 = 24.9 \simeq 25 \frac{J}{\text{mole K}}$

$\Delta T = T_f - T_i = 300 - 1200 = -900$

$$\boxed{-H = +0.14 \cdot 25 \cdot 900 = 3200 \text{ J}}$$

(b) $\frac{dH}{dt} = \sigma A \varepsilon T_i^4$ $\qquad \sigma = 5.7 \cdot 10^{-8} \frac{W}{m^2 K^4}$

$A = 6 \text{ cm}^2 = 6 \cdot 10^{-4} \text{ m}^2$
$\varepsilon = 1 \qquad T_i = 1200 K$

$$\frac{dH}{dt} = \underbrace{(5.7 \cdot 10^{-8}) \cdot (6 \cdot 10^{-4})}\, 1 \cdot (1200)^4$$

$$\frac{dH}{dt} = (\sigma A \varepsilon = 3.4 \cdot 10^{-11})(1200)^4$$

$$= (3.4\, 10^{-11})(2.1 \cdot 10^{12})$$

$$\boxed{\frac{dH}{dt} = 71 \text{ W}}$$

(c) Careful about signs... heat lost if dT goes down

$$dH = nC\,dT$$

lost heat is negative

$$nC\frac{dT}{dt} = -\sigma A\varepsilon T^4$$

$$\frac{dT}{T^4} = -\frac{\sigma A\varepsilon}{nC}dt$$

$$\int_{T_i}^{T_f}\frac{dT}{T^4} = -\frac{\sigma A\varepsilon}{nC}\int_{t_i}^{t_f}dt$$

$$-\frac{1}{3T^3}\Big|_{T_i}^{T_f} = -\frac{\sigma A\varepsilon}{nC}(t_f - t_i)$$

so $\boxed{(t_f - t_i) = \frac{1}{3}\frac{nC}{\sigma A\varepsilon}\left(\frac{1}{T_f^3} - \frac{1}{T_i^3}\right)}$

$$= \frac{1}{3}\;\frac{0,14\cdot 25}{3,4\cdot 10^{-11}}\left(\frac{1}{300^3} - \frac{1}{1200^3}\right)$$

$$\boxed{\begin{aligned}\Delta t = t_f - t_i &= 1240\,s\\ &= 21 \text{ minutes}\end{aligned}}$$

2. Nitrogen: $D = 5$ degrees of freedom

$$C_v = \frac{5}{2}R = 21\ \frac{J}{mol\,K}$$

(a) $\boxed{\Delta U = nC_v\Delta T} = 2\times C_v\cdot 100$

$\boxed{\Delta U = 4150\ J}$

(b) $W = p\Delta V$ (since isobaric)

$$pV = nRT \quad , \quad \Delta V = (V_2 - V_1) = \frac{nR(T_2 - T_1)}{p}$$

$$\boxed{\begin{array}{l} W = p\Delta V = nR\Delta T = 2 \cdot 8.3 \cdot 100 \\ W = 1660\ \text{J} \end{array}}$$

(c) $$\boxed{\begin{aligned} \Delta U = Q - W \quad , \quad Q &= \Delta U + W \\ &= 4150 + 1660 \\ &= 5810\ \text{J} \\ &= (nC_v + nR)\Delta T \\ &= n(C_v + R)\Delta T \\ &= nC_p \Delta T \end{aligned}}$$

(d) $$dS = \frac{dQ}{T} = nC_p \frac{dT}{T}$$

$$\boxed{\Delta S = nC_p \int_{T_i}^{T_f} \frac{dT}{T} = nC_p \ln\left(\frac{T_f}{T_i}\right)}$$

$$= 2 \cdot \frac{7}{2} R \ln\left(\frac{373}{273}\right)$$

$$\boxed{\Delta S = 18\ \text{J/K}}$$

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3. $$V_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$$

$$\boxed{\begin{array}{l} T = \dfrac{\frac{1}{3} M V_{rms}^2}{R} \\ T = 0.53\ \text{K} \end{array}} = \frac{\frac{1}{3} \cdot 131 \cdot 10^{-3} (10)^2}{8.3}$$

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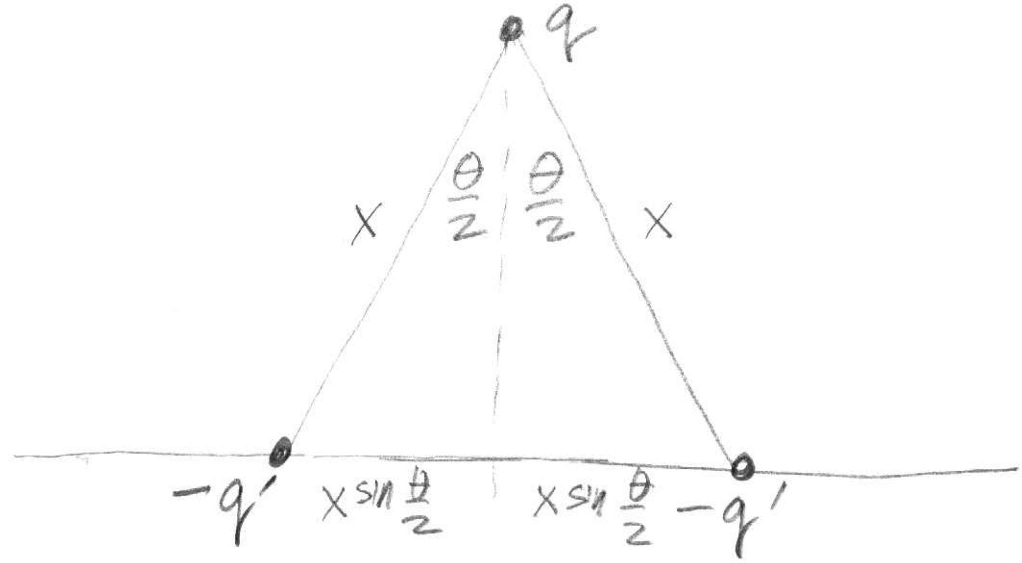
4.



(a) $$U = \frac{-2qq'}{x} + \frac{q'^2}{2x\sin\theta/2}$$

$$\frac{\partial U}{\partial x} = \frac{2qq'}{\cancel{x^2}} - \frac{q'^2}{2\cancel{x^2}\sin\frac{\theta}{2}} = 0$$

$$q - \frac{q'}{4\sin\frac{\theta}{2}} = 0$$

$$\boxed{\left(\frac{q}{q'}\right) = \frac{1}{4\sin\frac{\theta}{2}}}$$

(b) $\sin 30^\circ = \frac{1}{2}$ $$\boxed{\left(\frac{q}{q'}\right) = \frac{1}{4\cdot\frac{1}{2}} = \frac{1}{2}}$$

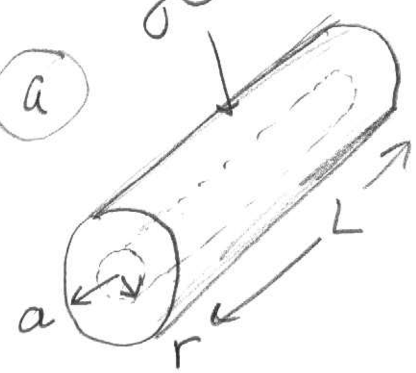
(c) $\sin\frac{\theta}{2} = \sin 30^\circ = \frac{1}{2}$

$$U = \frac{1}{x}\left(-2qq' + \frac{q'^2}{2\cdot\frac{1}{2}}\right)$$

$$= \frac{q'^2}{x}\left(-2\left(\frac{q}{q'}\right) + 1\right)$$

when $\left(\frac{q}{q'}\right) < \frac{1}{2}$, $U(x) > 0$ for all x, and to minimize energy, $x \to \infty$: the two charges go ∞ far away. The positive charge is too small to attract the − charges in.

5 (a)



Gaussian surface also a cylinder of radius r

$\underline{r < a}$ $\quad \Phi_E = 4\pi Q$

$E_r (2\pi r) \cdot L = 0$

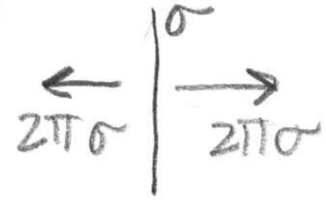
⊥ to axis → $\boxed{E_r = 0}$ all other components 0 by symmetry

$\underline{r > a}$ $\quad \Phi_E = 4\pi Q$

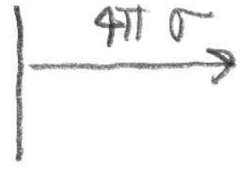
$E_r (2\pi r) \cdot \cancel{L} = 4\pi (2\pi a) \cancel{L} \sigma$

⊥ → $\boxed{E_r = 4\pi \dfrac{\sigma a}{r}}$ all other components 0

(b) Get very close to sheet, expect



<u>see</u>



<u>Conclude</u>:

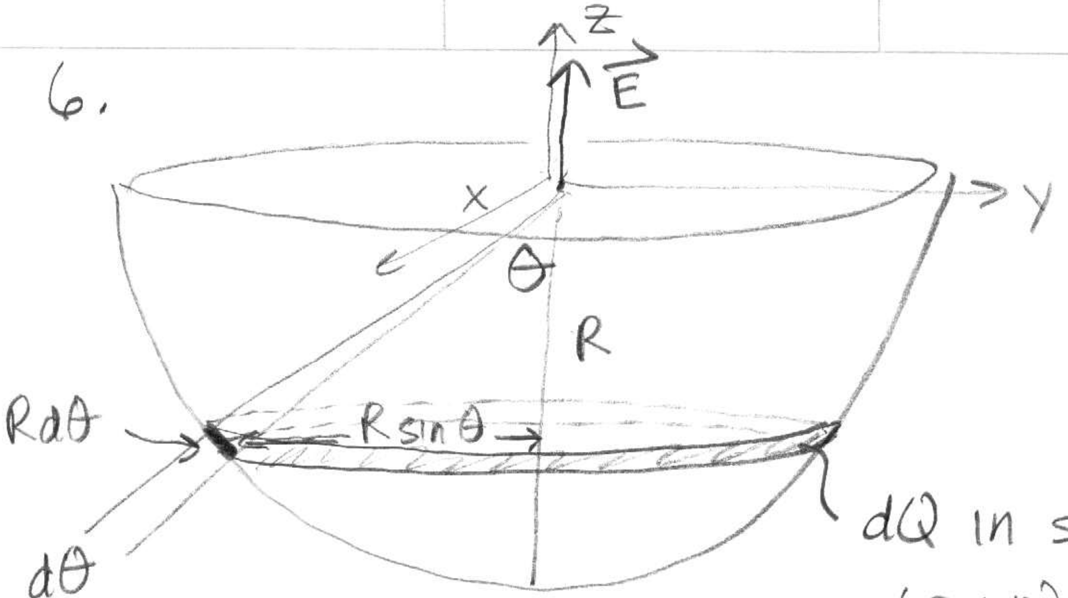
$\xrightarrow{2\pi\sigma}$

$E_{other} = 2\pi\sigma$

$F = (\sigma A)(2\pi\sigma)$

$\boxed{\dfrac{F}{A} = p = 2\pi\sigma^2}$

6.



dQ in strip is

$= \sigma \cdot (R\,d\theta)(2\pi R\sin\theta)$

$$dQ = 2\pi R^2\sigma \sin\theta\, d\theta$$

$$dE_z = \frac{dQ}{R^2}\cos\theta = 2\pi\sigma \sin\theta\cos\theta\, d\theta$$

$$E_z = 2\pi\sigma \int_0^{\pi/2} \sin\theta\cos\theta\, d\theta$$

$$= 2\pi\sigma \cdot \frac{1}{2}\sin^2\theta \Big|_0^{\pi/2}$$

$$\boxed{E_z = \pi\sigma}$$

$E_x = E_y = 0$ by symmetry