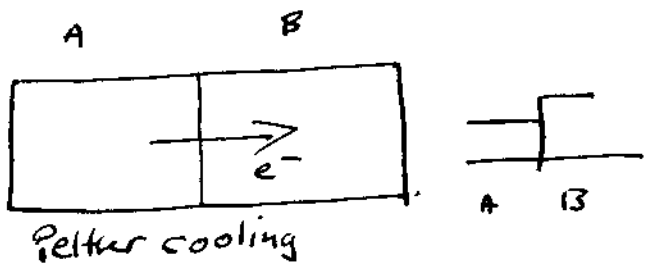
Problem sheet 2: Electrical Sensors

① Done elsewhere

②

(a)



Peltier cooling

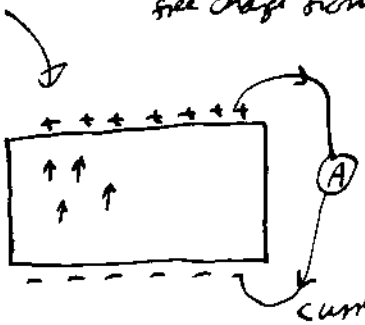
Contact potential difference is temp-dependent.
⇒ imbalance when junction @ different temps
⇒ emf (capacitor voltage)

Current will flow if the ckt is closed.

Conversely, if we force a current in the correct dirn, the e^- gain/lose energy and heat/cool.

Seebeck (thermocouple)

Surface charge usually compensated by free charge from atm.



current flows when temp changes

nb- stops flowing when temp stops changing

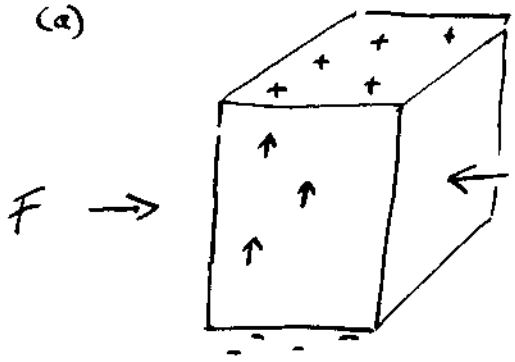
Pyroelectric - increasing the temp changes (decreases) the dipole moment b/c of thermal expansion. Surface charge changes, and current flows in external ckt.

Both Seebeck & Pyroelectric effects can be used to measure temp. Seebeck needs a reference jn. Big difference is that Seebeck applys to conductors and Pyro applies to insulators.

(b) (i) Peltier cooling (no moving parts, but inefficient)
(ii) Heat powered engine (good for spacecraft, because 2nd Law)

(3) Pset 2 : Electrical sensors

(a)



Squeeze crystal to change dipole moment ⇒ surface charge changes.

Note no temperature change involved

Larger charge than pyro.

(b)

$$dF = Q \quad (1)$$

↑ assume symmetry to make most of the dim go away.

(2) $Q = \frac{\Sigma A V}{t d}$ using t for thickness to avoid confusion w/ dim

$$(1)=(2) \quad Fd = \frac{\Sigma A V}{t} \Rightarrow V = \frac{tFd}{\Sigma A}$$

(c) $t = 10^{-3}\ m$

$A = (10^{-2})^2 = 10^{-4}\ m^2$

$V = 1.6 \times 10^3$

$\Sigma = 12 * \varepsilon_0$ (PVDF)

$d = 78\ pC/N$

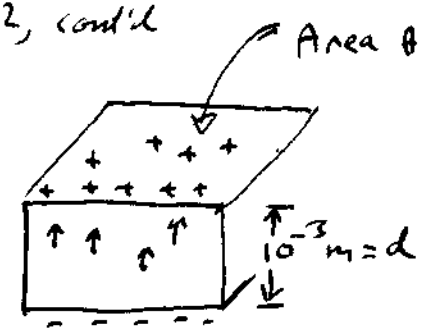
$$F = \frac{\Sigma A V}{t d}$$

(d) $V = \frac{tFd}{\Sigma A}$

↑ $1700\varepsilon_0$

Psheet 2 Q2, cont'd

(c)



① $Q = P_Q A \Delta T$ Pyroelectric effect

$Q = CV$, $C = \frac{\Sigma A}{d}$ } $Q = \frac{\Sigma A V}{d}$ ② capacitor

$\Delta T = 50\,K$

$P_Q = 4 \times 10^{-4}\ C/m^2K$

$\Sigma = \Sigma_r \Sigma_0$

Σ_r: 1700

① = ② $\quad P_Q A \Delta T = \frac{\Sigma A V}{d}$

$V = \frac{d P_Q \Delta T}{\Sigma}$ (subsin)

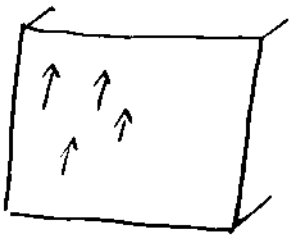
(d)

$\Delta T = \frac{\Sigma V}{d P_Q}$ $\qquad \Sigma_r = 12$

(e)

④

(a)



AFM/STM Piezo is charge buildup/loss upon to stress. No temp change

IR detector Pyro is charge b/c of thermal expansion/contraction. No Force externally.

Note both may occur upon heating: "Secondary Pyro"

(b)

78 pC/N

0.5 N

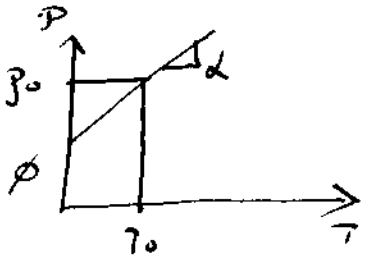
(i) $Q = dF$

(ii) $V = \frac{tQ}{\varepsilon A} = \frac{tdF}{\varepsilon A}$

(iii) $\frac{\Delta V}{\Delta F} = \frac{td}{\varepsilon A}$ (plug in)

(5)

~~$\rho = \rho_0[1+\alpha(T-T_0)]$~~ $\rho = \rho_0 + \alpha(T-T_0)$



(a)

$\rho = 1.69 \times 10^{-6}$ [illegible] $+ 3.9 \times 10^{-3}$ (T