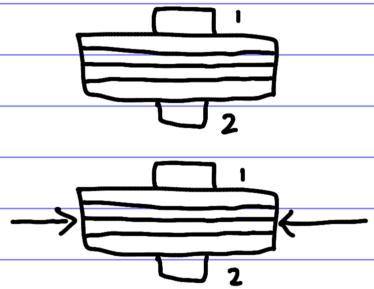
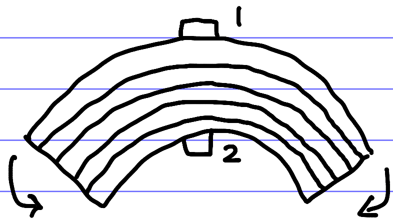
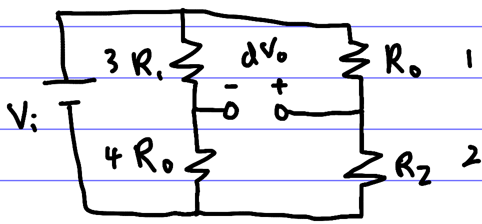
1)




Axial




Bending




$$S_1 = S^a + S^b + S^T$$

$$S_2 = S^a - S^b + S^T$$

$$\frac{dV_0}{V_i} = \frac{1}{4} G \left( \frac{dR_2}{R_2} - \cancel{\frac{dR_0}{R_0}} + \frac{dR_1}{R_1} - \cancel{\frac{dR_0}{R_0}} \right)$$

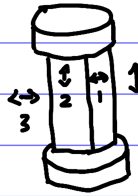
$$= \frac{1}{4} G (S_2 + S_1)$$

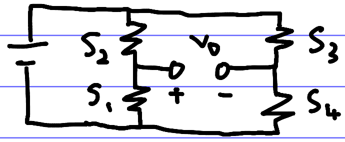
$$= \frac{1}{4} G (S^a \cancel{- S^b} + S^T + S^a \cancel{+ S^b} + S^T)$$

$$= \frac{1}{4} G (2S^a + 2S^T)$$

$$= \frac{1}{2} G (S^a + S^T)$$

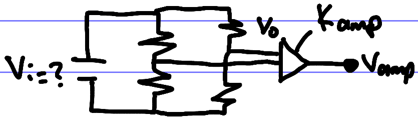
2)




$$S_2 = S_4 = S^a + S^T$$
$$S_1 = S_3 = -S^a + S^T$$
$$= -\nu S^a + S^T$$

$$\frac{V_0}{V_i} = \frac{1}{4} G (S_1 - S_2 + S_3 - S_4)$$
$$= \frac{1}{4} G(-\nu S^a \cancel{+ S^T} - S^a \cancel{- S^T} - \nu S^a \cancel{+ S^T} - S^a \cancel{- S^T})$$
$$= \frac{1}{4} G(-2\nu S^a - 2S^a)$$
$$= -\frac{1}{2} G (1+\nu) S^a$$
$$= -\frac{1+\nu}{2} G S^a$$




$V_{amp} = 1V$

$2 \times V_{in} = 2 \rightarrow V_0$

$V_{max} = ?$

$I_{max} = 30mA$

Nominal resistance, $R_0$

$$V_{max} = 2R_0 I$$
$$= 2(100)(30 \times 10^{-3})$$
$$= 6V$$
$$V_{max} \leq 6V$$

$$V_{amp} = K_{amp} V_0$$
$$V_0 = \frac{V_{amp}}{K_{amp}}$$

$$\frac{V_0}{V_{in}} = \frac{V_{amp}}{K_{amp} V_{in}} = -\frac{1+\nu}{2} G S^a$$
$$\frac{V_{amp}}{K_{amp} V_{in}} = -\frac{1+\nu}{2} G \left(\frac{-F_0}{AE}\right)$$
$$K_{amp} = \frac{2 V_{amp} AE}{(1+\nu) G F_0 V_{in}}$$
$$= \frac{2(1)(1 \times 10^{-2})(210 \times 10^9)}{(1+0.29)(2.1)(10^5)(6)}$$
$$= 2583.979328$$
$$\approx 2584$$

3) $\frac{dR}{R} = \left(\frac{d\rho}{\rho}\frac{1}{S} + 1+2\nu\right)S$

$$R = \rho\left(\frac{L}{A}\right)$$

$$dR = d\rho\left(\frac{L}{A}\right) + dL\left(\frac{\rho}{A}\right) + \rho L\, d\left(\frac{1}{A}\right)$$

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} + \frac{dA}{A}$$

$$A = \pi r^2$$

$$= \frac{\pi}{4}\phi^2$$

$$dA = \frac{\pi}{4}(2\phi\, d\phi)$$

$$\frac{dA}{A} = \frac{\cancel{\frac{\pi}{4}}(2\cancel{\phi}\, d\phi)}{\cancel{\frac{\pi}{4}}\phi^{\cancel{2}}}$$

$$= \frac{2\,d\phi}{\phi}$$

$$\frac{d\phi}{\phi} = \frac{dL}{L}(-\nu)$$

$$= -\nu\frac{dL}{L}$$

$$\therefore \frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - \left(-2\nu\frac{dL}{L}\right)$$

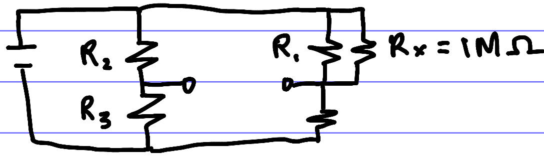
$$= \frac{d\rho}{\rho} + (1+2\nu)\frac{dL}{L}$$

$$= \frac{d\rho}{\rho} + (1+2\nu)S \qquad \because S = \frac{dL}{L}$$

$$= \left(\frac{d\rho}{\rho}\frac{1}{S} + 1 + 2\nu\right)S \quad \text{(shown)}$$

4)

$R_1 = R_2 = R_3 = 120\Omega$




$$\frac{dR_g}{R_g} = G^* S$$

$$\frac{dR_1}{R_1} = \frac{R_1 // R_x}{R_1} - \frac{R_1}{R_1}$$

$$= \frac{R_x}{R_1 + R_x} - 1$$

$$= \frac{\cancel{R_x}}{R_1 + R_x} - \frac{R_1 + \cancel{R_x}}{R_1 - R_x}$$

$$= -\frac{R_1}{\cancel{R_1} + R_x}$$

$$\approx -\frac{R_1}{R_x} \quad \because \; R_1 << R_x$$

$$= -\frac{120}{1\times 10^6}$$

$$= -1.2\times 10^4$$

$$\frac{dR_g}{R_g} + \frac{dR_1}{R_1} = 0$$

$$\frac{dR_g}{R_g} = -\frac{dR_1}{R_1}$$

$$= -(-1.2\times 10^{-4})$$

$$= 1.2\times 10^{-4}$$

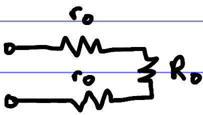
$$G^* S = 1.2\times 10^{-4}$$

$$G^* (100\times 10^{-6}) = 1.2\times 10^{-4}$$

$$G^* = 1.2$$

4) Why is $G^* = 1.2$, which is much less than the expected value of 2.1?

1. Poor bonding.
2. Possible misalignment
3. Long wire resistance




$$S_G = \frac{dR_o}{R_o} \qquad S_G^* = \frac{dR_g}{R_g} \qquad R_g = 2r_o + R_o$$

$$S_G^* = \frac{d(2r_o + R_o)}{2r_o + R_o}$$

$$= \frac{dR_o}{2r_o + R_o}$$

$$= \frac{dR_o}{R_o}\left(\frac{R_o}{2r_o + R_o}\right)$$

$$= S_G\left(\frac{R_o}{2r_o + R_o}\right)$$