1. a). Eliminate options (1) & (3), since for $t<0$, source is moving towards the detector so the frequency would be higher than f.

Eliminate (2) since it does not account for Doppler effect.

For L1, the comp. of velocity along the line joining the source & the detector does not change. This does change however for L2, with time. Thus, we have a step function for L1 & a gradual change for L2.

Hence, answer is (4)

b) $R_1 = \frac{\rho L}{A_1}$ $R_2 = \frac{2\rho L}{A_2}$ $R_3 = \frac{3\rho L}{A_3}$ $\rho \rightarrow$ resistivity.

Since volt. diff. across each resistor is the same,

$I_1 R_1 = I_2 R_2 = I_3 R_3$ Now, $J_i = \frac{I_i}{A_i}$

$$\Rightarrow I_1 \frac{\rho L}{A_1} = I_2 \frac{\rho 2L}{A_2} = I_3 \frac{\rho 3L}{A_3}$$

$$\Rightarrow J_1(\rho L) = 2J_2(\rho L) = 3J_3(\rho L).$$

$$\Rightarrow J_1 = 2J_2 = 3J_3.$$ (2)

c) Note: $P_A = P_B$ (Equal resistors in parallel : V^2/R)

: $P_C = P_D$ (Equal resistors in series : I^2R).

Now, notice that the current flowing through limb "C & D" of the circuit is less than the current flowing through A or B.

$$\Rightarrow P_A = P_B > P_C = P_D.$$

Only option with this relation is (5).

2 a). Freq. that the truck hears / reflects :

$$f' = \frac{V_S - V_T}{V_S - V_P} f_P.$$

f' is reflected from the truck. The police car hears a doppler shifted version f_P' of f':

$$f_P' = \left(\frac{V_S + V_P}{V_S + V_T}\right) f' = \left(\frac{V_S + V_P}{V_S - V_P}\right)\left(\frac{V_S - V_T}{V_S + V_T}\right) f_P.$$

b) $f_p' = \left(\frac{1+v_P/v_S}{1-v_P/v_S}\right)\left(\frac{1-v_T/v_S}{1+v_T/v_S}\right) f_P$

$\approx \left(1+v_P/v_S\right)\left(1+v_P/v_S\right)\left(1-\frac{v_T}{v_S}\right)\left(1-\frac{v_T}{v_S}\right) f_P.$

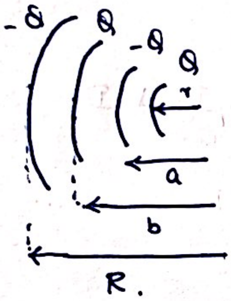
Binomial approximatn: $(1+x)^n \approx 1+nx$ for $x \ll 1$.

$\approx \left(1+\frac{2v_P}{v_S}-\frac{2v_T}{v_S}\right) f_P$

Beat frequency: $|f_P - f_P'| = \frac{2}{v_S}|v_P - v_T| f_P = \frac{2}{v_S}(v_P - v_T) f_P.$

When $v_P = v_T$, there is no relative motion b/w the truck & the police car $\Rightarrow$ no Doppler effect $\Rightarrow$ no beats.

3a)



Notice how the charge is distributed on the inserted metal cylinder. (Use Gauss' law to justify this distribution).

Now, the configuration looks like two capacitances in series with each other: (i) cylinder with inner & outer radii b & R, respectively
(ii). " " " " r & a, " .

(i) $C_1 = 2\pi\epsilon_0 \frac{L}{\log(R/b)}$

(ii) $C_2 = 2\pi\epsilon_0 \frac{L}{\log(a/r)}$

$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} \Leftrightarrow \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{2\pi\epsilon_0 L}\left[\log\left(R/b\right) + \log\left(a/r\right)\right]$

$\Rightarrow C_{eq} = \frac{2\pi\epsilon_0 L}{\log\left(\frac{Ra}{br}\right)}$

b) Energy stored $= \frac{Q^2}{2C_{eq}}.$

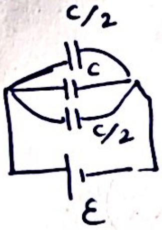
$= \frac{Q^2}{2} \cdot \frac{1}{2\pi\epsilon_0 L} \log\left(\frac{Ra}{rb}\right).$

Need to maximise $\log(r/a) + \log(R/b) \Leftrightarrow$ $a = b$

$\Rightarrow$ Have only one capacitor : maximize region with $E \neq 0$ for storing more electrostatic energy.

c)

=



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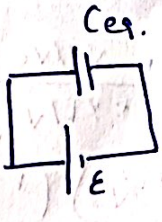


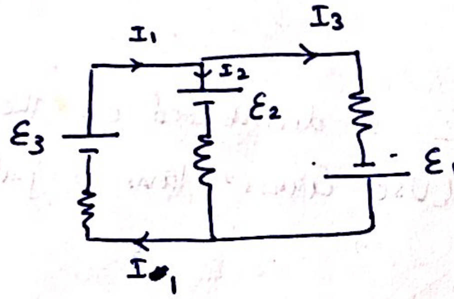
$C_{eq} = \frac{C}{2} + C + \frac{C}{2}$

$= \underline{\underline{2C}}$

Energy $= \frac{1}{2} C_{eq}\, \varepsilon^2$

$= \underline{\underline{C\varepsilon^2}}$.

4a).



$I_1 = I_2 + I_3$

independent currents = I_2 & I_3.

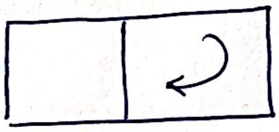
b)

Loop law:

$-\varepsilon_2 - I_2 R - I_1 R + \varepsilon_3 = 0$

$\Rightarrow \varepsilon_3 - \varepsilon_2 = R(I_1 + I_2)$

$= R(2I_2 + I_3)$. ---- (*).



loop law:

$-I_3 R + \varepsilon_1 + I_2 R + \varepsilon_2 = 0$

$\Rightarrow \varepsilon_2 + \varepsilon_1 = (I_3 - I_2) R$ --- (**).

c). Want $I_1 = 0 \Rightarrow I_2 = -I_3$

(*) $\Rightarrow$ $-RI_3 = \varepsilon_3 - \varepsilon_2$

(**) $\Rightarrow$ $\varepsilon_2 + \varepsilon_1 = 2RI_3$

$\Rightarrow \varepsilon_1 + \varepsilon_2 = 2RI_3 = 2(\varepsilon_2 - \varepsilon_3) \Rightarrow \boxed{\varepsilon_1 - \varepsilon_2 + 2\varepsilon_3 = 0}$

$\Rightarrow \varepsilon_3 = \frac{1}{2}(\varepsilon_2 - \varepsilon_1)$

Current through $\varepsilon_2 = I_2 = -I_3 = \frac{\varepsilon_3 - \varepsilon_2}{R}$

$= -\frac{1}{2R}(\varepsilon_1 + \varepsilon_2)$

* -ve sign indicates opp. direction

=> current flows upwards.