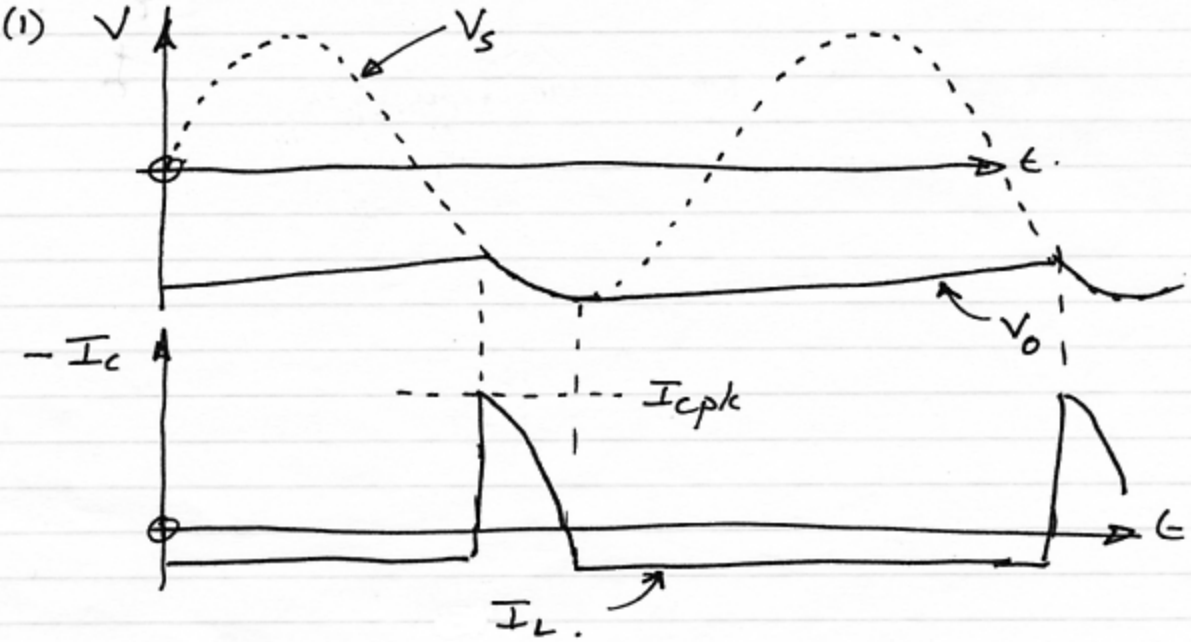
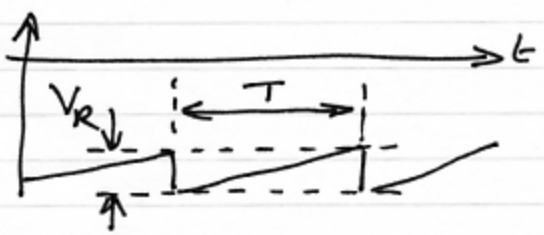
Solutions to EEE103 "Analogue Circuits" June 2003.

Q1. (i)



The peaky nature of the current waveform is unattractive to electricity suppliers because it gives an rms current $\gg$ average current and creates a high level of harmonic content on the supply lines. These two effects reduce the efficiency of the electricity supply system and the harmonics can interfere with other equipment.

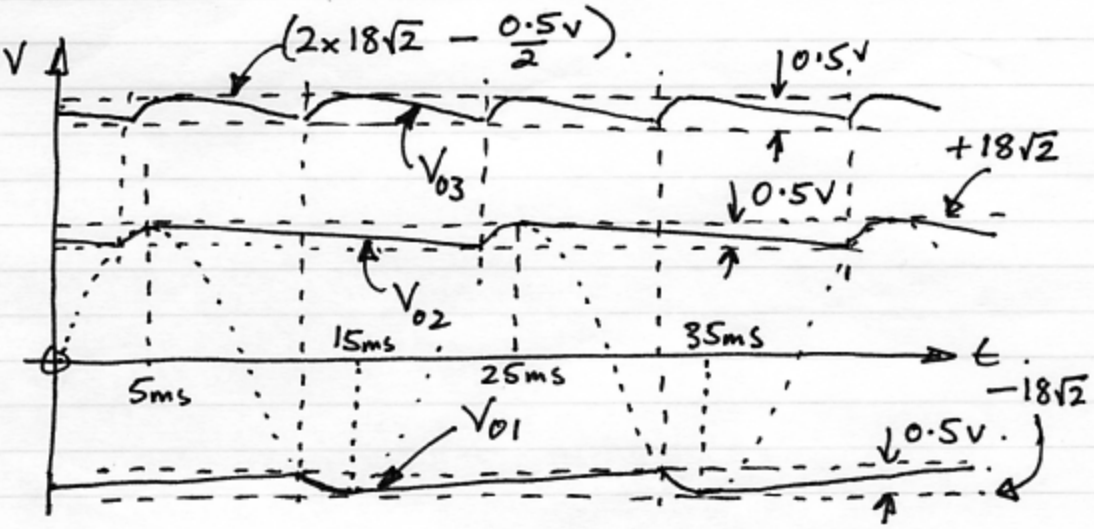
(ii) Assume C charges instantaneously and I_L = const...



$$I_L = C\frac{dV}{dt} = C\frac{V_R}{T}$$

$$= C\frac{V_R}{1/f} \quad \therefore \quad C = \frac{I_L}{V_R f} = \frac{0.1}{0.5\times 50} = \underline{\underline{4000\,\mu F}}.$$

(iii)



Assumes diodes are ideal.

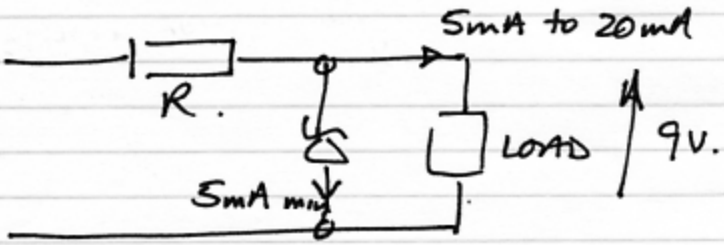
EEE103 June 2003 Sols.

Q1 cont....

(iv). $V_{02} = 18\sqrt{2} - \frac{0.5}{2}$

$= 25.21.$

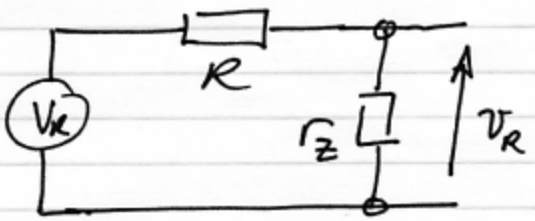
(assuming ideal diodes).



$$R_{max} = \frac{25.21 - 9}{5mA + 20mA} = \frac{16.21}{25mA} = \underline{\underline{648\Omega}}.$$

(a range of approximations is possible here – all reasonable ones will get full marks as long as they are stated.).

(v) The ripple (small signal) equivalent cct is:-



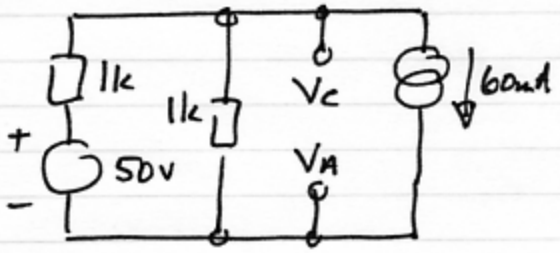
[load assumed to draw a constant current]

$$\therefore v_R = V_R \frac{r_z}{R + r_z} = 0.5 \times \frac{5}{648 + 5}$$

$$= \underline{\underline{308mV}} \text{ pk-pk}.$$

EEE 103 June 2003 Sols

Q2. a) replace the diode with an open cct and work out $V_A - V_C$ .....



due to 60mA source,

$V_A - V_C = 60\text{mA} \times 1\text{k}\Omega \,//\, 1\text{k}\Omega$

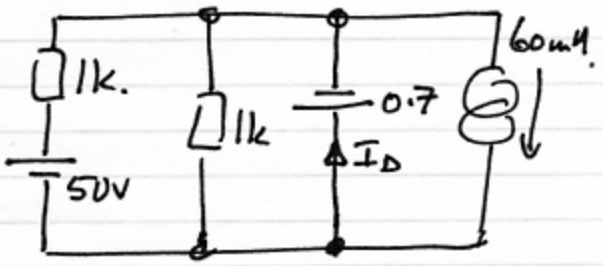
$= 30\text{V}.$

due to 50V source

$V_A - V_C = -50 \times \frac{1\text{k}\Omega}{1\text{k}\Omega + 1\text{k}\Omega} = -25\text{V}.$

$\therefore$ Total $V_A - V_C = 30\text{V} + (-25\text{V}) = 5\text{V} \rightarrow$ diode conducts.

replace diode with a 0.7V source & work out current through it....



due to 60 mA source,

$I_D = 60\text{ mA}$

due to 0.7v source,

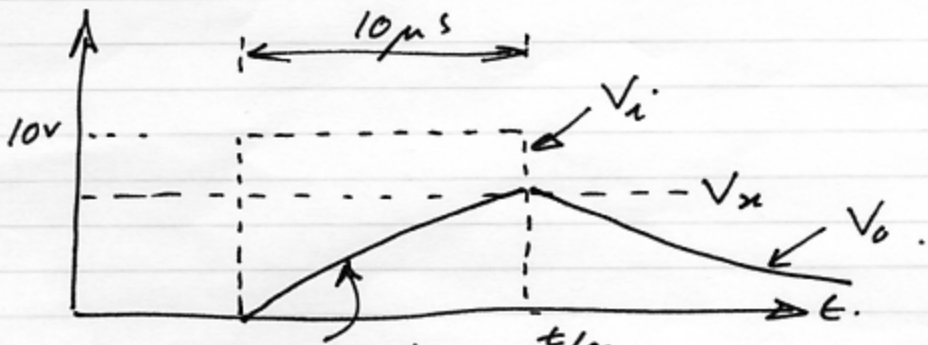
$I_D = -\frac{0.7}{1\text{k}\Omega \,//\, 1\text{k}\Omega} = -1.4\text{mA}$

due to 50V source

$I_D = -\frac{50\text{V}}{1\text{k}\Omega} = -50\text{mA}$

$\therefore$ Total $I_D = 60 - 1.4 - 50 = \underline{\underline{8.6\text{mA}}}.$

b)(i).



$V(t) = 10\left(1 - e^{-t/\tau}\right).$ $\tau = 1\text{nF} \times 10\text{k}\Omega$

$= 10\mu\text{S}.$

EEE 103 June 2003 sols

Q2 cont.....

after 10μs $V(t) = 10\left(1 - e^{-10\mu s/10\mu s}\right) = 10\left(1 - \frac{1}{e}\right) = V_{\infty}$.

$V_{\infty} = \underline{\underline{6.32\,V}}$.

V(t) reaches 5v when...

$5 = 10\left(1 - e^{-t/10\mu s}\right)$.

or $e^{-t/10\mu s} = 0.5$ or $t = 10\mu s \ln 2$

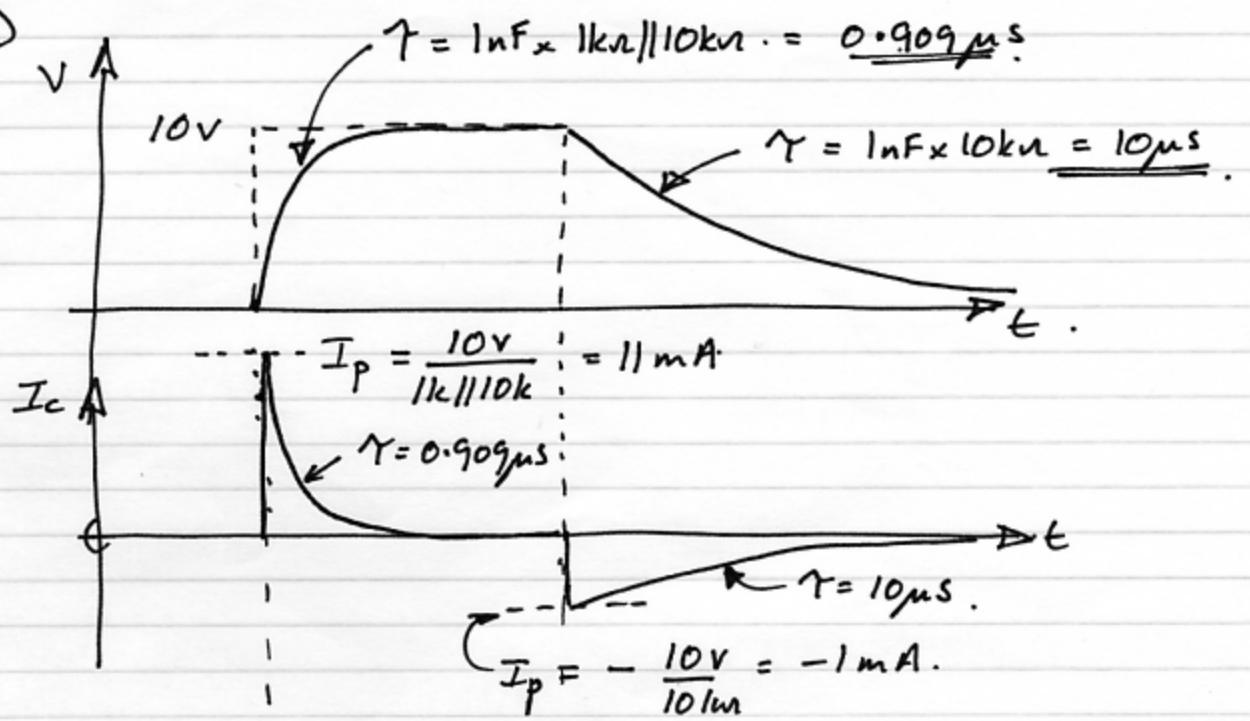
$= 6.93\mu s$.

Falling exponential is $V(t) = 6.32\, e^{-t/10\mu s}$ and this falls to 5v when

$5 = 6.32\, e^{-t/10\mu s}$ or $t = 10\mu s \ln \frac{6.32}{5} = 2.34\mu s$.

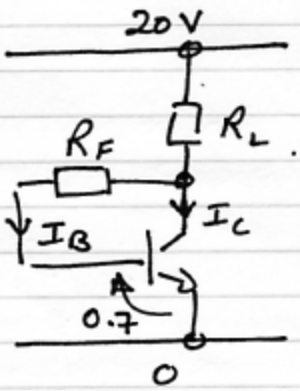
$\therefore$ time >5V = $10\mu s - 6.93\mu s + 2.34\mu s = \underline{\underline{5.41\,\mu s}}$.

(ii)



EEE103 June 2003 sols.

Q3 (i) There are two unknown currents so two equations are needed....



$I_C = h_{FE} I_B$ ——— (1)

$0.7 + I_B R_F + (I_B + I_C) R_L = 20$ ——— (2)

eliminating I_B ....

$$0.7 + \frac{I_C}{h_{FE}} R_F + \left(\frac{I_C}{h_{FE}} + I_C\right) R_L = 20$$

$$I_C \left[\frac{R_F}{h_{FE}} + \frac{R_L}{h_{FE}} + R_L\right] = 19.3 \quad \text{or} \quad I_C = \frac{19.3}{\frac{R_F + R_L}{h_{FE}} + R_L}$$

when $h_{FE} = 50$

$$I_C = \frac{19.3}{684.7/50 + 4.7}\ \text{mA} = 1.05\text{mA} \quad \therefore I_B = \frac{1.05\text{mA}}{50} = 21\mu\text{A}$$

when $h_{FE} = 500$

$$I_C = \frac{19.3}{684.7/500 + 4.7}\ \text{mA} = 3.18\text{mA} \quad \therefore I_B = \frac{3.18\text{mA}}{500} = 6.36\mu\text{A}$$

when $I_C = 1.05\,\text{mA}$, $V_C = 20 - (1.05 + 0.021) \times 4.7 = 14.96\text{V}$

when $I_C = 3.18\,\text{mA}$, $V_C = 20 - (3.18 + 0.006) \times 4.7 = 5.03\text{V}$.

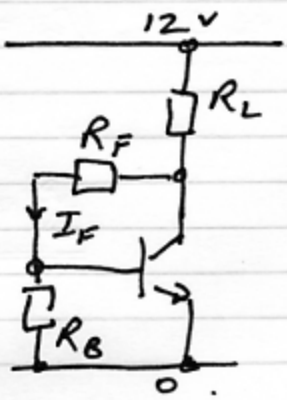
$\therefore$ range of values...

$h_{FE} = 50 \rightarrow$ $I_C = 1.05\,\text{mA}$, $V_C = 15\text{V}$

$h_{FE} = 500 \rightarrow$ $I_C = 3.18\,\text{mA}$, $V_C = 5\text{V}$.

This is a poor bias circuit because it fails to control I_C effectively against the spread of h_{FE}.

(ii) If the cct is well designed, I_B is negligible, so ...



$0.7 = I_F R_B$

$12 = 0.7 + I_F R_F + (I_C + I_F) R_L$

eliminating I_F...

$$12 = 0.7 + \frac{0.7}{R_B} \cdot R_F + I_C R_L + \frac{0.7}{R_B} \cdot R_L$$

$$12 - 0.7 - \frac{0.7}{R_B}(R_F + R_L) = I_C R_L = 5.05$$

$\therefore$ $I_C = 1.07\,\text{mA}$.

EEE 103 June 2003 sols.

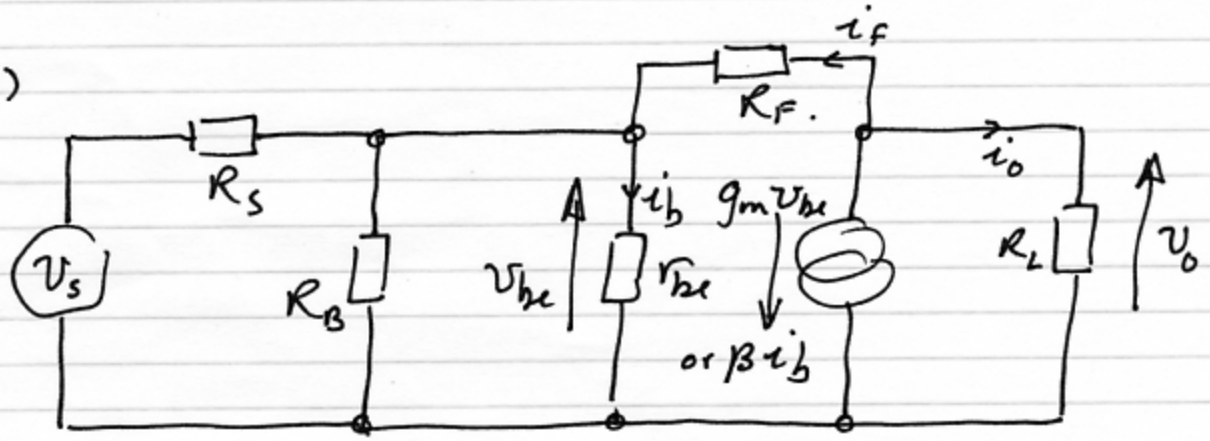
Q3 pt(ii) cont....

$$V_c = 12 - (I_F + I_c)R_L = 12 - 5.05 - \frac{0.7 R_L}{R_B} = \underline{6.47\ V}$$

$$g_m = \frac{eI_c}{kT} = \frac{1.07\ mA}{0.026\ V} = \underline{41\ mA/V.}$$

$$r_{be} = \beta / g_m = 600 / 0.041 = \underline{14.6\ k\Omega}.$$

(iii)



(iv). summing currents at output node.....

$$i_o + i_f + g_m v_{be} = 0 \quad \text{or} \quad \frac{v_o}{R_L} + \frac{v_o - v_{be}}{R_F} + g_m v_{be} = 0 \qquad (1).$$

at the base node, $v_s = v_{be}$ since $R_s = 0$.

$\therefore$ (1) becomes...

$$v_o\left[\frac{1}{R_L} + \frac{1}{R_F}\right] + v_s\left[g_m - \frac{1}{R_F}\right] = 0.$$

$$g_m = 41 \times 10^{-3}\ mA/V. \quad \frac{1}{R_F} = 17.9 \times 10^{-6}\ S$$

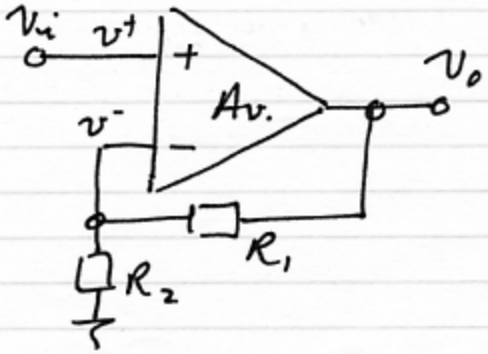
$$\therefore g_m - \frac{1}{R_F} \approx g_m$$

$$\therefore 2.306 \times 10^{-4}\, v_o = -0.041\, v_s$$

$$\therefore \frac{v_o}{v_s} = \underline{-178}.$$

EEE103 June 2003 sols

Q4 a)

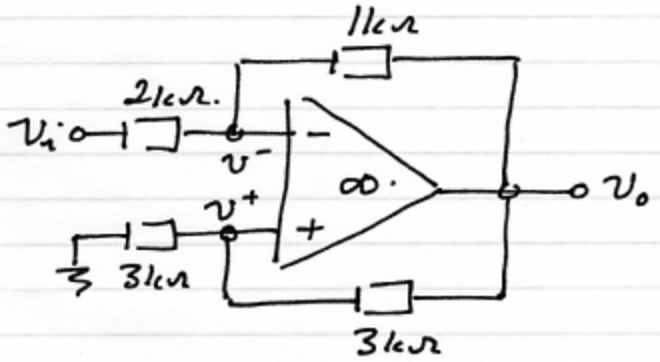


$$\frac{v_o}{v_i} = \frac{R_1 + R_2}{R_2}.$$

Assumes that $A_v \Rightarrow \infty$

When the assumption $A_v \Rightarrow \infty$ is valid, calculations are simplified because v^+ must be equal to v^-. Analysing a circuit then involves working out v^+ & v^- in terms of v_i + v_o and equating them.

b) (i)



$v^+ = v_o/2$ by pot. div.

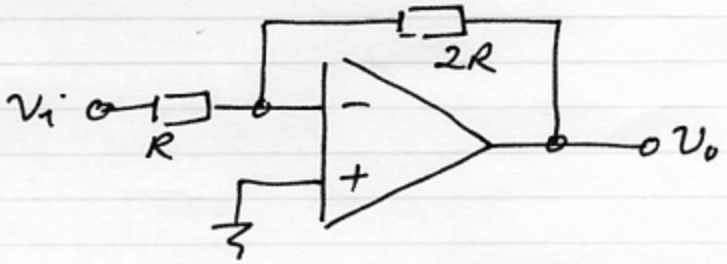
$$v^- = v_i \cdot \frac{1}{3} + v_o \cdot \frac{2}{3}.$$

equating the two ....

$$\frac{v_o}{2} = \frac{v_i}{3} + \frac{2v_o}{3} \quad \text{or} \quad \frac{v_i}{3} = -\frac{v_o}{6}.$$

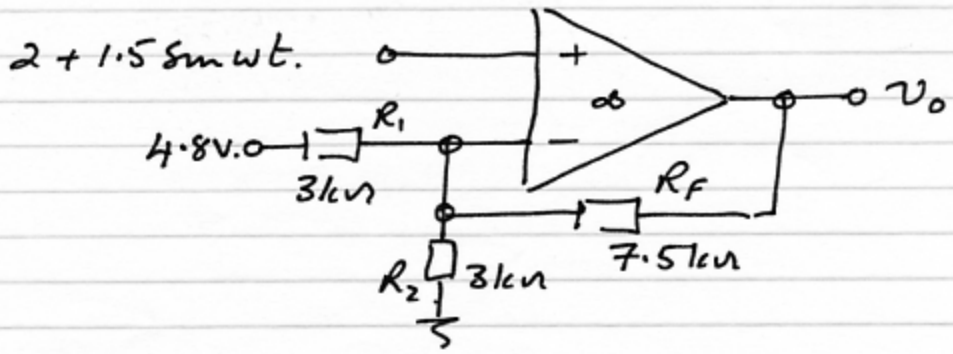
$$\text{or} \quad \frac{v_o}{v_i} = -2.$$

(ii) an easier way to achieve the function of pt (i) is ...



EEE 103 June 2003 sols.

Q4 c



as far as v^+ is concerned, $R_1 + R_2$ are in parallel ....

V_o due to v^+ is

$$(2 + 1.5 \sin \omega t) \times \frac{R_F + R_1 \| R_2}{R_1 \| R_2}$$

$$\frac{R_F + R_1 \| R_2}{R_1 \| R_2} = \frac{7.5\text{k}\Omega + 1.5\text{k}\Omega}{1.5\text{k}\Omega} = 6.$$

$\therefore$ V_o due to v^+ is $12 + 9 \sin \omega t$.

as far as 4·8V is concerned, v^- is a virtual earth ..

$$\therefore V_o \text{ due to } 4.8\text{V} = -4.8 \times \frac{R_F}{R_1} = -4.8 \times \frac{7.5}{3}$$

$$= -4.8 \times \frac{5}{2} = -12.$$

$$\therefore \text{total } V_o = 12 + 9 \sin \omega t - 12$$

$$= 0 + 9 \sin \omega t$$

$\therefore$ a = 0V
b = 9V.