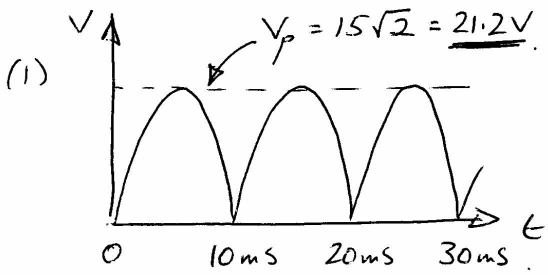
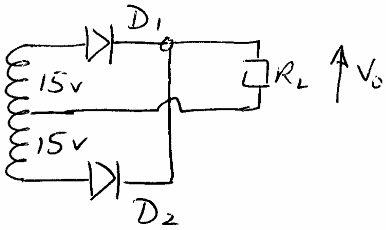
Q1

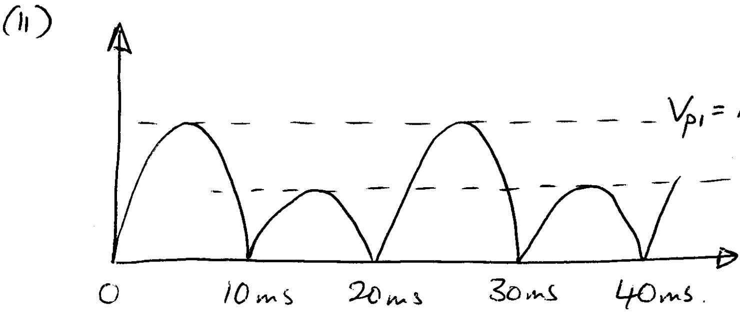
(i)





$$I_{R_L\,peak} = V_p/R_L = \frac{15\sqrt{2}}{100} = \underline{\underline{212mA}}$$

(ii)



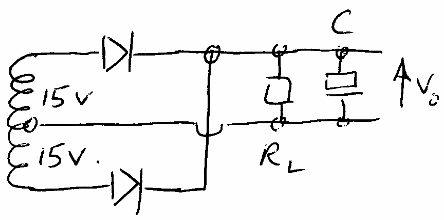
$V_{p1} = 15\sqrt{2} = \underline{\underline{21.2V}}$

$$V_{p2} = V_{p1}\frac{R_L}{100+R_L} = \frac{V_{p1}}{2} = \underline{\underline{10.6V}}$$

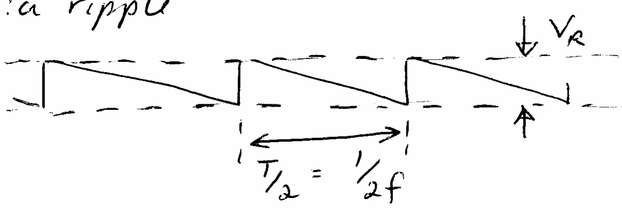
(iii) V_{AVE} = V_{AVE} for V_{p1} half cycles + V_{AVE} for V_{p2} half cycles

$$= \frac{V_{p1}}{\pi} + \frac{V_{p2}}{\pi} = 6.75 + 3.37 = 10.12$$

(iv) Assume:
instantaneous charging
constant I_L



this leads to a ripple model:



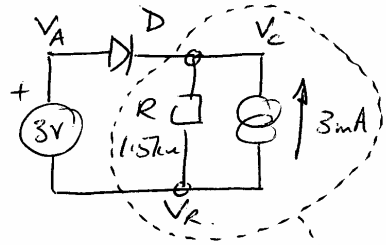
$$\therefore \quad I_L = C\frac{dV}{dt} = C\,\frac{V_R}{(1/2f)} = V_P/R_L$$

$$\text{or} \quad C = \frac{V_P}{2f V_R R_L} = \underline{\underline{4.24\,mF.}}$$

(v) The diode conducts only for a short time in each charging cycle if the smoothing is effective.
The charge lost between charging events because of current flow from C to R_L must be replaced when the diode conducts.
Since $t_{(\text{diode conduction})} \ll t_{(C \text{ supplies } I_L)}$
$I_{(\text{diode conduction})} \gg I_L$ to achieve a charge balance.

Spikey waveforms have a large harmonic content and a large $\frac{rms}{ave}$ ratio – in other words the heating losses in the supply system are relatively large compared to what one might expect by considering the d.c. output current magnitude.

Q2 (a) (i) Assume diode is not conducting.... replace diode by an open circuit.



Thus $V_A = 3V$ w.r.t. V_R.

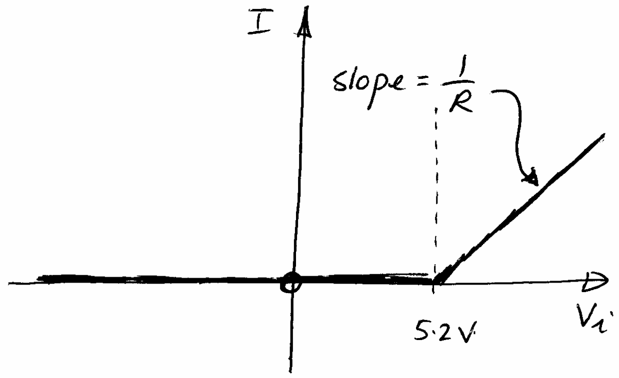
$V_C = 3mA \times R$ w.r.t. $V_R = 4{\cdot}5V$.

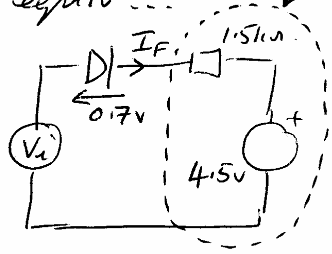
$\therefore V_A - V_C = 3 - 4{\cdot}5 = -1{\cdot}5V$

$\therefore$ diode non-conducting + reverse biased by $\underline{\underline{1{\cdot}5V}}$.

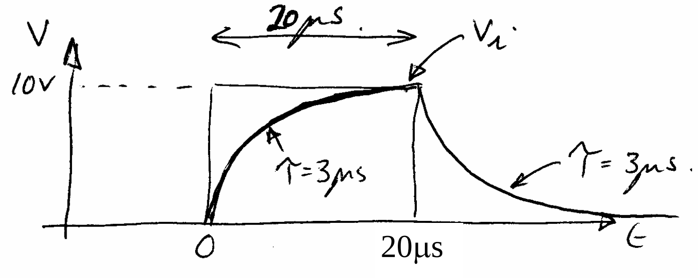
(ii) The V_i at which the diode will be on the point of changing state will be ...

$V_A = 0{\cdot}7v + 3mA \times R = 5{\cdot}2V$. For voltages bigger than this value, a current $\frac{V_i - 5{\cdot}2}{R}$ will flow through R. This is easier to see if the 3mA + 1.5kΩ are replaced by a Thevenin equiv ...





(b)



rising exponential $= 10(1-e^{-t/3\mu s})$ so time to reach 7.5V is ....

$$7.5 = 10(1-e^{-t/3\mu s}).$$

or $e^{-t/3\mu s} = 1 - 0.75 = 0.25$

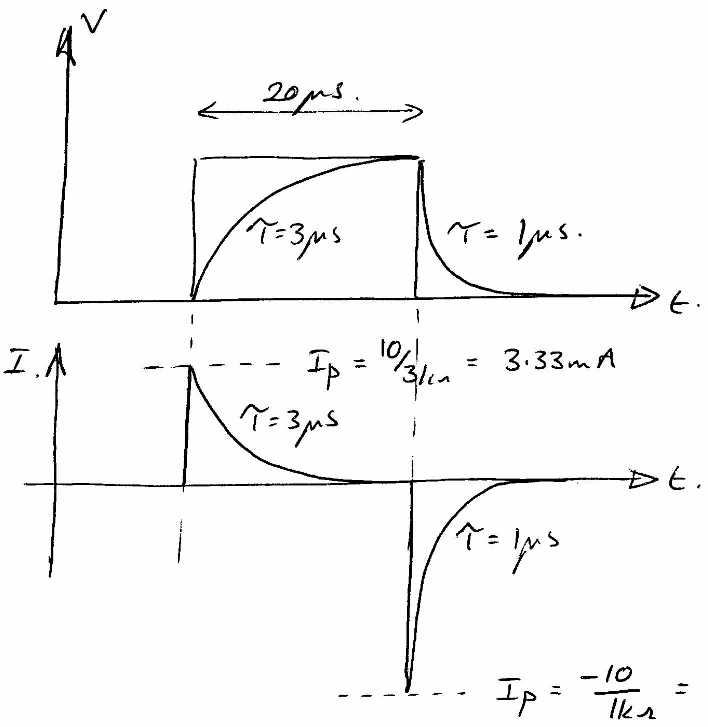
or $-t/3\mu s = \ln 0.25$ or $t = 3\mu s \ln 4 = 4.16\mu s.$

falling exponential $= 10\, e^{-t/3\mu s} = 7.5V.$

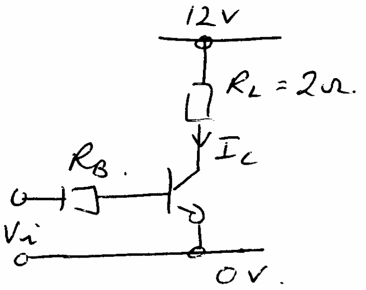
or $e^{-t/3\mu s} = 0.75$ or $t = 3\mu s \ln \frac{4}{3} = 863 ns.$

$\therefore$ t above 7.5V $= 20\mu s + 0.86\mu s - 4.16\mu s = \underline{\underline{16.7\mu s}}$

(ii)



Q3 (a) (i)



$$I_{C(ON)} \approx \frac{V_{supply}}{R_L} = \frac{12}{2} = 6A.$$

(ii) If $I_{C(ON)} = 6A$,

$$I_{B(ON)} = \frac{6A}{h_{FE}} = \frac{6A}{50} = 120mA.$$

$$I_{B(ON)} = 120mA = \frac{V_{i(ON)} - 0.7}{R_B}$$

$$= \frac{12 - 0.7}{R_B} \quad \text{or} \quad \underline{\underline{R_B = 94\Omega}}.$$

(iii) can take two approaches here ...

- assume 12V >> V_{CESAT} so V_{CESAT} does not significantly change I_{CON}.
  Then $P_D = 6A \times 0.3V = \underline{1.8W}$.
- or allow for effect of V_{CESAT} on $I_{C(ON)}$

$$I_{C(ON)} = \frac{12 - 0.3}{2} = 5.85A.$$

$$P_D = 5.85A \times 0.3V = \underline{\underline{1.755\,W}}$$

[full marks for either].

(b) (i) Assume I_B is negligible ....

$$V_B = 20 \times \frac{R_2}{R_1 + R_2} = 20 \times \frac{30}{150} = \underline{\underline{4V}}.$$

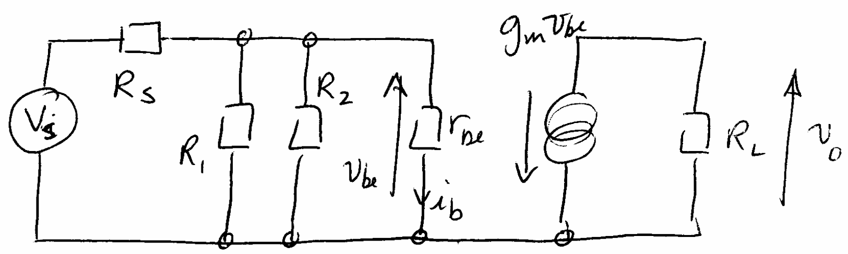
$$\therefore I_C \approx I_E = \frac{V_B - 0.7}{R_E} = \frac{4 - 0.7}{3.3k\Omega} = \underline{\underline{1mA}}.$$

$$V_C = V_{CC} - I_C R_L = 20 - 8.2 = \underline{\underline{11.8V}}.$$

$$g_m = \frac{eI_c}{kT} = \frac{1mA}{.026\,V} = \underline{\underline{38.5\,mA/V}} = 0.0385\,A/V$$

$$r_{be} = \beta/g_m = \frac{400}{0.0385} = \underline{\underline{10.4\,k\Omega}}.$$

(ii)



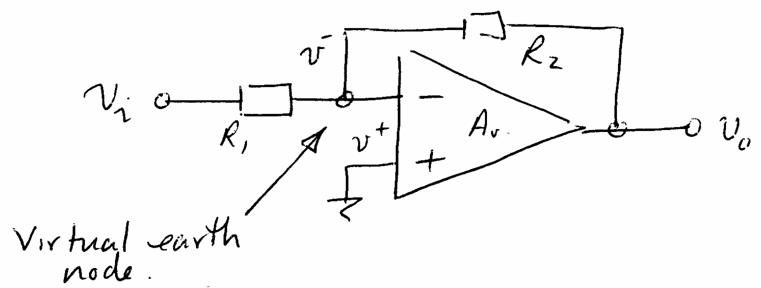
(iii) $$\frac{v_o}{v_{be}} = -g_m R_L = -315.7.$$

$$\frac{v_{be}}{v_s} = \frac{r_{be}\,//\,R_1\,//\,R_2}{R_S + R_1//R_2//r_{be}} = \frac{7.26\,k\Omega}{2.2\,k\Omega + 7.26\,k\Omega}$$

$$= 0.767.$$

$$\therefore \frac{v_o}{v_s} = \frac{v_o}{v_{be}} \times \frac{v_{be}}{v_s} = -315.7 \times 0.767 = \underline{\underline{-242}}.$$

Q4 (a)

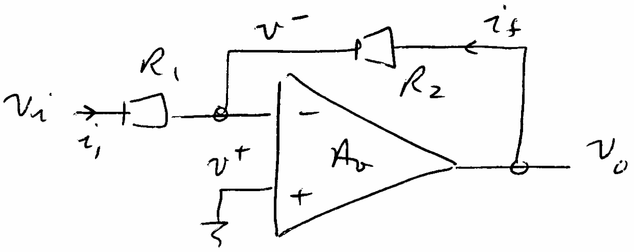


A "virtual earth" is a cct node that has a potential that is always very close to earth but not electrically connected to it.

The virtual earth exists because of a very large A_v in conjunction with a grounded non-inverting input. Since A_v is very large, $v^+ \approx v^-$ and since $v^+ = 0$, $v^- \approx 0$. The virtual earth is maintained by the feedback process.

[any virtual earth circuit can attract full marks].

(b)



$$i_1 + i_f = 0 = \frac{v_i - v^-}{R_1} + \frac{v_o - v^-}{R_2}.$$

$$\text{or } v^- = v_i \frac{R_2}{R_1 + R_2} + v_o \frac{R_1}{R_1 + R_2}.$$

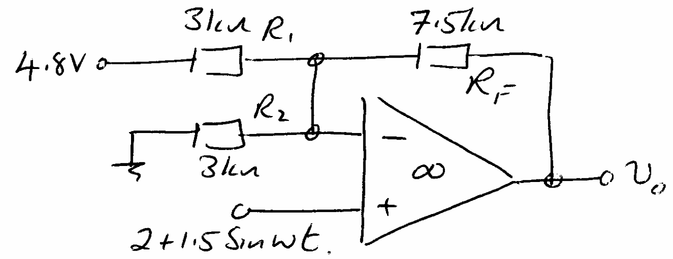
using the op-amp equation,

$$A_v(v^+ - v^-) = v_o = A_v\left(0 - v_i \frac{R_2}{R_1 + R_2} - v_o \frac{R_1}{R_1 + R_2}\right)$$

$$v_o\left[1/A_v + R_1/(R_1+R_2)\right] = -v_i\, R_2/(R_1+R_2)$$

$$\frac{v_o}{v_i} = \frac{-\,R_2/(R_1+R_2)}{1/A_v + R_1/(R_1+R_2)}$$

(c)



First the a.c. component (4.8V input = ac ground)

$$\therefore v_{o(ac)} = 1.5 \cdot \frac{R_F + R_1 /\!/ R_2}{R_1 /\!/ R_2}$$

$$= 1.5 \cdot \frac{7.5+1.5}{1.5} = 9.0. \;(= b)$$

Then the d.c. component (by superposition).

$$v_{o(dc)2V} = 2 \cdot \frac{R_F + R_1 /\!/ R_2}{R_1 /\!/ R_2} = 12V.$$

$$v_{o(dc)4.8V} = 4.8 \times \left(-\frac{7.5k\Omega}{3k\Omega}\right)$$

$$= -4.8 \times 2.5 = -12V$$

$$\therefore v_{o(dc)\,tot} = 12V - 12V = 0. \;(= a)$$

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