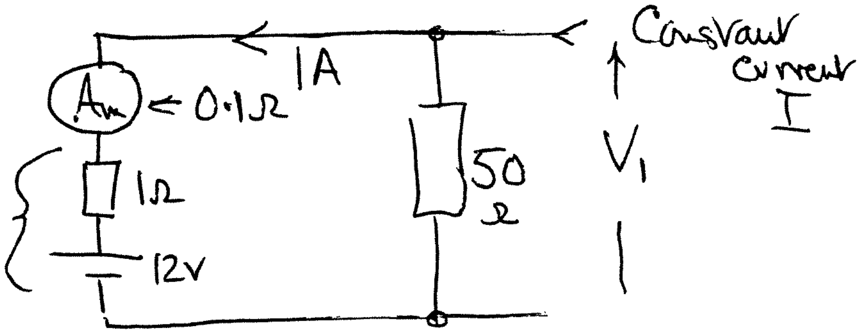
(1).

Answers

1/ Ammeter Am, dropping 1V and on its 10 A fsd range is modelled as a 0.1Ω resistance.

Circuit is



So when Am reads 1A, for left hand circuit, KVL:

$$V_1 = 12 + 1(1+0.1) = 13.1 V$$

so current in 50 Ω resistor = 13.1/50 = 0.262 A

So $\underline{\underline{I = 1.262 A}}$ = Constant current supply

---

Power input to battery = 12×1 = 12 W

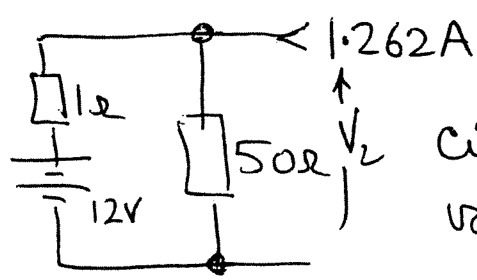
Power in battery as heat = $1^2 \times 1\Omega$ = 1W

Power lost in Ammeter = $1^2 \times 0.1$ = 0.1W

Power in 50Ω = $I^2R = 0.262^2 \times 50 = 3.43$ W

Total Power in = $\underline{\underline{16.53 \text{ W}}}$ { Check = 13.1 × 1.262

Efficiency = $12/16.53 = 0.726$ or $\underline{\underline{72.6\%}}$



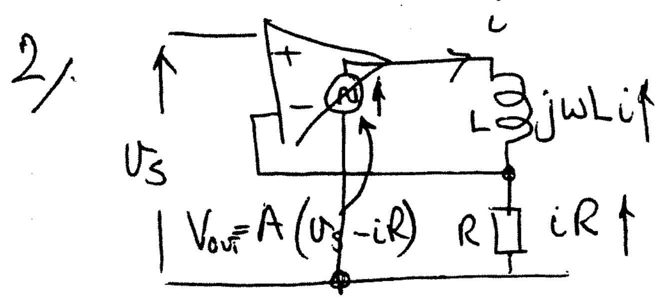
With the Ammeter replaced, the circuit becomes as shown. The new voltage V_2 across the circuit given by

KCL: $\dfrac{V_2}{50} + \dfrac{V_2 - 12}{1} = 1.262$ so $.02V_2 + V_2 = 13.262$

so $V_2 = \dfrac{13.262}{1.02} = 13.002$ V.

Current into battery = 13.002 − 12 = 1.002 A.

2/



For the output current i, voltages are shown as from the Data Book, V_{OUT} $i(j\omega L + R) = A(v_S - iR)$ — ①

So $v_S = iR + \frac{i(j\omega L + R)}{A}$ ② $= iR$ when A is large.

So conductance $= i/v_S = \underline{\underline{1/R}}$

If A is finite, equation ② gives:-

Conductance $= i/v_S = \frac{1}{R + \left(j\frac{\omega L + R}{A}\right)} = \underline{\underline{\frac{1}{\left(R + \frac{R}{A}\right) + j\frac{\omega L}{A}}}}$

If $A = 100/1 + jf/f_c$, $\frac{1}{\text{Conductance}} = R + \frac{1}{100}\left(1 + j\frac{f}{f_c}\right)(R + j\omega L)$

$-3dB$ point is when Real = Imag parts; ie when

$100R + R - \omega L \cdot \frac{f}{f_c} = \frac{f}{f_c} \cdot R + \omega L.$

But $f/f_c = \omega/\omega_c$, so $101R - \frac{\omega^2 L}{\omega_c} = \frac{\omega}{\omega_c} \cdot R + \omega L.$

As $\omega_c = R/L$ or $L = R/\omega_c$, $101R - \frac{\omega^2 R}{\omega_c^2} = \frac{\omega R}{\omega_c} + \omega\frac{R}{\omega_c} = \frac{2\omega R}{\omega_c}$

Or $\omega^2 + 2\omega\omega_c - 101\omega_c^2 = 0.$

So $\omega = -\omega_c \pm \sqrt{\omega_c^2 + 101\omega_c^2} \triangleq 9.1\omega_c$

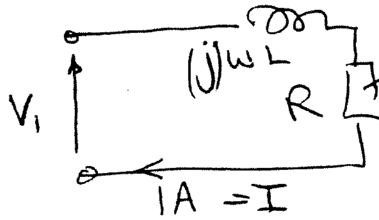
as the positive answer.

So ~~w~~ $\underline{\underline{f = 9.1 f_c}}$ is the turnover frequency

(ie 9.1 times better than that derived by the basic LR circuit).

③

3

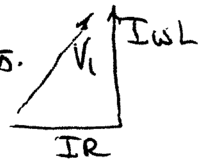


→ Power out from Watt-rate,
1kg lifted at 1m/sec = 9.8 watts (mgv)

2 methods

As $\omega L = 2\pi . f . L = 2\pi \times 50 \times 50 \times 10^{-3}$
$= 15.708\ \Omega$.

$\omega L I =$ 15.708 Volts.
$IR =$ 9.8 Volts



So $V_1 = \sqrt{9.8^2 + 15.708^2} = 18.51\text{V}$

From power f = $V_1 I \cos\phi$

$\cos\phi = \dfrac{9.8}{18.51 . 1} = \underline{\underline{0.53}}$

or Watts out = 9.8

VARs = $I^2 . \omega L$ -

$= 1^2 . 15.708 = 15.708$

VA in circuit = $\sqrt{W^2 + VAR^2}$

= 18.51

& power factor = $\dfrac{\text{Watts}}{\text{VA}} = 0.53$

Transformer ratio 20:1 means $1/20$A = current in for 1A out of transformer

Input voltage = $20 \times V_1 =$ 370.2 V

A capacitor C in <u>parallel</u> across the input has

VARS = $V^2 / \frac{1}{\omega C} = 370.2^2 . 2\pi . 50 . C = 15.71$

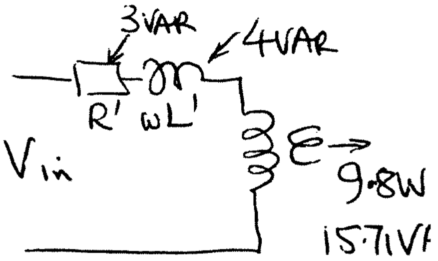
for Zero power factor.

Hence $C = 3.65 \times 10^{-7}$ or $\underline{0.365\ \mu\text{F}}$

As watts & VARs are conserved, Power in = 3 + 9.8 = 12.8

VARs in = 4 + 15.71 = 19.71

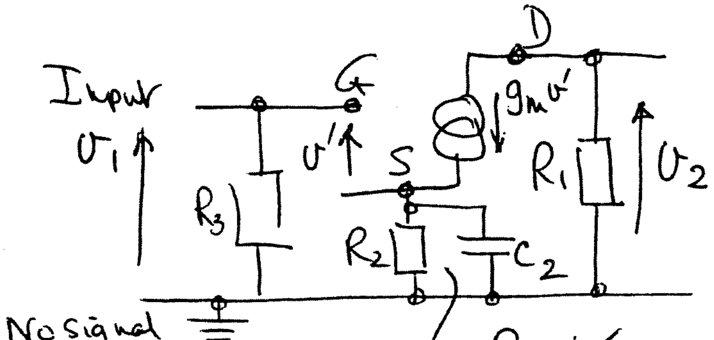
So VA in = $\sqrt{W^2 + VAR^2}$ = 23.50.



As current in = $1/20$A, <u>Volts in = 470.0</u>

Input Power factor = $\dfrac{\text{Watts}}{\text{Volt Amps}} = \dfrac{12.8}{23.50} = \underline{\underline{0.545}}$.

4/



Circuit is :

At a freq ω,

$$Z = \frac{R_2 \cdot 1/j\omega C_2}{R_2 + 1/j\omega C_2} = \frac{R_2}{1 + j\omega C_2 R_2}$$

KVL at input: $v_1 = v' + g_m \dfrac{v' \cdot R_2}{1 + j\omega C_2 R_2}$ so $v' = \dfrac{v_{in}}{1 + \frac{g_m R_2}{1 + j\omega C_2 R_L}}$ — ①

KVL at output: $v_{OUT} = -g_m v' R_1 = \dfrac{-g_m R_1 v_{in}}{1 + (g_m R_2)/(1 + j\omega C_2 R_2)}$

Hence the given gain expression.

If C_2 is very large – second term in denominator $= 0$,
So gain $= -g_m R_1$ (Simple amp)

If $\omega \to 0$ at DC, Gain $= -g_m R_1 / (1 + g_m R_2)$

From the equation, putting in values :–

$$\text{Gain} = \frac{-0.05 \times 1000}{1 + 50/(1 + j \cdot 2\pi \cdot 10^3 \times 300 \times 10^{-9} \cdot 1000)}$$

$$= \frac{-50}{1 + 50/(1 + j1.885)} = \frac{-50}{1 + 10.98 - j20.7} \quad ⊛$$

$$= \frac{-50}{12 - j20.7} = -1.05 - 1.81j = 2.09 \angle -120.0° \quad ⊛$$

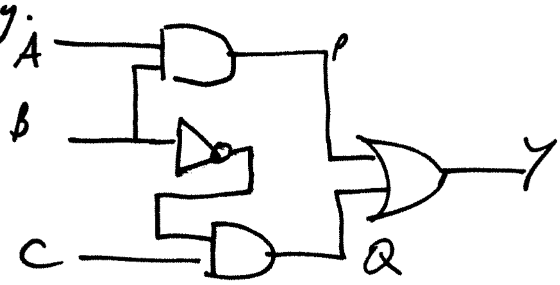
Step ⊛ Use calculator in complex mode

So Gain = 2.09 in magnitude and phase change is −120°.

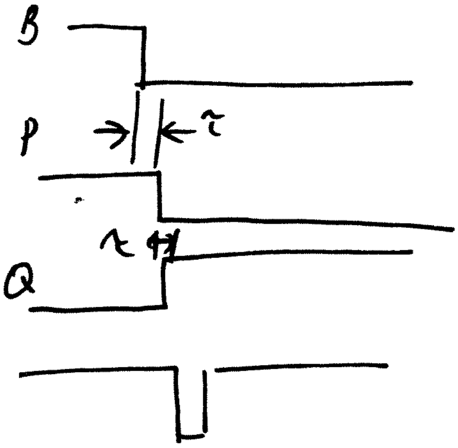
5) SECTION B PAPER 3

5. a) Let there be two input states to a combinational logic circuit $\underline{a}^1$ & $\underline{a}^2$ which both have the same output state $\underline{b}^1 = \underline{b}^2 = \underline{b}$. When the logic input changes from $\underline{a}^1$ or $\underline{a}^2$ to the other it is possible to momentarily change o/p to $\bar{\underline{b}}$, for certain logic designs. This is a static hazard.

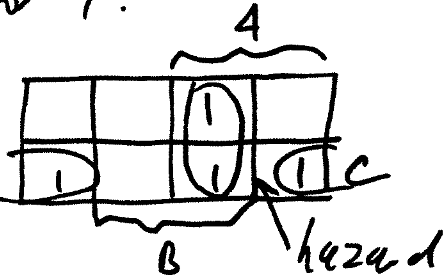
E.g.



This circuit exhibits a static one hazard when $A = C = 1$ & B changes $1 \to 0$



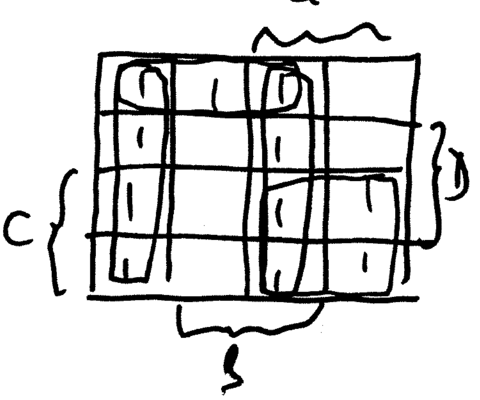
To eliminate a static-1 hazard draw the k-map for Y.



Fix hazard by adding an extra gate $A.C$ to the circuit so that there is overlap in k-map.

i.e. $Y = AB + A.C + \bar{B}C$.

b) i)

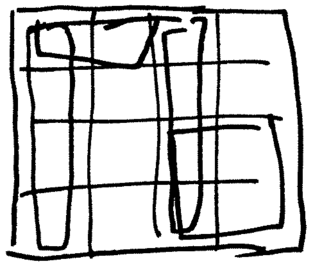


terms $A.B$ & $\bar{A}.B$ in all solution

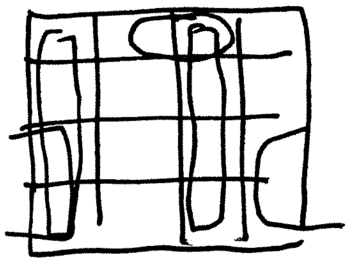
for F_1 also have $A.\underline{C}$ & $B.\bar{C}.\bar{D}$

as shown here.

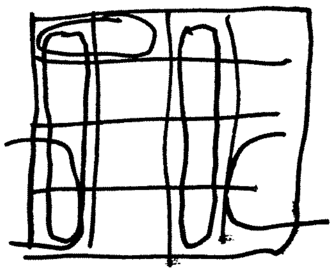
5(b) ii) Also other ~~term~~ combination
(cont'd)



$AB + \bar{A}\bar{B} + AC + \bar{A}\bar{C}D$



$\bar{A}.\bar{B} + AB + B\bar{C}\bar{D} + \bar{B}C$



$\bar{A}\bar{B} + AB + \bar{A}\bar{C}\bar{D} + \bar{B}C$

They all have potential for static hazards, as not all terms overlapped.

iii) $F_1 = \overline{\overline{A.B + \bar{A}\bar{B} + AC + B.\bar{C}\bar{D}}}$

$F_1 = \overline{\overline{A.B} \cdot \overline{\bar{A}.\bar{B}} \cdot \overline{A.C} \cdot \overline{B.\bar{C}.\bar{D}}}$

Need in 2 input form

$\overline{X.Y.Z} \Rightarrow \overline{\overline{\overline{X.Y}}.Z}$

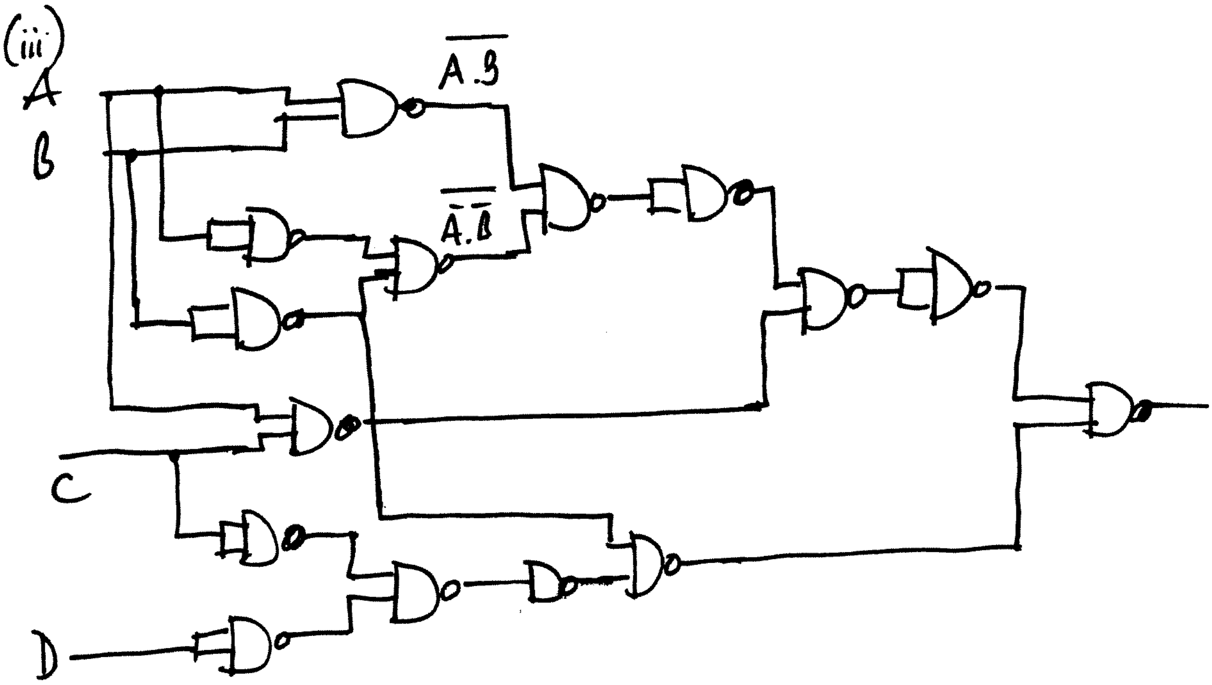
$\overline{W.X.Y.Z} \Rightarrow \overline{\overline{\overline{\overline{\overline{W.X}}.Y}}.Z}$

~~Hence~~ Also $\bar{X}$ = 

Hence cct.

7

5b(iii)



6 a) An unused state is a state of the logic that is not used in the normal operation of the circuit.

Circuits can be designed so that, should an unused state occur [see b(iii)] it will return to normal operation on the next clock pulse. If this is not done the subsequent operation is not defined by the required logic sequence & is therefore arbitrary. This would often lead to malfunction.

b) i)

CURRENT ABCD	NEXT ABCD	J_A	K_A	J_B	K_B	J_C	K_C	J_D	K_D
0011	0100	0	X	1	X	X	1	X	1
0100	010φ	0	X	X	0	0	X	1	X
0101	0110	0	X	X	0	1	X	X	1
0110	φφφφ	0	X	X	0	X	0	1	X
0111	1000	1	X	X	1	X	1	X	1
1000	1001	X	0	0	X	0	X	1	X
1001	1010	X	0	0	X	1	X	X	1
1010	1011	X	0	0	X	X	0	1	X
1011	1100	X	0	1	X	X	1	X	1
1100	0011	X	1	X	1	1	X	1	X

b ii) J_B

	X	X	0
	X		0
1	X		1
	X		0

$J_B = C.D$

K_B

	0	1	X
	0		X
X	1		X
	0		X

$K_B = C.D + A$

	0	1	0
	1		1
X	X		X
	X		X

$J_C = A.B + D$

	X	X	X
	X		X
1	1		1
	0		0

$K_C = C.D$

9

6 b) iii) Either redesign based on full (16 line) state table resulting in complete K-maps & giving a cct that will return to the correct sequence from all unused states

or

Build logic to detect unused state & use preset & clear inputs to the bistable to reset them to e.g. ABCD = 0011

Alternatively could just do the above on power up as this is the most usual time when there is a problem of this type.

7 a) Addressing modes determine where the operands ('the data') for an instruction come from

```
ADDA   #12     IMMEDIATE – load A with 12
ADDA   $12     DIRECT – load A from 2 byte
                        address 12H
ADDA   $1200   EXTENDED – load A from 2 byte
               address 1200H
ADDA   X,0     INDEXED – load A with contents
               stored in X
```

b)
```
     Cycles
     i) 3   LOOPA :  LDX   #$1000   load X with value
                                     $1000 H.
      [ 5   LOOPB :  LDAA  X,0      load Acc A from address in X
      | 5            STAA  $E000    store A to DAC
21x64 | 4            INX            inc X
      | 3            CPX   #$1040   compare X to $1040
      [ 4            BNE   LOOPB    branch if compare not true
        3            LDX   #$1000   ld X with $1000
      [ 2   LOOPC :  CLRA           clear Acc A
      | 5            SUBA  X,0      subtract value at X
      |                              from A → A  i.e. A → -A
23x64 | 5            STAA  $E000    store to DAC
      | 4            INX            next value to X
      | 3            CPX   #$1040
      [ 4            BNE   LOOPC    to next value in loop
        3            BRA   LOOPA    start again
```

LOOPC outputs the negative half cycle of the waveform.

ii) From cycle in above figure total through loop A

$= 3 + 21 \times 64 + 23 \times 64 + 4 + 3$
$= 10 + 44 \times 64$
$= 2826$

This takes 0.353 ms at 8MHz clock.

iii) For 0.353 ms / 128 sample ⇒ <u>362.35 kHz</u> av. sampling freq.

iv) For 8kHz need 1 sample every 1000 cycles. Therefore add a delay loop [eg loop of NOP's] in appropriate place.

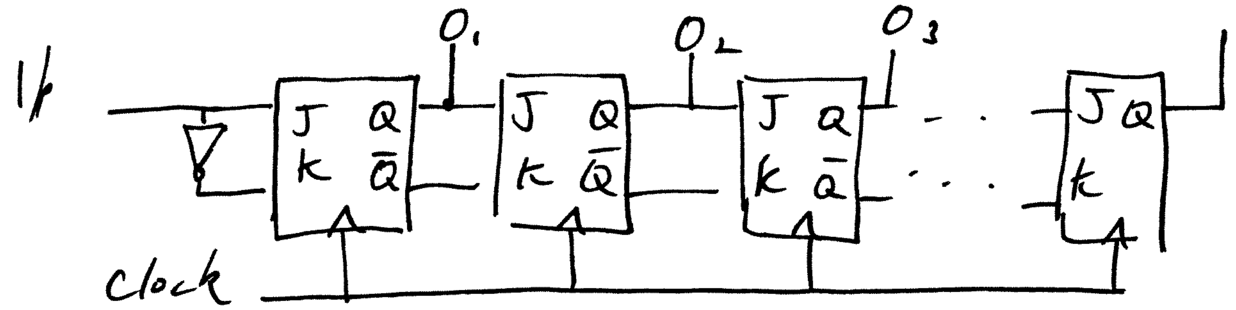
In loop B add a delay of $1000 - 21 = 979$ cycle

In loop C . . . . . of $1000 - 23 = 977$ sample.

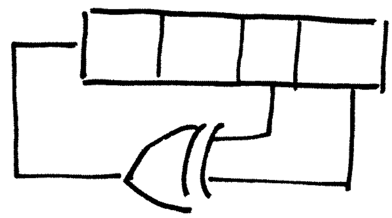
Add these after each sample has been stored.

8 a) i) A shift register is a set of storage [1 bit] element arranged in series so that the content moves one along on each clock & the (N+1)th bistable takes on the value of the Nth from the one before.

From J-K bistables:



ii)



Sequence. 0000

1111
0111
0011
0001
1000
0100
0010
1001
1100
0110
0101
1010
1101
1110

15 long sequence. This is the longest sequence.

b) i) 64 kbit & $= 2^{16}$ bit
4 data lines $= 2^2$
hence $2^{(16-2)}$ locations $\Rightarrow 2^{14}$ location
$\Rightarrow$ 14 address lines.

4 data lines, 14 address
$\overline{CS}$ - chip select
R/$\overline{W}$ - read, not write.

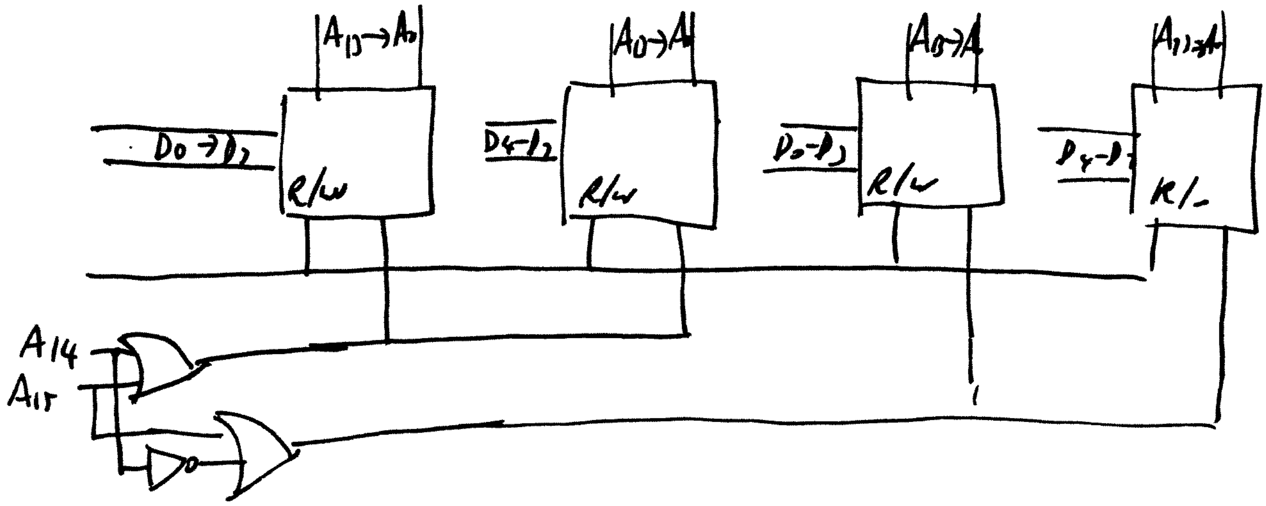
ii) 32 kbytes $= 32 \times 2^3$ bit i.e. 2^{18} bit.
Hence $2^{18}/2^{16}$ devices $= 2^2 = \underline{\underline{4}}$

iii) 32 k byte, 8 data lines
Each chip has 16k, 4 bit addresses.

Use same decoding for low address range to 2 chips. [\$0000 → \$3FFF]
& high range [\$4000 → \$7FFF]

	A_{15}			A_0	
\$0000	0000	0000	0000	0000	low range
\$3FFF	0011	1111	1111	1111	
\$4000	0100	0000	0000	0000	
\$7FFF	0111	1111	1111	1111	

i.e. need low A_{15}, low A_{14} for low range
. . . , high A_{14} . . . high range.



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Question 9, paper 3 - Electrical and Information Engineering

a)

$r := 10 \cdot cm \qquad e_0 := 8.854 \cdot 10^{-12} \cdot \frac{farad}{m}$

$d := 2 \cdot r$

$E := \frac{q}{4 \cdot \pi \cdot e_0 \cdot r^2}$

$$V := \int_{r}^{\infty \cdot cm} E \, dr$$

$$V := \frac{q}{(4 \cdot \pi \cdot e_0 \cdot r)}$$

$$q := ((4 \cdot \pi \cdot e_0 \cdot r)) \cdot 100 \cdot 10^3 \cdot volt$$

$$q = 1.113 \cdot 10^{-6} \cdot coul$$

b)

$F := q \cdot E$

$$F := \frac{q^2}{4 \cdot \pi \cdot e_0 \cdot d^2}$$

$$F = 0.278 \cdot newton$$

c) Use method of images and then the time taken to fall is time taken for force between balloon and its image to drop to the weight of the ballooon

$$Balloon\_weight := 5 \cdot 10^{-3} \cdot kg \cdot 9.81 \cdot m \cdot sec^{-2}$$

$$Charge\_at\_drop\_off := \left(Balloon\_weight \cdot 4 \cdot \pi \cdot e_0 \cdot d^2\right)^{0.5}$$

$$Charge\_at\_drop\_off = 4.672 \cdot 10^{-7} \cdot coul$$

$$time := \frac{q - Charge\_at\_drop\_off}{10^{-9} \cdot coul \cdot sec^{-1}}$$

time =

Question 10, paper 3 - Electrical and Informmation Engineering

a) Use ampere's law to integrate round the central core one half of the C chape and across the gap between the C and the core. Don't forget that the H in the central co$\mu_r$spl1000th left and right round the core and therefore needs to multiplied by 2

$N := 500 \qquad I := 0.5 \cdot \text{amp} \qquad \mu_0 := 4 \cdot \pi \cdot 10^{-7} \cdot \frac{\text{henry}}{\text{m}}$

$$H_{central} := \frac{2 \cdot N \cdot I}{(25 + 30 + 20 + 30 \cdot 2 + 2.5 \cdot \mu_r) \cdot \text{mm}}$$

$$H_{central} = 189.753 \cdot \frac{\text{amp}}{\text{m}}$$

b)

H (and B) need to be recalculated because the gap has changed

$$B := \frac{\mu_r \cdot \mu_0 \cdot 2 \cdot N \cdot I}{(25 + 30 + 20 + 2 \cdot 29 + 2 \cdot \mu_r \cdot 1 + 2.5 \cdot \mu_r) \cdot \text{mm}}$$

$B = 0.136 \cdot \text{tesla}$

energy per unit volume is given by:

$B = \mu_0 \cdot H$

$$\text{Energy} = \int B \, dH$$

$$\text{Energy} := \frac{B^2}{2 \cdot \mu_0}$$

$\text{Energy} = 7.318 \cdot 10^3 \cdot \text{m}^{-3} \cdot \text{joule}$

c) the force is simply the energy per unit volume multiplied by the area. But note the question asks for the force to pull out hence we must use the results from part a not part b

$B := H_{central} \cdot (\mu_0 \cdot \mu_r) \qquad \text{area} := 5 \cdot \text{mm} \cdot \text{mm}$

$B = 0.238 \cdot \text{tesla}$

$$\text{force} := \frac{B \cdot B \cdot \text{area}}{2 \cdot \mu_0}$$

$\text{force} = 0.113 \cdot \text{newton}$

6) Question 11 paper No. 3.

a) From the Maxwell-Ampere equation (databook p11)

$$\oint_c \underline{H}.\underline{dl} = \int_s (\underline{J} + \dot{\underline{D}}).\underline{ds}$$

But the displacement current $\dot{\underline{D}}$ is zero. Hence the right hand side is the current I and the solution is:

$$H = \frac{I}{2\pi r}$$

b)

The EMF is simply the rate of change of flux:

$$emf = -\dot{\phi}$$

Hence the voltage is:

$$V = -\frac{d\phi}{dt}$$

c) The total flux is given by:

$$\phi = \int_s \underline{B}.\underline{dS} = l\mu_0 \int_a^b H(r)dr$$

Hence from part a)

$$\phi = l\mu_0 \int_a^b I/_{2\pi r}\, dr = \frac{l\mu_0}{2\pi} I \ln(b/_a)$$

from which

$$\dot{\phi} = \frac{l\mu_0}{2\pi} \dot{I} \ln(b/_a)$$

Hence from b) we get

$$V = -\frac{l\mu_0}{2\pi} \dot{I} \ln(b/_a)$$

and the inductance per unit length

$$= \frac{V}{\dot{I}l} = \frac{l\mu_0}{2\pi} \dot{I} \ln(b/_a)$$