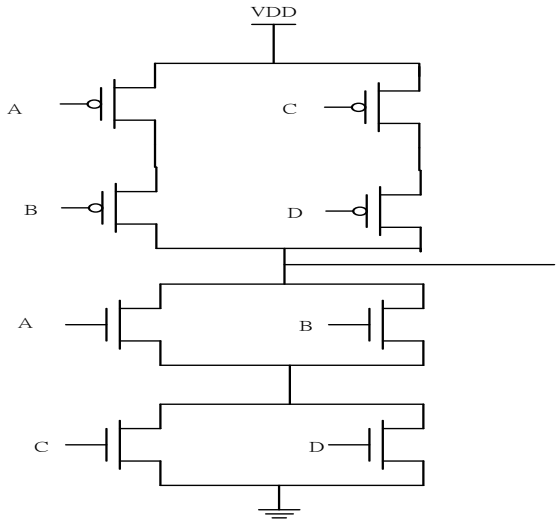
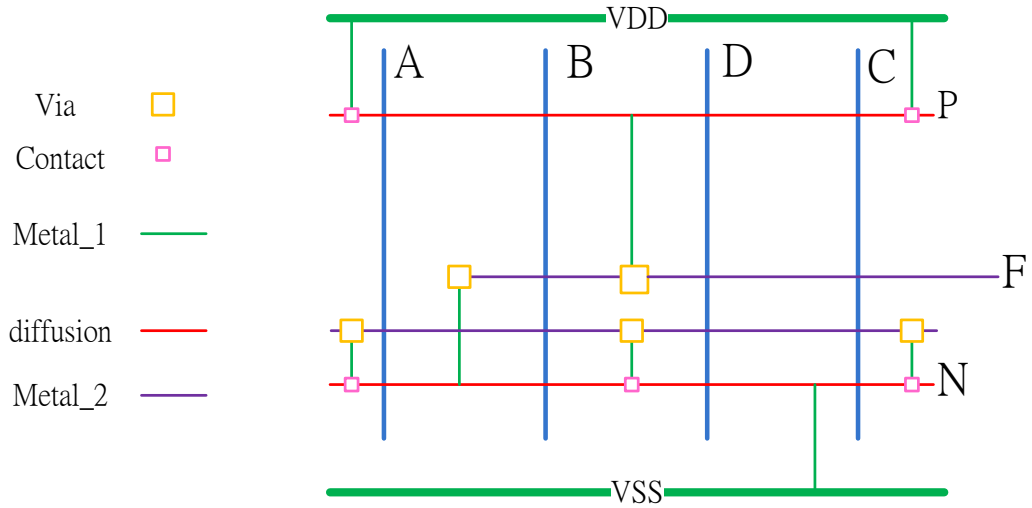
2010 VLSI Solution of Midterm Examination

1.

Ans:

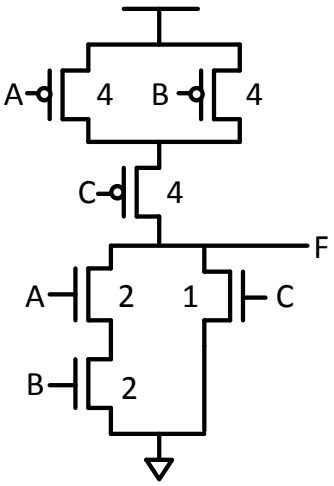
$$F = \overline{(A+B).(C+D)}$$





2.

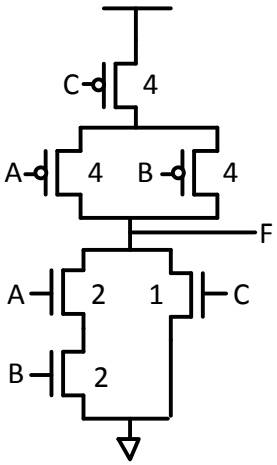
Method(1)



(a) $g_A = \frac{4+2}{3} = 3$, $g_B = \frac{4+2}{3} = 3$, $g_C = \frac{4+1}{3} = \frac{5}{3}$ (2.5% , no partial)

(b) p $= \frac{4+2+1}{3} = \frac{7}{3}$ (2.5% , no partial)

Method(2)



(a) $g_A = \frac{4+2}{3} = 3$, $g_B = \frac{4+2}{3} = 3$, $g_C = \frac{4+1}{3} = \frac{5}{3}$ (2.5% , no partial)

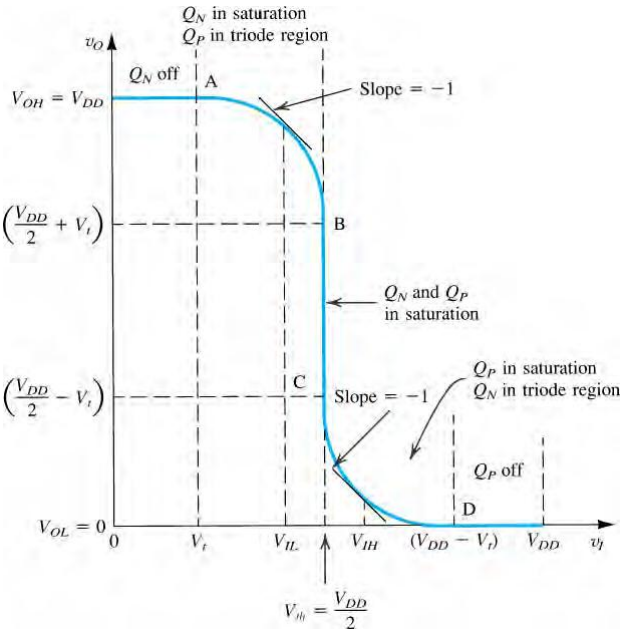
(b) p $= \frac{4+4+2+1}{3} = \frac{11}{3}$ (2.5% , no partial)

3.

(a) 2.5%

Ans: (W/L)p= 6um/0.18um

(b) 2.5% (one correct: 1.5%)



$NM_H = V_{OH} - V_{IH}$

$NM_L = V_{IL} - V_{OL}$

$(V_{OH})A = (V_{OH})B = (V_{OH})C$

$(V_{OL})A = (V_{OL})B = (V_{OL})C$

and

$(V_{IH})A < (V_{IH})B < (V_{IH})C$

$(V_{IL})A > (V_{IL})B > (V_{IL})C$

Therefore

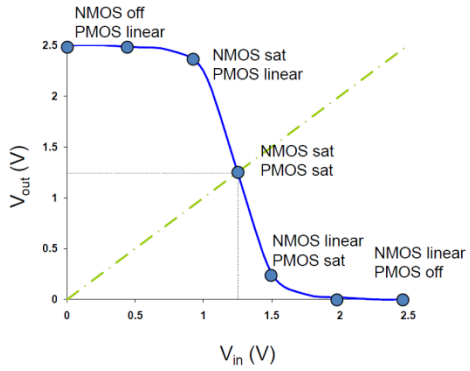
Ans:

NM_H: A < B < C

NM_L: A > B > C

4.

Ans:



Region	nMOS	pMOS
A	cutoff	linear
B	Sat.	linear
C	Sat.	Sat.
D	linear	Sat.
E	linear	cutoff

5.

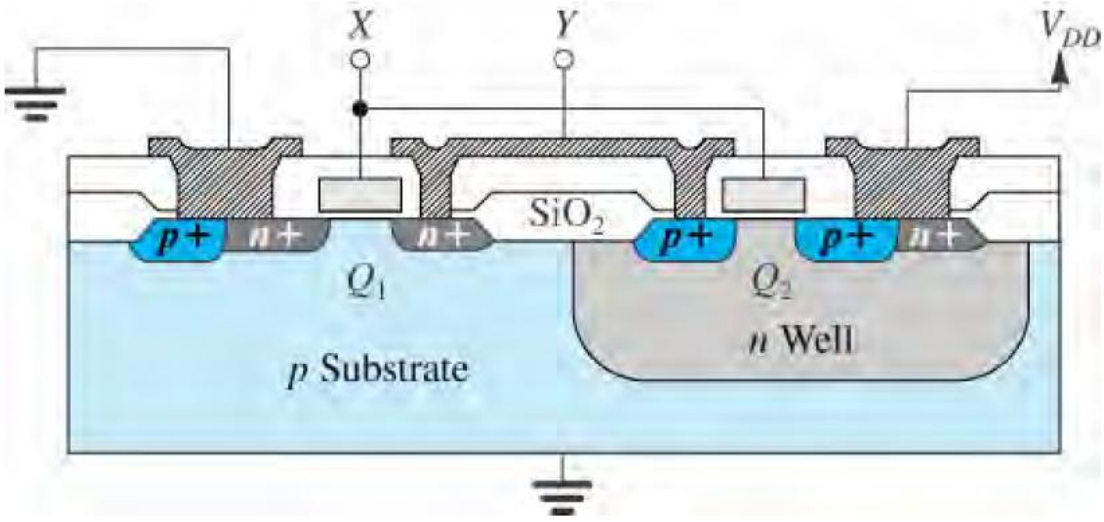
Ans:

i,d,j,b,c,f,a,l,g,h,k,m

6.

Ans:

(a) (v)➔(i)➔(ii)➔(iii)=(iv)➔(vii)➔(vi) (2.5% , no partial)



(b)

(2.5% , no partial)

7.

Initial value: Vout1=Vout2=0V

Ans:

(a) 2.5% v

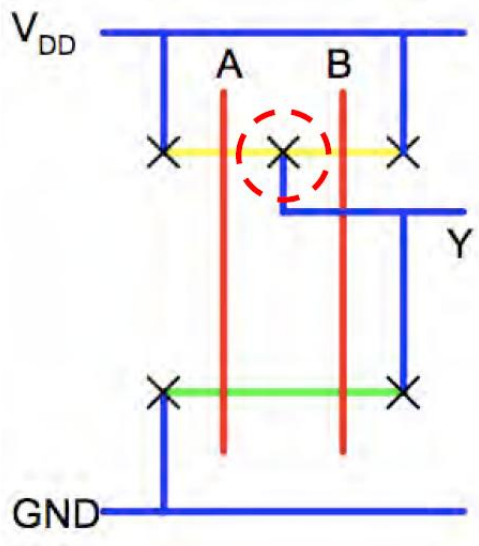
$$\text{Vout1} = 0 \rightarrow 1\text{V}$$
$$\text{Vout2} = 0 \rightarrow 0.5\text{V}$$

(b) 2.5% (one correct: 1.5%)

$$\text{Vout1} = 0 \rightarrow 0.9\text{V}$$
$$\text{Vout2} = 0 \rightarrow 0.4\text{V}$$

8.

Ans:



9.

Ans:

(a)

$$d = gh + p = 2$$

$$f_{osc} = \frac{1}{2Nd'} = \frac{1}{2 \times 9 \times 2 \times 1k \times 10f} = 2.778G\ (Hz)$$

(b)

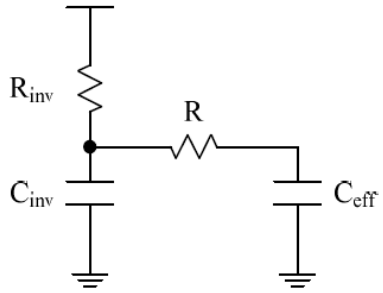
Unit inverter g_{avg}=1

Skewed inverter g_{avg}=$\frac{5}{4}$

$$f_{osc} = \frac{1}{2Nd} = \frac{1}{2 \times 9 \times 2 \times 1k \times 10f \times \frac{5}{4}} = 2.22G\ (Hz)$$

10.

Ans:



$$R_{inv} = 1k, \qquad C_{inv} = 10f \qquad\qquad R = \frac{0.1}{um} * 1mm = 100ohm$$

$$C_{gd} = \frac{0.3f}{um} * 1mm = 0.3pF, \qquad\qquad C_{adj} = \frac{0.2f}{um} * 1mm = 0.2pF$$

a) For X=0->1, Y=0->1, $C_{eff} = C_{gnd}$

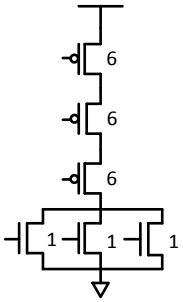
$$Tpd = Rinv * Cinv + (R + Rinv) * Ceff = 340ps$$

b) For X=1->0, Y=0->1, $C_{eff} = C_{gnd}+2C_{adj}$

$$Tpd = Rinv * Cinv + (R + Rinv) * Ceff = 780ps$$

11.

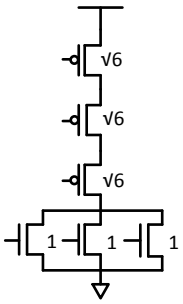
(a)



$$g_{avg} = \frac{6+1}{3}$$

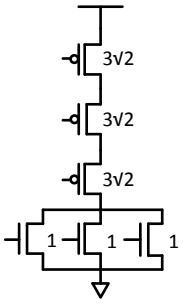
(b)

Method(1)



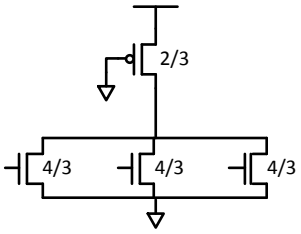
$$g_u = \frac{\sqrt{6}+1}{\frac{\sqrt{6}}{3}+\frac{\sqrt{6}}{6}} = 2.816\,, g_d = \frac{\sqrt{6}+1}{2+1} = 1.15\,, g_{avg} = \frac{g_u+g_d}{2} = 1.983$$

Method(2)



$$g_u = \frac{3\sqrt{2}+1}{\sqrt{2}+\frac{\sqrt{2}}{2}} = 2.47\,, g_d = \frac{3\sqrt{2}+1}{2+1} = 1.748\,, g_{avg} = \frac{g_u+g_d}{2} = 2.109$$

Method(3)



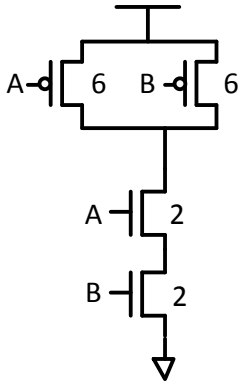
$$g_u = \frac{\frac{4}{3}}{1} = \frac{4}{3}, g_d = \frac{\frac{4}{3}}{3} = \frac{4}{9}\,, g_{avg} = \frac{g_u+g_d}{2} = \frac{8}{9}$$

12.

Due to the defect of the question, you can get the score for following computation:

Method 1.

(a) 2.5%



Ans: (gu: 1%, gd: 1%, gavg: 0.5%)

$$\text{gu} = \frac{6+2}{6+3} = \frac{8}{9}$$

$$\text{gd} = \frac{6+2}{2+1} = \frac{8}{3}$$

$$\text{gavg} = \frac{\frac{8}{9}+\frac{8}{3}}{2} = \frac{16}{9}$$

(b) 2.5%

Ans. 1:

Because of resizing A to $\frac{5}{6}$, then resistance of A is $\frac{6}{5}$R, which is larger then the original R

$\therefore$ we can't get the correct size of B for keeping the resistance as the smae as original.

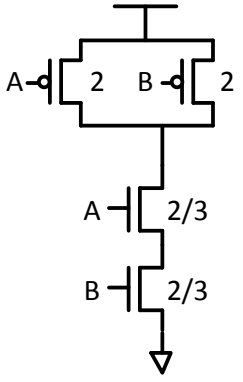
Ans. 2:

Under the condition of keeping the pull-down resistance the same, we need to minimize the effect of B. Therefore we have to resize B as big as possible for over large size of A, which is resized to bigger than the effective pull-down resistance R from the request of (b).

You can get the score for similar answers above.

Method 2.

(a)



Ans: (gu: 1%, gd: 1%, gavg: 0.5%)

$$\text{gu} = \frac{2+\frac{2}{3}}{2+1} = \frac{8}{9}$$

$$\text{gd} = \frac{2+\frac{2}{3}}{\frac{1}{3}+\frac{2}{3}} = \frac{8}{3}$$

$$\text{gavg} = \frac{\frac{8}{9} + \frac{8}{3}}{2} = \frac{16}{9}$$

(b)

Ans: (WB: 1.5%)

$$\frac{1}{\frac{6}{5} + \frac{1}{WB}} = \frac{1}{3}$$

$$\rightarrow \text{WB} = \frac{5}{9}$$

∴ **Ans**: (guA & gdA: 1% OR guB & gdB: 1%)

$$\text{guA} = \frac{2 + \frac{5}{6}}{2 + 1} = \frac{17}{18}$$

$$\text{guB} = \frac{2 + \frac{5}{9}}{2 + 1} = \frac{23}{27}$$

$$\text{gdA} = \frac{2 + \frac{5}{6}}{\frac{1}{3} + \frac{2}{3}} = \frac{17}{6}$$

$$\text{gdB} = \frac{2 + \frac{5}{9}}{\frac{1}{3} + \frac{2}{3}} = \frac{23}{9}$$

You can get the score for either guA & gdA or guB & gdB.

13.

a) $D = NF^{1/N} + \sum_{i=1}^{n1} Pi + (N - n1)Pinv$

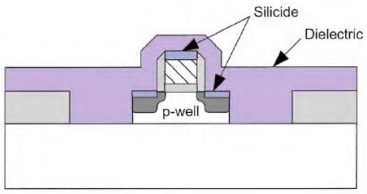
b) $\frac{dD}{dN} = -F^{1/N} \, lnF^{1/N} + F^{1/N} + Pinv = 0$ and $\rho = F^{1/N}$, $Pinv = 1$

Thus, the above equation can be rewritten to

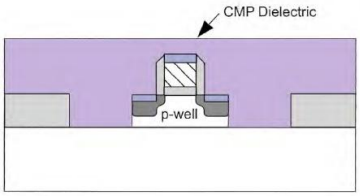
$Pinv + \rho(1 - \ln\rho) = 0$, and plug in $Pinv = 1$, we can find that $\rho = 3.59$

14.

(a) Salicide: self-aligned silicide Refractory metal to reduce the interconnection resistance of gate, source/drain.

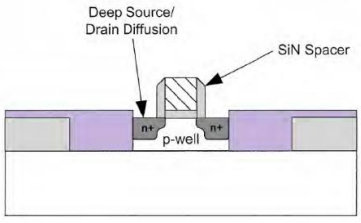


(b) CMP : Structure planarization for further stack process.

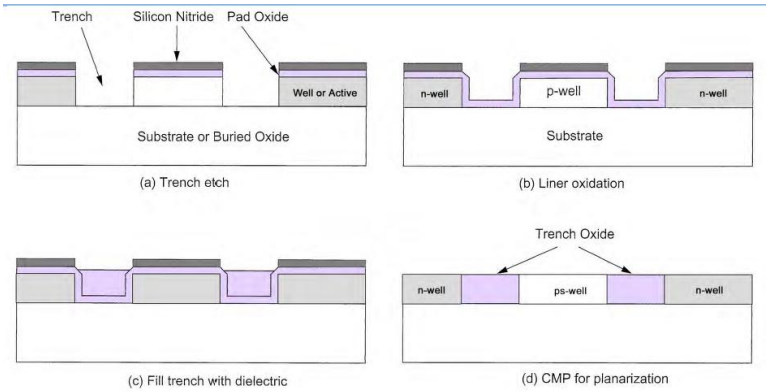


(c) High-K: Replacing the silicon dioxide gate dielectric with a high-κ material allows increased gate capacitance without the concomitant leakage effects,(thinner EOT)

(d) LDD: Reduce electrical field of drain junction & hot-electron damage; High sheet resistance.



(e) STI: Shallow Trench Isolation High density & better isolation, need Chemical Mechanical Polishing (CMP) to planarize the structure.(without bird's beak(LOCOS))



(get 1% when match one red-mark, 2% max)

15.

(a) 5%

Find gavg:

$$\text{gu} = \frac{\frac{4}{3}}{\frac{2}{3}+\frac{1}{3}} = \frac{4}{3}$$

$$\text{gd} = \frac{\frac{4}{3}}{2+1} = \frac{4}{9}$$

$$\text{gavg} = \frac{\frac{4}{3}+\frac{4}{9}}{2} = \frac{8}{9}$$

Find pavg:

$$\text{pu} = \frac{8\times\frac{4}{3}+\frac{2}{3}}{\frac{2}{3}+\frac{1}{3}} = \frac{34}{3}$$

$$\text{pd} = \frac{8\times\frac{4}{3}+\frac{2}{3}}{2+1} = \frac{34}{9}$$

$$\text{pavg} = \frac{\frac{34}{3}+\frac{34}{9}}{2} = \frac{68}{9}$$

Find path delay:

$$\text{G} = 1\times\frac{8}{9} = \frac{8}{9}$$

$$\text{F} = \text{GBH} = \frac{8}{9}\times 1\times\frac{64}{4}$$

$$\text{P} = 1+\frac{68}{9} = \frac{77}{9}$$

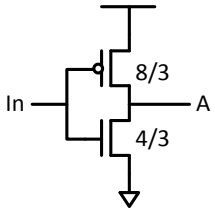
$$\text{N} = 2$$

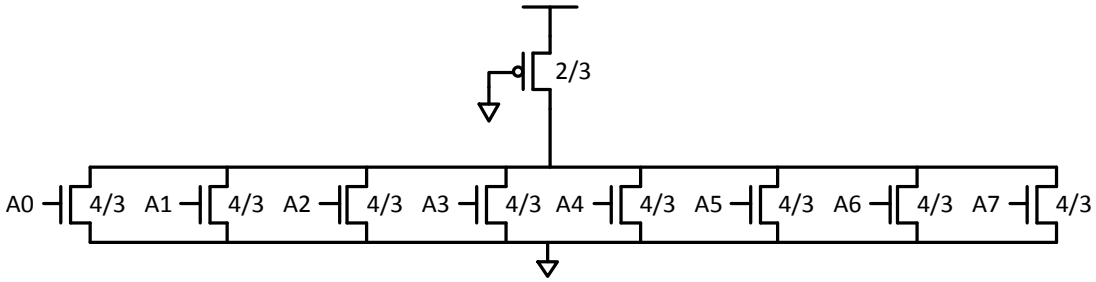
$$\text{D} = 2\times\sqrt{\frac{128}{9}}+\frac{77}{9} = \frac{77+48\sqrt{2}}{9} = 16.1$$

Ans: 16.1 (Time Unit)

(b.) 5%

Ans 1:





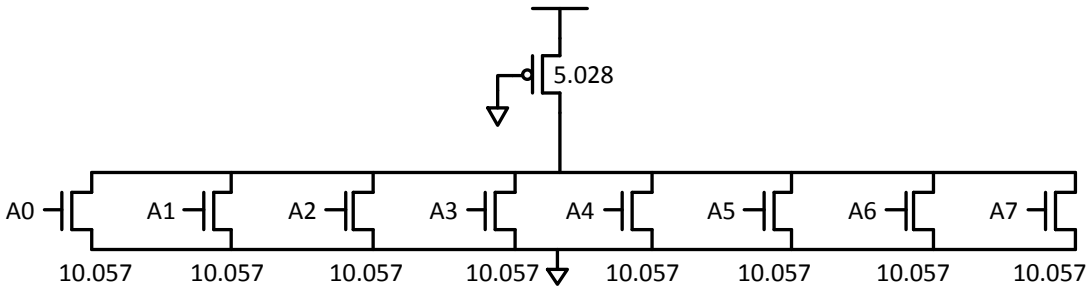
Ans 2:

$$\text{f} = \sqrt{F} = \sqrt{\frac{128}{9}} = gh = \frac{8}{9} \times \frac{64}{x}$$

$$\rightarrow \text{x} = 15.085$$

$$\text{PMOS: } 15.085 \times \frac{\frac{2}{3}}{\frac{2}{3} + \frac{4}{3}} = 5.028$$

$$\text{NMOS: } 15.085 \times \frac{\frac{4}{3}}{\frac{2}{3} + \frac{4}{3}} = 10.057$$



16.

Ans:

(a)

A→C

$$\text{G} = (\frac{4}{3}) \times (\frac{5}{3}) \times (\frac{7}{3}) = \frac{140}{27}$$

$H = \frac{80}{8} = 10$

$B = 3 \times 2 = 6$

$F = G \times H \times B = \frac{2800}{9}$

$\hat{f} = \sqrt[3]{F} = 6.776$

$\therefore y = \frac{80 \times \frac{7}{3}}{6.776} = 27.55$ ， $x = \frac{27.55 \times 2 \times \frac{5}{3}}{6.776} = 13.55$

B→D

$G = 1 \times 1 \times (\frac{5}{3}) \times (\frac{5}{3}) = \frac{25}{9}$

$H = \frac{80}{3}$

$B = 2 \times 2 = 4$

$F = G \times H \times B = \frac{8000}{27}$

$\hat{f} = \sqrt[4]{F} = 4.149$

$\therefore z = \frac{80 \times \frac{5}{3}}{4.149} = 32.14$ ， $x = \frac{32.14 \times 2 \times \frac{5}{3}}{4.149} = 25.82$ ， $w = \frac{25.82 \times 2 \times 1}{4.149} = 12.45$

Ps: 此題題意有瑕疵，若先算 A→C 者，只要 x、y 答對就全對；反之，若先算 B→D 者，z、x、w 答對亦可。

(b)

A→D

$G = (\frac{4}{3}) \times (\frac{5}{3}) \times (\frac{5}{3}) = \frac{100}{27}$

$H = 10$ ， $B = 6$

$F = \frac{2000}{9}$

$\hat{f} = 6.06$

$P = 2 + 3 + 2 = 7$

$D = 3 \times 6.06 + 7 = 25.18$

PS: 若利用 A 小題的 X 值帶入此題求出 D，亦可。

17.

Ans:

(a) F (b) F (c) T (d) T (e) T (f) T (g) F (h) F (i) T (j) T