NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF INDUSTRIAL TECHNOLOGY
DEPARTMENT OF CIVIL AND WATER ENGINEERING
BACHELOR OF ENGINEERING (HONOURS) DEGREE
PART III SECOND SEMESTER EXAMINATIONS APRIL/MAY 2006
IRRIGATION SYSTEMS DESIGN TCW 3204

INSTRUCTIONS
Answer any **four** questions. Illustrate your answers with clearly well labeled diagrams were applicable. Total Marks 100 Time 3 hours

QUESTION 1

(a) Differentiate between soil moisture tension and soil water potential [5 marks]

(b) "Irrigation is a systematically developed knowledge, based on long term observations and experiments of handling available sources of water for economic growth." Discuss. [20 marks]

QUESTION 2

2(a) Define the following terms:

(ii) Field capacity [2 marks]
(iii) Osmotic potential [2 marks]

(b) A schematic illustration to measure the soil hydraulic conductivity is shown in Fig. Q2.1. The constant discharge through the system is 0.021m^3/min.
Compute:

(i) Pressure potential [3 marks]
(ii) Hydraulic conductivity of the soil sample [3 marks]
(iii) Establish the direction of flow [3 marks]

(c) The filtration capacity of a soil is given in Table Q2.1 and also the following design parameters are applicable to a maize crop:

Root zone =1000mm
Field capacity =35%
Permanent wilting point =15%
Allowable level of moisture depletion =60%
Distribution pattern efficiency =87%

(i) Derive a fitting equation for the infiltration data. [7 marks]
(ii) Compute the irrigation interval [2 marks]
(iii) Determine the time of irrigation to apply the net depth [3 marks]

Table Q2.1

Time (min)	2	3.6	6.4	11.2	20	36	64	113	200
Depth of infiltration (mm)	0.5	0.7	1.0	1.5	2	3.1	4.6	6.5	9.8

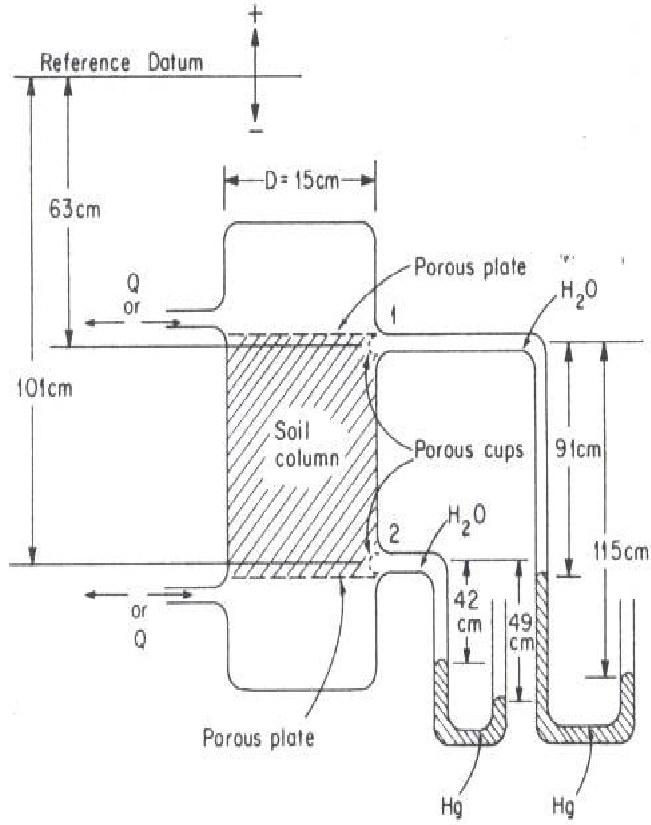


Fig. Q2.1

QUESTION 3

Using the FAO Modified Penman's equation, determine the ET_{crop} given the following design parameters. Additional design data is in Table Q3.1 and Table Q3.2.

Average design wind speed at height of 10.5m	=10km/hr
Minimum temperature	=15°C
Maximum temperature	=28°C
Maximum relative humidity	=80%
Minimum relative humidity	=45%
Incoming short wave radiation	=3cm/day
Outgoing long wave radiation	=1.5cm/day
Coefficient of albedo	=0.25
Altitude above sea level	=2050m
Day time wind speed	=300km/day
Night wind speed	=155km/day
Crop coefficient	=1.02

[11 marks]

(b) A two sized lateral line has 12 sprinklers on the first section and 6 sprinklers on the second section. Each sprinkler on the first section has a discharge of 0.95L/s, whilst those on the second section, each sprinkler has a discharge of 0.78L/s. On the first section, the first sprinkler is located at one-half the sprinkler spacing and on the second section, the first sprinkler is at full spacing. The remaining sprinklers are all spaced at 12m, and the respective diameters are of the two sections are 120mm and 90mm. The lateral is downhill at a slope of 0.0045. Compute the friction head losses in the lateral. Assume C=135; m=1.852; n=1.167 and K= 1.22 x 10^2. [14 marks]

QUESTION 4

(a) The following design parameters are applicable to the design of a level border. Additional design data is given in Table Q4.1.

Manning's roughness coefficient	=0.15
Slope	=0.003
Net depth of application	=105mm
Distribution pattern efficiency	=0.85
Application pattern efficiency	=100%
Length of border	=300m
Intake family coefficients	a=1.13
	b=0.742
	c=7

Compute:
- (i) Net opportunity time [2 marks]
- (i) Recession lag time [9 marks]
- (ii) Time to cut flow [2 marks]
- (iii) Depth of water in the border [2 marks]

(b) With aid of a sketch describe the time-distance relationships of water during application and infiltration into the soil for surface irrigation. [10 marks]

QUESTION 5

(a) A lateral line running up-hill at a slope of 0.006 has an operating pressure of 250kPa. The distance between the first and the last sprinkler on the lateral is 550m. The sprinklers as spaced at 18m and the first sprinkler is at half the spacing and all the sprinklers have a discharge of 0.45liters per second. Assuming C=135; m=1.852 and n=1.167, compute:

- (i) Maximum allowable friction head loss [3 marks]
- (ii) Pipe line diameter [7 marks]

(b) FAO Modified Penman's method is now recommended as the standard method for the definition and computation of the reference evapotranspiration. Discuss. [15 marks]

QUESTION 6

(a) Determine the length of an emitter and also the approximate length of the lateral given the following design criteria:

Plant water requirement	=10 liters per day
Irrigation cycle	=12 hrs after every 7 days
Application efficiency	=92%
Number of emitters per plant	=2
Emitter operation pressure head	=10m
Inside diameter of emitter	=1mm
Kinematic viscosity of water	=1.0×10^{-6} m^2/s
Lateral diameter	=15mm

Hazen Williams coefficient	=130
Emitter flow function	$=0.72\left[\frac{P}{\gamma}\right]^{0.81}$
Desired coefficient of uniformity	=91%
Proportionality factor that characterizes flow regime	=2.6
Ground slope (lateral sloping up-hill)	=0.4%
Emitter flow variation for the desired CU	=15%

[13 marks]

(b) The various layouts for sprinkler irrigation are shown in Fig. Q6.1. Outline the various factors which govern or affect each system. [12 marks]

Useful formulae

$$H_f = \frac{K\left(\frac{Q_1}{C}\right)^{1.852}}{D_1^{4.87}} \quad ET_o = c\left[\left(\frac{\Delta}{\Delta+\gamma}\right)R_n + \frac{\gamma}{\Delta+\gamma}f(u)\Delta e\right] \quad h_f = 6.377 fL\frac{Q^2}{D^5}$$

$$P_o = \left(\frac{P_o}{P_n}\right)\gamma\left[\frac{q_n}{K_e}\left(2-\frac{q_o}{q_n}\right)\right]^{\frac{1}{x}} \quad L_u = \frac{6\times10^4(Q_uT_t)}{a\frac{(T_t)^b}{1+b}+c+1798n^{3/8}Q_u^{9/16}T_t^{3/16}} \quad F = \frac{1}{m+1}+\frac{1}{2N}+\frac{(m-1)^{0.5}}{6N^2}$$

$$F = \frac{2}{2N-1}\left\{\frac{1}{m+n}+\frac{(m-1^{0.5})}{6N^2}\right\} \quad T_{rl} = \frac{(Q_u)^{0.2}n^{1.2}}{120\left[S+\frac{0.0094nQ_u^{0.175}}{T_n^{0.88}S^{0.5}}\right]^{1.6}} \quad Q = \frac{0.00167i_nL}{(T_n-T_{rj})e_de_a}$$

$$ET_o = \frac{\Delta}{\Delta+\gamma}(R_n-G)+\frac{\gamma}{\gamma+\Delta}f(u)\Delta e \qquad q = 0.11384(A)\left[2g\left(\frac{\sqrt{H}D}{fL}\right)\right]^{0.5} \qquad f = 3.16R_e^{0.25}$$

$$q = 0.11384A\left[2g\left(\frac{HD}{fL}\right)\right]^{0.5} \quad ET_O = c[\omega R_n + +(1-\omega)f(u)(e_s-e_a)]$$

$e_s = 6.1078e^x$, mb $\qquad e_s = 4.5812e^x$, mmHg $\qquad G = \frac{d_{gross}}{f_x}S_pS_r$

$$x = \frac{19.8374T_{mean}-0.00831T_{mean}^2}{T_{mean}+273.16} \qquad f = 3.42\times10^{-5}R_e^{0.85} \quad \gamma = \frac{e_s-e_a}{T_{dry}-T_{wet}} \quad f = \frac{64}{R_e}$$

$$\Delta = 2[0.00738T_{nean}+0.8072]^7-0.00116 \qquad P_w = \frac{N_PS_e\omega}{S_pS_r}\times100$$

$$H_f = H_f(L_1+L_2,D_1)-H_f(L_2,D_1)+H_f(L_2,D_2) = H_f(L_1,D_1)+H_f(L_2,D_2)$$

$$\frac{1}{\sqrt{f}} = 2\log\left(\frac{D}{\in}\right)+1.14 \qquad q = 3.6AC_o(2gH)^{0.5} \quad T_d = ET_{crop}\left[0.1(P_d)^{0.5}\right]$$

Table Q3.1 Values of Weighting Factor (I –W) for the Effect of Wind and Humidity on ETo at Different Temperatures and Altitudes

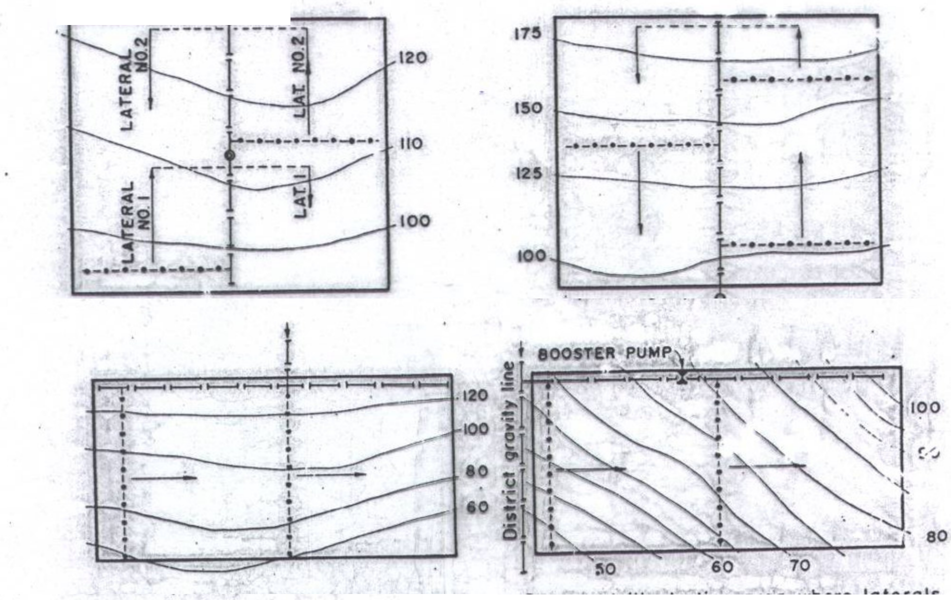
Temp (°C)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
altitude (m)																				
0	.57	.54	.51	.48	.45	.42	.39	.36	.34	.32	.29	.27	.25	.23	.22	.20	.19	.17	.16	.15
500	.56	.52	.49	.46	.43	.40	.38	.35	.33	.30	.28	.26	.24	.22	.21	.19	.18	.16	.15	.12
1000	.54	.51	.48	.45	.42	.39	.36	.32	.31	.29	.27	.25	.23	.21	.20	.18	.17	.15	.14	.13
2000	.51	.48	.45	.42	.39	.36	.32	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12
3000	.48	.45	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12	.11
4000	.46	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12	.11	.10

Table Q3.2: Adjustment factor in FAO modified Penman equation

	RH_{max}=30%					RH_{max}=60%					RH_{max}=90%			
R_s, mm/d	3	6	9	12		3	6	9	12		3	6	9	12
	$\left(\frac{U_{day}}{U_{night}}\right)=4$													
U_{day}, m/s														
0	0.86	0.90	1.00	1.00		0.96	0.98	1.05	0.05		1.02	1.06	1.10	1.10
3	0.79	0.84	0.92	0.97		0.92	1.00	1.11	1.19		0.99	1.10	1.27	1.32
6	0.68	0.77	0.87	0.93		0.85	0.96	1.11	1.19		0.94	1.10	1.26	1.33
9	0.55	0.65	0.78	0.90		0.76	0.88	1.02	1.14		0.88	1.01	1.16	1.27
	$\left(\frac{U_{day}}{U_{night}}\right)=3$													
0	0.86	0.90	1.00	1.00		0.96	0.98	1.05	1.05		1.02	1.06	1.10	1.10
3	0.76	0.81	0.88	0.94		0.87	0.96	1.06	1.12		0.94	1.04	1.18	1.28
6	0.61	0.68	0.81	0.88		0.77	0.88	1.02	1.10		0.86	1.01	1.15	1.22
9	0.46	0.56	0.72	0.82		0.67	0.79	0.88	1.05		0.78	0.92	1.06	1.18
	$\left(\frac{U_{day}}{U_{night}}\right)=2$													
0	0.86	0.90	1.00	1.00		0.96	0.98	1.05	1.05		1.02	1.06	1.10	1.10
3	0.69	0.76	0.85	0.92		0.83	0.91	0.99	1.05		0.89	0.98	1.10	1.14
6	0.53	0.61	0.74	0.84		0.70	0.80	0.94	1.02		0.79	0.92	1.05	1.12
9	0.37	0.48	0.65	0.76		0.59	0.70	0.84	0.95		0.71	0.81	0.96	1.06
	$\left(\frac{U_{day}}{U_{night}}\right)=1$													
0	0.86	0.90	1.00	1.00		0.96	0.98	1.05	1.05		1.02	1.06	1.10	1.10
3	0.64	0.71	0.82	0.89		0.78	0.86	0.94	0.99		0.85	0.92	1.01	1.05
6	0.43	0.53	0.68	0.79		0.62	0.70	0.84	0.93		0.72	0.82	0.95	1.00
9	0.27	0.41	0.59	0.70		0.50	0.60	0.75	0.87		0.62	0.72	0.87	0.96

Oppor. time, T_n (min)	Inflow rate, Q_u (m^3/s)			
	0.0005			
	0.0001	0.001	0.01	0.02

Table Q4.1



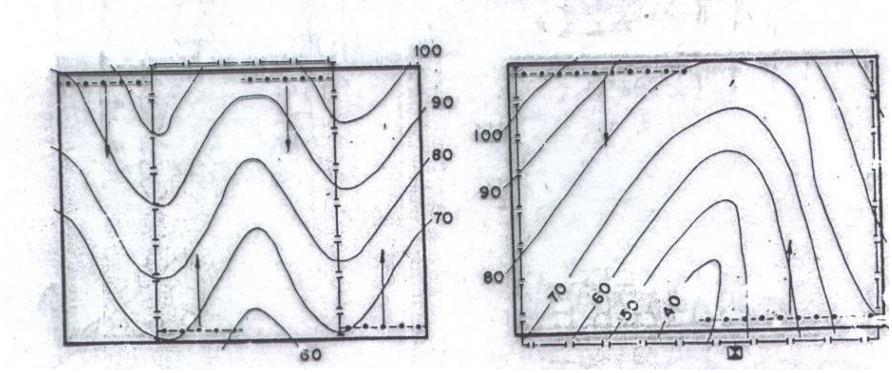


Fig. Q6.1