EGERTON UNIVERSITY

UNIVERSITY EXAMINATIONS

NJORO CAMPUS

SECOND SEMESTER 2011/2012

FOURTH YEAR EXAMINATIONS FOR THE DEGREE OF BACHELOR OF SCIENCE IN AGRICULTURAL ENGINEERING

AND

FIFTH YEAR EXAMINATIONS FOR THE DEGREE OF BACHELOR OF SCIENCE IN WATER AND ENVIRONMENTAL ENGINEERING

AGEN 455: IRRIGATION AND DRAINAGE ENGINEERING I

STREAM: 2008 (Y4) AGEN & 2007 (Y5) WEEN **TIME:** 2 hours

DAY/TIME: Tuesday, 08.30 – 10.30 am **DATE:** 15/05/2012

INSTRUCTIONS:

1. The paper contains two sections **A** and **B** and a total of **8** questions
2. Attempt the whole of **Section A** and any **FIVE (5)** questions in **Section B**
3. All questions carry equal marks.
4. Clearly indicate the number of each question and subsection.
5. Tables and other aid materials are provided at the back
6. **EACH QUESTION SHOULD BE STARTED ON A NEW PAGE.**

SECTION A – ATTEMPT ALL QUESTIONS

QUESTION ONE

(a) Define the following terms as used in irrigation:

(i) Net application depth

(ii) Gross application depth

(iii) Reservoir storage efficiency

(iv) Conveyance efficiency

(v) Application efficiency

(vi) Irrigation system efficiency **(12 marks)**

(b) A well is used to supply water to a quarter hectare of furrow irrigated plot in which a crop of Irish potatoes is grown. The soil has been tested and found to be a well-drained clay loam. The well discharges into a canal at the end of which has been installed a Parshall flume. Downstream of the flume the water enters a field ditch from which it is applied into furrows using siphon tubes. Before irrigation started, the soil was found to be at 20 percent moisture content expressed on volume basis. The intention is to raise the soil moisture level in the crop root zone to field capacity. For six hours during which irrigation was done, the following were recorded.

- Well discharge $Q_w = 8.5$ l/s
- Parshall flume discharge $Q_p = 6.8$ l/s
- Total discharge from siphons $Q_s = 6.4$ l/s

Sketch the system layout and:

(i) Identify and state applicable efficiencies. **(2 marks)**

(ii) Determine the value of each of the efficiencies. **(6 marks)**

QUESTION TWO

Explain briefly when and where each of the following land drainage systems would be most applicable.

(a) Bedding system **(2 marks)**

(b) Shallow ditch system **(2 marks)**

(c) Mole drainage system **(2 marks)**

(d) Shallow pipe drainage system **(2 marks)**

(e) Complementary measures **(2 marks)**

SECTION B – ANSWER <u>ANY FIVE</u> QUESTIONS

QUESTION THREE

Soil moisture level at field capacity was estimated as 35 percent on mass basis. Moisture level was allowed to reduce to 25 percent then, irrigation was carried out and the level restored back to field capacity. Assuming that the bulk density of this soil is 1.25 kg/m^3 or 1.25 g/cm^3 and the root zone depth is 1.0 metre, determine:

- **(a)** The equivalent depth of water applied by irrigation in mm **(4 marks)**
- **(b)** The volume of water required to supply the net requirement in **(a)** above for a 2 hectare plot. **(3 marks)**
- **(c)** The time required to give the net application if the application system discharges 20 l/s. **(3 marks)**

QUESTION FOUR

A farmer in Njoro wants to grow Kales ($K_c = 0.75$) during the months of January, February, and March. The following is the weather data for Njoro during the three months.

Month	Mean Temperature (˚C)	Wind Speed at 2 m (m/s)	Minimum Relative Humidity (%)	Effective Rainfall (mm)
January	21	6	40	54
February	23	4	20	33
March	25	2	30	49

- **(a)** State with justification, the most appropriate ET determination method. **(1 mark)**
- **(b)** Estimate the total amount of water required by the crop each month. **(3 marks)**
- **(c)** Estimate the irrigation water requirement for each month. **(2 marks)**
- **(d)** Estimate the total amount of water required by the crop during the season. **(2 marks)**
- **(e)** Estimate the irrigation water requirement during the season. **(2 marks)**

QUESTION FIVE

A furrow system has been laid out with furrow slope of 0.005 m/m. Flow rate into an individual furrow is 2.4 l/s. The length and width of the furrow is 210 m and 0.75 m, respectively. The integrated average runoff over 3 hours at the end of the furrow as measured with a Parshall flume is 0.6 l/s.

(a) Determine the net flow rate. **(2 marks)**

(b) Determine the infiltrated volume. **(2 marks)**

(c) Determine the equivalent infiltrated depth. **(2 marks)**

(d) Determine the application efficiency. **(2 marks)**

(e) Suggest ways of improving the application efficiency. **(2 marks)**

QUESTION SIX

(a) Briefly discuss the merits and demerits of Trickle irrigation system. **(4 marks)**

(b) A typical orchard is to be developed on field with dimensions 250 m by 375 m. The orchard trees spaced at 3 m-square will be irrigated using drip irrigation system laid out so that each tree is served by four emitters. The following drip system design conditions are based on peak period irrigation water requirement at full tree maturity.

- Operating pressure head at the emitter - 10 m
- Peak period crop water requirement - 5 mm/day
- Distribution efficiency - 92%
- Operating time - 18 hr/day

(i) Sketch the layout plan of the orchard showing relevant dimensions **(2 marks)**

(ii) Estimate the number of emitters required **(1 mark)**

(iii) Determine the required emitter discharge in l/hr. **(2 marks)**

(iv) Determine the total length of roll of lateral pipe for the whole orchard in metres. **(1 mark)**

QUESTION SEVEN

A sprinkler system consists of two (2) lateral lines which are operated simultaneously. The laterals are fixed 18 meters apart and each lateral carries 16 sprinklers spaced 12 m apart.

(a) Make a sketch of the layout and show the relative dimensions of the components. **(2 marks)**

(b) If the maximum gross application rate for the system is 13 mm/h, determine the expected average discharge of each sprinkler. **(2 marks)**

(c) Determine the expected net depth of irrigation if the application efficiency is 75 percent and irrigation is carried out for four hours. **(3 marks)**

(d) Determine the required pump discharge capacity for the system **(3 marks)**

QUESTION EIGHT

An irrigation pump is expected to deliver 0.063 m^3/s against a total head of 46 m. Determine the following for this pump:

(a) Water Power, (kilowatts) **(2 marks)**

(b) Brake Power, (kilowatts). Assume an efficiency of 65 percent for the pump. **(2 marks)**

(c) Size of electric motor to operate the pump assuming 10 percent power loss between the pump and the motor. **(3 marks)**

(d) Monthly cost of operating the pump at 8 hours a day, daily, if the power costs Shs. 6 per kilowatt-hour. **(3 marks)**

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Table A: Values of Maximum Allowed depletion (MAD) and Maximum Rooting Depth for 39 Crops

Crop	Maximum Allowed Depletion (fraction)	Maximum Root Depth -not Limited by Soil Depth (cm)
Alfalfa (Lucerne)	0.65	180
Apples (with/without cover)	0.65	180
Apricots (with/without cover)	0.65	180
Beans, dry	0.50	90
Beans, green	0.50	90
Carrots	0.50	90
Cherries (with/without cover)	0.50	180
Clover	0.65	60
Corn, grain	0.65	120
Corn, sweet	0.65	120
Cotton	0.65	120
Crucifers	0.50	60
Cucumbers	0.50	120
Grapes	0.50	180
Hops	0.65	180
Mint	0.65	60
Onions, dry	0.35	60
Onions, green	0.50	60
Pasture/tuft	0.50	60
Peaches(with/without cover	0.65	180
Peas	0.65	60
Pears and Plums (with/without cover	0.65	180
Potatoes	0.65	60
Radishes	0.3	60
Raspberries	0.50	120
Safflower	0.65	180
Sorghum	0.65	90
Soybean	0.65	90
Spinach	0.65	60
Strawberries	0.50	30
Sugar beets	0.65	105
Sunflower	0.65	180
Tomatoes	0.65	180
Wheat	0.50	90
	0.65	

Table B: Representative physical properties of soils

Soil Texture	Infiltration Rate[a] (mm/h)	Soil Porosity (percent)	Specific Gravity	Field Capacity (% by vol)	Crop Extractable Water (% by vol)	Total Available Water Volume Basis (percent)	Total Available Water Depth Basis (mm/m)
Sand	50 (25-250)	38 (32-42)	1.65 (1.55-1.80)	15 (10-20)	7 (3-10)	8 (6-10)	80 (60-100)
Sandy Loam	25 (13-6)	43 (40-47)	1.50 (1.40-1.60)	21 (15-27)	9 (612)	12 (9-15)	120 (90-150)
Loam	13 (8-20)	47 (43-49)	1.40 (1.35-1.50	31 (25-36)	14 (11-17)	17 (14-20)	170 (140-200)
Clay Loam	8 (2.5-15)	49 (47-51)	1.35 (1.30-1.40)	36 (31-42)	18 (15-20)	19 (16-22)	190 (160-220)
Silty Clay	2.5 (0.3-5)	51 (49-53)	1.30 (1.30-1.40)	40 (35-45)	20 (17-22)	20 (18-23)	200 (180-230)
Clay	0.5 (0.1-1)	53 (51-55)	1.25 (1.20-1.30)	44 (39-49)	21 (19-24)	23 (20-25)	230 (200-250)

Note: Normal ranges are shown in parenthesis

Table C: Pan coefficient Kp for Class A pan for different ground cover and levels of mean Relative Humidity and 24 h wind (For use in equation [4-1] to estimate ETo)

Class A Pan	Case A: Surrounded by short green crop				Case B: Surrounded by dry-fallow land			
Mean RH %		low <40	medium 40–70	high >70		low <40	medium 40–70	high >70
Wind run km/day	Upwind distance of green crop m				Upwind distance of dry fallow m			
Light <175	0	0.55	0.65	0.75	0	0.70	0.80	0.85
	10	0.65	0.75	0.85	10	0.60	0.70	0.80
	100	0.70	0.80	0.85	100	0.55	0.65	0.75
	1000	0.75	0.85	0.85	1000	0.50	0.60	0.70
Moderate 175--425	0	0.50	0.60	0.65	0	0.65	0.75	0.80
	10	0.60	0.70	0.75	10	0.55	0.65	0.70
	100	0.65	0.75	0.80	100	0.50	0.60	0.65
	1000	0.70	0.80	0.80	1000	0.45	0.55	0.60
Strong 425--700	0	0.45	0.50	0.60	0	0.60	0.65	0.70
	10	0.55	0.60	0.65	10	0.50	0.55	0.65
	100	0.60	0.65	0.70	100	0.45	0.45	0.60
	1000	0.65	0.70	0.75	1000	0.40	0.45	0.55
Very strong >700	0	0.40	0.45	0.50	0	0.50	0.60	0.65
	10	0.45	0.55	0.60	10	0.45	0.50	0.55
	100	0.50	0.60	0.65	100	0.40	0.45	0.50
	1000	0.55	0.60	0.65	1000	0.35	0.40	0.45

Table D: Mean daily percent (p) of annual daytime hours for different latitudes.

Latitude	North / South	Jan / July	Feb / Aug	Mar / Sept	Apr / Oct	May / Nov	June / Dec	July / Jan	Aug / Feb	Sept / Mar	Oct / Apr	Nov / May	Dec / June
60°		.15	.20	.26	.32	.38	.41	.40	.34	.28	.22	.17	.13
58		.16	.21	.26	.32	.37	.40	.39	.34	.28	.23	.18	.15
56		.17	.21	.26	.32	.36	.39	.38	.33	.28	.23	.18	.16
54		.18	.22	.26	.31	.36	.38	.37	.33	.28	.23	.19	.17
52		.19	.22	.27	.31	.35	.37	.36	.33	.28	.24	.20	.17
50		.19	.23	.27	.31	.34	.36	.35	.32	.28	.24	.20	.18
48		.20	.23	.27	.31	.34	.35	.35	.32	.28	.24	.21	.19
46		.20	.23	.27	.30	.34	.35	.34	.32	.28	.24	.21	.20
44		.21	.24	.27	.30	.33	.34	.34	.31	.28	.25	.22	.20
42		.21	.24	.27	.30	.33	.34	.33	.31	.28	.25	.22	.21
40		.22	.24	.27	.30	.32	.33	.33	.31	.28	.25	.22	.21
35		.23	.25	.27	.29	.31	.33	.32	.30	.28	.25	.23	.22
30		.24	.25	.27	.29	.31	.32	.31	.30	.28	.26	.24	.23
25		.24	.26	.27	.29	.30	.31	.31	.29	.28	.26	.25	.24
20		.25	.26	.27	.28	.29	.30	.30	.29	.28	.26	.25	.25
15		.26	.26	.27	.28	.29	.29	.29	.28	.28	.27	.26	.25
10		.26	.27	.27	.28	.28	.29	.29	.28	.28	.27	.26	.26
5		.27	.27	.27	.28	.28	.28	.28	.28	.28	.27	.27	.27
0		.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27

Table E: Values of b as a function of RH_{min}, U_{day}, n/N

n/N	RHmin (percent) 0	20	40	60	80	100	U_{day}
0.0	0.84	0.8	0.74	0.64	0.52	0.38	0
0.2	1.03	0.95	0.87	0.76	0.63	0.48	
0.4	1.22	1.10	1.01	0.88	0.74	0.57	
0.6	1.38	1.24	1.13	0.99	0.85	0.66	
0.8	1.54	1.37	1.25	1.09	0.94	0.75	
1.0	1.68	1.50	1.36	1.18	1.04	0.84	
0.0	0.97	0.90	0.81	0.68	0.54	0.40	2
0.2	1.19	1.08	0.96	0.84	0.66	0.50	
0.4	1.41	1.26	1.11	0.97	0.77	0.60	
0.6	1.60	1.42	1.25	1.09	0.89	0.70	
0.8	0.79	1.59	1.39	1.21	1.01	0.79	
1.0	1.98	1.74	1.52	1.31	1.11	0.89	
0.0	1.08	0.98	0.87	0.72	0.56	0.42	4
0.2	1.33	1.18	1.03	0.87	0.69	0.52	
0.4	1.56	1.38	1.19	1.02	0..82	0..62	
0.6	1.78	1.56	1.34	1.15	0.94	0.73	
0.8	2.0	1.74	1.50	1.28	1.05	0.83	
1.0	2.19	1.90	1.64	1.39	1.16	0.92	
0.0	1.18	1.06	0.92	0.74	0.58	0.43	6
0.2	1.44	1.27	1.10	0.91	0.72	0.54	
0.4	1.70	1.48	1.27	1.06	0.85	0.64	
0.6	1.94	1.67	1.44	1.21	0.97	0.75	
0.8	2.18	1.86	1.59	1.34	1.09	0.85	
1.0	2.39	2.03	1.74	1.46	1.20	0.95	
0.0	1.26	1.11	0.96	0.76	0.60	0.44	8
0.2	1.52	1.34	1.14	0.93	0.74	0.55	
0.4	1.79	1.56	1.32	1.10	0.87	0.66	
0.6	2.05	1.76	1.49	1.25	1.00	0.77	
0.8	2.30	1.96	1.66	1.39	1.12	0.87	
1.0	2.54	2.14	1.82	1.52	1.24	0.98	
0.0	1.29	1.15	0.98	0.78	0.61	0.45	10
0.2	1.58	1.38	1.17	0.96	0.75	0.56	
0.4	1.86	1.61	1.36	1.13	0.89	0.68	
0.6	2.13	1.83	1.54	1.28	1.03	0.79	
0.8	2.39	2.03	1.71	1.43	1.15	0.89	
1.0	2.63	2.22	1.86	1.56	1.27	1.00	

USEFUL FORMULAS

CROP WATER RELATIONS

(20) $ET_o = a + b[p(0.46T + 8.13)]$ (2) $a = 0.0043(RH_{min}) - n/N - 1.41$ (3) $U_{2m} = U_z[2.0/z]^{0.2}$

(3) $b = 0.82 - 0.0041(RH_{min}) + 1.07(n/N) + 0.066(U_{day}) - 0.006(RH_{min})(n/N) - 0.0006(RH_{min})(U_{day})$

(4) $K_p = 0.475 - 0.24*10^{-3}(U_{2m}) + 0.00516(RH_m) + 0.00118(d) - (0.16*10^{-4}(RH_m)^2$

(20) $0.101*10^{-5}(d)^2 - 0.8*10^{-8}(RH_m)^2(U_{2m}) - 1.0*10^{-8}(RH_m)^2(d)$ () $ET_c = K_cET_o$

(5) $ET_o = K_pE_p$ (6) $IR = CWR - P_e$ (7) $P_e = f(D)[1.25(P_t)^{0.824} - 2.93]*10^{(0.000955ETc)}$

(8) $f(D) = 0.53 + 0.0116D - 8.94*10^{-5}(D)^2 + 2.32 * 10^{-7}(D)^3$ (9) $IR_p = \Sigma[\Sigma(IR_c)_d]$

SOIL WATER RELATIONS

(1) $M_t = M_a + M_w + M_s$ (2) $V_t = V_b = V_a + V_w + V_s$ (3) $V_p = V_a + V_w$ (4) $\theta_g = M_w/M_s$

(5) $\rho_b = M_s/V_b$ (6) $\theta_v = V_w/V_b = \rho_b\theta_g$ (7) $N = V_p/V_b$ () $N_a = V_a/V_b$ (8) $\theta_{vs} = V_p/V_b$ (9) $\theta_{ms} = \rho_w V_p/M_s$

(10) $\theta_d = \rho_b*\theta_m*D_{rz}$ (11) $N = 1 - (\rho_b/\rho_s)$ (12) $\rho_b = (1 - N)\rho_s$ (13) $TAM = FC - CEW$

(14) $RAM = TAM*MAD$ (15) $II = RAM/ET_c$ (16) $T = z + p + p_{os}$ (17) $h = z + p$ (18) $\theta_i = \theta_{i-1} - (ET - P_e)$

SURFACE IRRIGATION SYSTEM

(1) $E_i = 100[E_r*E_e*E_c*E_d*E_a*E_s*E_u]$ (2) $I_r = a(t)^b$ (3) $I_c = [a/(b+1)]\ t^{(b+1)}$ (4) $FAR = T_t/T_n$

(5) $Q_{max} = C/S$ (6) $I_e = (1/LP)(V_{in} - V_{out} - V_s)$ $P = 0.265[Qn/S^{0.5}]^{0.425} + 0.227$

(7) $V_s = (L/0.305)[2.947(Qn/S^{0.5})^{0.735} - 0.0217]$

SPRINKLER IRRIGATION SYSTEM

(1) $UC_C = 1 - \Sigma[abs(xi - x)]/(nx)$ (2) $UC_H = 1 - [2/\pi]^{0.5}(s/x)$ (3) $E = 1 - L_d$

(4) $Ec = (1 - L_d)(1 - L_s)$ (5) $e_s - e_a = 0.61\exp[17.27\ T/(T + 273.3)]\ (1 - RH)$

(6) $L_s = [1.98(D)^{-0.72} + 0.22(e_s - e_a)^{0.63} + 3.6\ 10^{-4}(h)^{1.16} + 0.14(U)^{0.7}]^{4.2}$ (7) $A_{rg} = 3600[q_s/(S_l*S_m)]$

(8) $A_{rn} = A_{rg}(1 - L_s)$ (9) $q_s = K(p)^{0.5}$ (10) $Q_s = 2.778[I_g(A)]/[Nop(Top)]$ (11) $N_s = Q_s/q_s$

(12) $H_{la} = [P_d(H_o) - H_e)]/L$ (13) $H_{ac} = F(H_f)$ (14) $H_f = 1.22*10^{10}[\{(Q/C)^{1.852}\}/D^{4.87}]$

(15) $F = 1/(m+1) + 1/(2N) + (m-1)^{0.5}/(6N^2)$ (16) $F = 2N/(2N-1)[1/(m+1) + (m-1)^{0.5}/(6N^2)]$

(17) $H_{jm} = H_o + 0.75(H_f + H_e) + H_r$ (18) $H_{v-i} = (v_i)^2/2g$ (19) $H_i = H_n + H_{f\_in} + H_{e\_in} + H_{v\_in}$

(20) $TDH_i = H_i + H_{f\_pl} + H_{e\_sl} + H_{f\_s}$ (21) $T_s = (ET_s/I_{nr})T_r$ (22) $T_a = D_wT_r/2\pi r$ (23) $A_{nd} = A_{ng}(1 - L_s)$

(24) $CPA_{rm} = (4/\pi)(A_{nd}/T_a)$ (25) $Q_p = 2.78(A(A_{dg})/T_r)$ (26) $q_{sr} = rs_r[2Q_p/(r_{max})^2]$

(27) $LMA_{rm}\ 3600(4/\pi)(Q_{lm}/L(D_w)$ (28) $(TMA_{rm}\ 3600\{4q_s/[\pi(0.9D_w)^2]\}(360/\Phi)$ (28) $TMA_{dg} = 60q_s/S_t(v_t)$

TRICKLE IRRIGATION SYSTEM

(1) $q_e = k(H)^x$ (2) $q_e = 3.6\ (A)C_o(2gH)^{0.5}$; (3) $q_e = 0.11384(A)[2g(HD/fL)]^{0.5}$;

(4) $q_e = 0.11384(A)[2g\{(HD)^{\frac{1}{2}}/fL\}]^{0.5}$; (5) $f = 64/R_N$; (6) $1/f^{\frac{1}{2}} = 2\log(D/\epsilon) + 1.14$

(7) $U_e = 100[1.0 - (1.27/n)C_v]q_{min}/q_{avg}$ (8) $q_{var} = 100[1 - q_{min}/q_{max}]$ (9) $h_f = 6.377fLQ^2/D^5$

(10) $h_{ac} = Fh_f$ (11) $LSI = pH_m - pH_c$ (12) $K_s = (Ca^{2+})(CO_3^{2-})$ (13) $K_d = [(H^+)(CO_3^{2-})] / (HCO_3^-)$

(14) $pH_c = (pK_d - pK_s) + p[Ca^{2+}] + p[HCO_3^-] + p(ACF)$ (15) $pK_d - pK_s = 2.586 - 2.621*10^{-2}T + 1.01*10^{-4}T^2$

(16) $p(ACF) = 7.790*10^{-2} + 2.610*10^{-2}TDS - 5.477*10^{-4}TDS^2 + 5.323*10^{-6}TDS^3$

(17) $C = 100\exp[-q_t(t)/100]$ (18) $D = [15.13Q_t/C_oP^{\frac{1}{2}}]^{0.5}$

PUMPING SYSTEMS

(1) $N_S = 0.2108N(Q^{0.5}) / H^{0.75}$; (2) $Q_1/Q_2 = N_1/N_2$; (3) $Q_1/Q_2 = D_1/D_2$;

(4) $[(H_1/H_2) = (N_1/N_2)]^2$; (5) $[(H_1/H_2) = (D_1/D_2)]^2$; (6) $[(P_1/P_2) = (N_1/N_2)]^3$; (7) $[(P_1/P_2) = (D_1/D_2)]^3$;

(8) $P = QH\gamma/0.102E$; (9) $NPSH_A = P_{atm} - Z_S - H_{FS} - P_V - F_S$; (10) $P_W = Q(H)/0.102$; (11) $TDH = H_{FT} + H_{VT}$;

(12) $H_{ST} = H_{SS} + H_{DS}$; (13) $H_{VT} = H_{DD} + H_F + H_{OP} + H_V$; (14) $Q_{Series} = Q_A = Q_B$; (15) $H_{Series} = H_A + H_B$;

(16) $P_{Series} = P_A + P_B$; (17) $E_{Series} = Q_{Series}(H_A + H_B)/[0.102(P_A + P_B)]$; (18) $H_{Para} = H_A = H_B$;

(19) $Q_{Para} = Q_A + Q_B$; (20) $P_{Para} = P_A + P_B$; (21) $E_{Para} = H_{Para}(Q_A + Q_B) / [0.102(P_A + P_B)]$