# MACHAKOS UNIVERSITY

**University Examinations 2016/2017**

**SCHOOL OF ENGINEERING AND TECHNOLOGY**

**DEPARTMENT OF BUILDING AND CIVIL ENGINEERING**

**THIRD YEAR SECOND SEMESTER EXAMINATION FOR DEGREE IN**

**BACHELOR OF SCIENCE IN CIVIL ENGINEERING**

**ECV 307 HYDROLOGY I**

**DATE: 12/6/2017** **TIME: 2:00 – 4:00 PM**

**INSTRUCTIONS**

**Answer Question One and Any Other Two Questions**

**QUESTION ONE (COMPULSORY) (30 MARKS)**

a) 97% of the Earth's water is stored in the oceans. With aid of a well labelled sketch, describe the various natural physical processes involved in the translation of oceanic water to an upland stream (4 marks)

b) Show, from first principles, that precipitable water from the atmosphere is expressed as

$$W = \frac{0.1}{g}\sum_{P_2}^{P_1} q\Delta P$$

where, W is precipitable water, q is specific humidity, g is the gravitational acceleration, and P is pressure (4 marks)

c) The following aerological observations were taken from a radiosonde ascent

| Pressure (mb) | 1006 | 920 | 800 | 740 | 700 | 660 | 600 | 500 | 400 |
|---|---|---|---|---|---|---|---|---|---|
| Specific humidity (g/kg) | 14.0 | 13.4 | 10.2 | 9.4 | 7.2 | 6.6 | 5.6 | 4.0 | 1.8 |

If 60% of the precipitable water is produced from the air up to the 600 mb level to form precipitation at ground level, what would be the depth of the rainfall? (6 marks)

d) With aid of a well labelled sketch, define the components of a runoff hydrograph and the generating hyetograph (4 marks)

e) Figure Q1 (e) is the internal mechanism of the Meteorological Office tilting-syphon rain recorder. (4 marks)

i. Name the parts labelled A to H

ii. Explain the operating mechanism of the recorder

f) With aid of an appropriate formula, identify and define the necessary elements in the water budget method of estimating evaporation loss from a reservoir (3 marks)

g) The antecedent precipitation index for a station was 53 mm on 1st October; 55 mm rain fell on 5th October; 30 mm on 7th October and 25 mm on 8th October. Compute the antecedent precipitation index, $I_p$ (5 marks)

**QUESTION TWO (20 MARKS)**

In Table Q2 is the total streamflow hydrograph draining a catchment of 18 km2, and following a rainstorm. Assume baseflow rises linearly during the period of runoff from 20 to 60 m3/s.

a) Separate direct runoff (5 marks)

b) Plot the total and direct runoff hydrographs on the same axis (5 marks)

c) Estimate the total volume of direct runoff (3 marks)

d) Estimate the Φ-index for the storm, stating the assumptions made (5 marks)

e) Estimate excess rainfall (2 marks)

**Table Q2**

| Time | Observed rain (mm) | streamflow (cms) |
|---|---|---|
| 9:30 | 6 | 42 |
| 10:00 | 8 | 28 |
| 10:30 | 36 | 22 |
| 11:00 | 58 | 44 |
| 11:30 | 55 | 136 |
| 12:00 | 7 | 234 |
| 12:30 | 4 | 282 |
| 1:00 | | 300 |
| 1:30 | | 304 |
| 2:00 | | 298 |
| 2:30 | | 280 |
| 3:00 | | 246 |
| 3:30 | | 218 |
| 4:00 | | 192 |
| 4:30 | | 166 |
| 5:00 | | 146 |
| 5:30 | | 126 |
| 6:00 | | 110 |

| | |
|---|---|
| 6:30 | 92 |
| 7:00 | 76 |
| 7:30 | 64 |
| 8:00 | 54 |
| 8:30 | 48 |
| 9:00 | 44 |
| 9:30 | 38 |
| 10:00 | 32 |

**QUESTION THREE (20 MARKS)**

a) The precipitation falling on a catchment area of 50 $km^2$ is sampled by six rain gauges. From the measurements in Table Q3 (a).

i. Deduce the areal rainfall for 2008.

ii. If a dam is built at the catchment outfall and a statutory minimum discharge of 0.1 m3/s is maintained throughout the year in the river downstream, assess the volume of water available for supply.

(Assume the drainage basin is water tight and there is a total evaporation loss of 400 mm)

Table Q3 (a)

| Rain gauge | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2008 rainfall (mm) | 2052 | 1915 | 1868 | 1723 | 1640 | 1510 |
| Thiessen polygon area ($km^2$) | 7.8 | 8.3 | 10.2 | 11.5 | 5.4 | 6.8 |

(10 marks)

b) The areas (in Table Q3(b)) contained within given isohyets were obtained for a 2-day storm over Machakos, when the maximum point total measured was 210 mm. Calculate the areal rainfall within each isohyet and plot the Depth-Area curve.

Table Q3 (b)

| Isohyet (mm) | 200 | 175 | 150 | 125 | 100 |
|---|---|---|---|---|---|
| Area ($km^2$) | 50 | 630 | 1800 | 2600 | 5200 |

(10 marks)

**QUESTION FOUR (20 MAKRS)**

a) In a catchment area, the measurements of evaporation (mm) shown in Table Q4 (a) were made for the period 1978-1982 and 1988-1992. For the year 1988-1992, measurements from the US Class A pan only were available. Estimate the volume of water lost each year in the later period from a reservoir of surface area 1.4 $km^2$ (6 marks)

**Table Q4 (a)**

| Year | UK tank | US Class A pan | Year | US Class A pan |
|---|---|---|---|---|
| 1978 | 351 | 491 | 1988 | 621 |
| 1979 | 536 | 713 | 1989 | 681 |
| 1980 | 502 | 653 | 1990 | 687 |
| 1981 | 437 | 586 | 1991 | 624 |
| 1982 | 486 | 612 | 1992 | 568 |

b) The data in Table Q4 (a) was recorded at a climatological station, latitude $1.2^0$S; during the month of April 1995

**Table Q4 (b)**

Temperature = $19^oC$

Vapour pressure = 11 mm Hg

Wind speed at 10 m above the ground = 6.6 miles/hour

Sunshine hours = 10 hours/day

Albedo = 0.05

Calculate the evaporation for the station for the month of April 1995 (14 marks)

**QUESTION FIVE (20 MARKS)**

A rainstorm commenced at 1600 hours. The rainfall depths at 15 minutes interval are as shown in Table Q5

**Table Q5**

| Time (hours) | Rainfall (mm) |
|---|---|
| 1600 | 0 |
| 1615 | 11.2 |
| 1630 | 9.8 |
| 1645 | 8.5 |
| 1700 | 14.5 |
| 1715 | 8.2 |
| 1730 | 14.6 |
| 1745 | 20.9 |
| 1800 | 11.0 |
| 1815 | 6.1 |
| 1830 | 7.1 |
| 1845 | 4.0 |
| 1900 | 1.0 |

a) Derive and draw the maximum-intensity (I) against time (*t*) graph for a period of up to 3 hours (15 marks)

b) If the relationship in (a) is given by the general equation

$$I = \frac{a}{t^n}$$

where, a and n are the locality constants, derive the specific equation (5 marks)