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CIVIL ENGINEERING

CONVENTIONAL PRACTICE SETS VOLUME - III

CONTENTS

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FLUID MECHANICS

CONVENTIONAL PRACTICE SETS

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1 CHAPTER Fluid Properties

Q.1 The space between two square flat parallel plates is filled with oil. Each side of the plate is 60 cm. The thickness of the oil film is 12.5 mm. The upper plate, which moves at 2.5 metre per sec requires a forces of 98.1 N to maintain the speed. Determine:
(i) the dynamic viscosity of the oil in poise, and
(ii) the kinematic viscosity of the oil in stoke if the specific gravity of the oil is 0.95.

Solution:

Given: Each side of a square plate = 60 cm = 0.60 m

∴ Area, $A = 0.6 \times 0.6 = 0.36\ \text{m}^2$

Thickness of oil firm, $dy = 12.5\ \text{mm} = 12.5 \times 10^{-3}\ \text{m}$

Velocity of upper plate, $u = 2.5$ m/sec

∴ Change of velocity between plates,

$du = 2.5$ m/sec

Force required on upper plate, $F = 98.1$ N

∴ Shear stress, $\boxed{\tau = \dfrac{\text{Force}}{\text{Area}} = \dfrac{F}{A}}$

$$= \frac{98.1\ \text{N}}{0.36\ \text{m}^2} = 27.25\ \text{N/m}^2$$

(i) Let μ = Dynamic viscosity of oil

$$\boxed{\tau = \mu \frac{du}{dy}}$$

or $$27.25 = \mu \times \frac{2.5}{12.5 \times 10^{-3}}$$

∴ $$\mu = 27.25 \times \frac{12.5 \times 10^{-3}}{2.5} = 1.3635\ \text{Ns/m}^2 \qquad \left(\because 1\ \text{Ns/m}^2 = 10\ \text{poise}\right)$$

$= 1.3635 \times 10 = 13.635$ Poise

(ii) Specific gravity of oil, $S = 0.95$

Let ν = kinematic viscosity of oil

Mass density of oil, $\rho = S \times 1000 = 0.95 \times 1000 = 950\ \text{kg/m}^3$

Using the relation, $$\nu = \frac{\mu}{\rho}$$

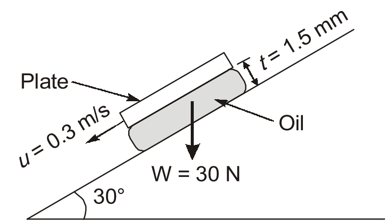
We get, $$\nu = \frac{1.3635\ \text{Ns/m}^2}{950\ \text{kg/m}^3} = 0.001435\ \text{m}^2/\text{sec}$$

$= 0.001435 \times 10^4\ \text{cm}^2/\text{s}$

$= 14.35$ stokes

Q2 Calculate the dynamic viscosity of an oil, which is used for lubrication between a square plate of size 0.8 m × 0.8 m and an inclined plane with angle of inclination 30° as shown in figure. The weight of the square plate is 300 N and it slides down the inclined plane with a uniform velocity of 0.3 m/s. The thickness of oil film is 1.5 mm.

Solution:



Given: Area of plate, $A = 0.8 \times 0.8 = 0.64\ m^2$

Angle of plane, $\theta = 30°$

Weight of plate, $W = 300$ N

Velocity of plate, $u = 0.3$ m/s

Thickness of oil film, $t = dy = 1.5\ mm = 1.5 \times 10^{-3}$ m

Let the viscosity of fluid between plate and inclined plane is μ.

Component of weight W, along the plane = $W \cos 60° = 300 \cos 60° = 150$ N

Thus the shear force, F, on the bottom surface of the plate = 150 N

and shear stress, $$\boxed{\tau = \frac{F}{\text{Area}}} = \frac{150}{0.64}\ \text{N/m}^2$$

Now, $$\boxed{\tau = \mu \frac{du}{dy}}$$

du = change of velocity = $u - 0 = 0.3$ m/sec

$dy = t = 1.5 \times 10^{-3}$ m

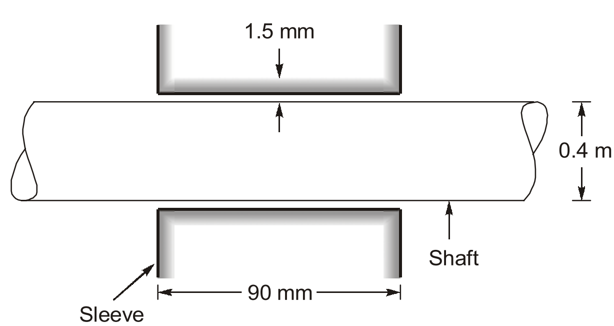
$$\therefore \quad \frac{150}{0.64} = \mu \times \frac{0.3}{1.5 \times 10^{-3}}$$

$$\mu = \frac{150 \times 1.5 \times 10^{-3}}{0.64 \times 0.3} = 1.17\ \text{Ns/m}^2 = 11.7\ \text{Poise}$$

Q3 The dynamic viscosity of an oil, used for lubrication between a shaft and sleeve is 6 poise. The shaft is of diameter 0.4 m and rotates at 190 rpm. Calculate the power lost in the bearing for a sleeve length of 90 mm. The thickness of the oil film is 1.5 mm.

Solution:

Given:



Viscosity, $\mu = 6$ Poise

$$= \frac{6}{10} \frac{\text{Ns}}{\text{m}^2} = 0.6\ \text{Ns/m}^2$$

Dia. of shaft, D = 0.4 m

Speed of shaft, N = 1900 rpm

Sleeve length, $L = 90 \text{ mm} = 90 \times 10^{-3}$ m

Thickness of oil film, $t = 1.5 \text{ mm} = 1.5 \times 10^{-3}$ m

Tangential velocity of shaft, $$\boxed{u = \frac{\pi DN}{60}}$$

$$= \frac{\pi \times 0.4 \times 190}{60} = 3.98 \text{ m/s}$$

Using the relation, $$\boxed{\tau = \mu \frac{du}{dy}}$$

where, du = Change of velocity $= u - 0 = u = 3.98$ m/s

dy = Change of distance $= t = 1.5 \times 10^{-3}$ m

$$\tau = 10 \times \frac{3.98}{15 \times 10^{-3}} = 1592 \text{ N/m}^2$$

This is shear stress on shat,

∴ Shear force on the shaft, $$\boxed{F = \text{Shear stress} \times \text{Area}}$$

$$= 1592 \times \pi D \times L = 1592 \times \pi \times 0.4 \times 90 \times 10^{-3} = 180.05 \text{ N}$$

Torque on the shaft, $$\boxed{T = \text{Force} \times \frac{D}{2}}$$

$$= 180.5 \times \frac{0.4}{2} = 36.01 \text{ Nm}$$

∴ $$\boxed{\text{Power lost} = \frac{2\pi NT}{60}}$$

$$= \frac{2\pi \times 190 \times 36.01}{60} = 716.48 \text{ W}$$

Q.4 A vertical gap 23.5 mm wide of infinite extent contains oil of specific gravity 0.9 and viscosity 2.5 N-s/m^2. A metal plate 1.5 m × 1.5 m × 1.5 mm weighing 50 N is to be lifted through the gap at a constant speed of 0.1 m/sec. Estimate the force required to lift the plate.

Solution:

Given:

Width of gap = 23.5 mm

Viscosity, μ = 2.5 Ns/m^2

Specific gravity oil = 0.9

∴ Weight density of oil = $0.9 \times 1000 = 900$ kgf/m^3

= 900×9.81 N/m^3 (∵ 1 kgf = 9.81 N)

Assuming that the plate lies in the middle of the gap

Volume of plate = 1.5 m × 1.5 m × 1.5 mm

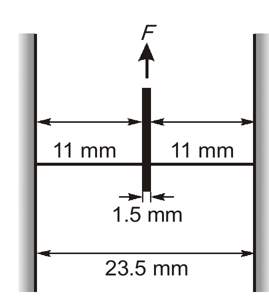
= $1.5 \times 1.5 \times 0.0015$ m^3

= 0.003375 m^3

Thickness of plate = 1.5 mm

Velocity of plate = 0.1 m/sec

Weight of plate = 50 N



When the plate is in the middle of the gap, the distance of plate from

$$\text{Vertical surface of the gap} = \left(\frac{\text{Width of gap} - \text{Thickness of plate}}{2}\right)$$

$$= \left(\frac{23.5 - 1.5}{2}\right) = 11 \text{ mm} = 0.011 \text{ m}$$

Now, shear force on left side of the metallic plate

$$F_1 = \text{Shear stress} \times \text{Area}$$

$$= \mu\left(\frac{du}{dy}\right)_1 \times (1.5 \times 1.5) = 2.5 \times \left(\frac{0.1}{0.011}\right) \times 1.5 \times 1.5 = 51.136 \text{ N}$$

Similarly, the shear force on the right side of the metallic plate

$$F_2 = \text{Shear stress} \times \text{Area}$$

$$= 2.5 \times \left(\frac{0.1}{0.011}\right) \times (1.5 \times 1.5) = 51.136 \text{ N}$$

∴ Total shear force $= F_1 + F_2 = 51.136 + 51.136 = 102.272$ N

In this case the weight of plate (which is acting downward) and upward thrust is also to be taken into account.

∴ The upward thrust = weight of fluid displaced = $\rho v g$

= (unit weight of fluid) × Volume of fluid displaced

= $9.81 \times 900 \times 0.003375$

= 29.80 N

The net force acting in the downward direction due to the weight of the plate and upward thrust

= weight of plate – upward thrust = 50 – 29.80 = 20.20 N

∴ Total force required to lift the plate up

= Total shear force + 20.20 = 102.272 + 20.20 = 122.472 N

Q.5 The pressure outside the droplet of water of diameter 0.04 mm is 10.32 N/cm² (atmospheric pressure). Calculate the pressure within the droplet if surface tension is given as 0.0725 N/m of water.

Solution:

Given, dia. of droplet, $d = 0.04 \text{ mm} = 0.04 \times 10^{-3}$ m

Pressure outside the droplet $= 10.32 \text{ N/cm}^2 = 10.32 \times 10^4 \text{ N/m}^2$

Surface tension, $\sigma = 0.0725$ N/m

The **pressure inside the droplet**, in excess of outside pressure is given by

$$p = \frac{4\sigma}{d}$$

$$= \frac{4 \times 0.0725}{0.04 \times 10^{-3}} = 7250 \text{ N/m}^2$$

$$= \frac{7250 \text{ N}}{10^4 \text{ cm}^2} = 0.725 \text{ N/cm}^2$$

Pressure inside the droplet = p + pressure outside the droplet

$= 0.725 + 10.32 = 11.045 \text{ N/cm}^2$

Q.6 Calculate the capillary effect in mm in a glass tube 3 mm in diameter when immersed in (a) water (b) mercury. Both the liquids are at 20°C and the values of the surface tensions for water and mercury at 20°C in contact with air are respectively 0.0736 N/m and 0.51 N/m. Contact angle for water = 0° and for mercury = 130°.

Solution:

The capillary rise (or depression) is given as

$$\boxed{h = \frac{2\sigma\cos\theta}{\rho g r}}$$

(a) For water $\theta = 0$,

$$\cos\theta = 1$$
$$\sigma = 0.0736 \text{ N/m}$$
$$\rho g = 9810 \text{ N/m}^3$$
$$d = 3 \text{ mm}$$
$$r = \frac{3}{2} = 1.5 \text{ mm} = 1.5\times10^{-3} \text{ m}$$

By substitution, we get

$$h = \frac{2\times0.0736\times1}{9810\times1.5\times10^{-3}}$$
$$= 1.00\times10^{-2} \text{ m} = 10 \text{ mm}$$

(b) For mercury $\theta = 130°$,

$$\cos\theta = -0.6428$$
$$\sigma = 0.51 \text{ N/m}$$
$$\rho g = (13.6\times9810) \text{ N/m}^3$$
$$r = \frac{3}{2} = 1.5 \text{ mm} = 1.5\times10^{-3} \text{ m}$$

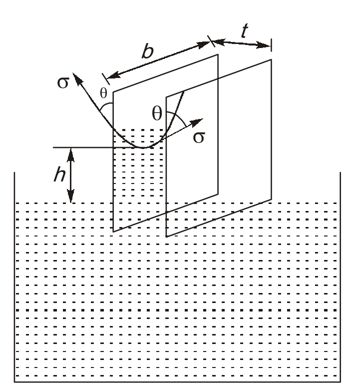
By substitution, we get

$$h = \frac{2\times0.51\times(-0.6425)}{13.6\times9810\times1.5\times10^{-3}}$$
$$= -3.276\times10^{-3} \text{ m}$$
$$= -3.276 \text{ mm}$$

The negative (–) sign in the case of mercury indicates that there is capillary depression.

Q.7 For capillarity rise between two thin vertical plates spaced '*t*' distance apart. Calculate the distance between the plates when the capillarity rise is not to exceed 60 mm. Assume surface tension of water at 20°C as 0.075 N/meter.

Solution:



For two vertical plates, '*t*' distance apart

Let width of plate be '*b*' and contact angle be 'θ'

Force due to surface tension = Force due to gravity

$$2\sigma\cos\theta\, b = \rho g\,(b\times t)h$$

Height of capillarity rise,

$$\boxed{h = \frac{2\sigma\cos\theta}{\rho g t}}$$

For $\sigma = 0.075$ N/m and $h = 60$ mm

Assuming $\theta = 0°$ i.e., $\cos\theta = 1$

$$0.06 = \frac{2\times0.075\times1000}{9.81\times1000\times t}$$
$$t = 0.255 \text{ mm}$$

ENVIRONMENTAL ENGINEERING

CONVENTIONAL PRACTICE SETS

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1 CHAPTER Water Demand

Q.1 **The present population of a community is 28000 with an average water consumption of 4200 m^3/d. The existing water treatment plant has a design capacity of 6000 m^3/d. It is expected that the population will increase to 44000 during the next 20 years. Find the number of years from now when the plant will reach its design capacity, assuming an arithmetic rate of population growth**

Solution:

Given dat: Present population, P_0 = 28000; Population after 20 years, P_n = 44000

∴ Increase in population per year, $\bar{x}$

$$\boxed{P_n = P_0 + n\bar{x}}$$

$$\bar{x} = \frac{P_n - P_0}{n} \qquad (n = 20)$$

$$= \frac{44000 - 28000}{20} = 800$$

Now, for population for 28000, water consumption = 4200 m^3/d

Hence, population for water consumption of 6000 m^3/d

$$= \frac{28000}{4200} \times 6000 = 40000 \text{ persons} = \text{Population at design capacity}$$

∴ No. of years from now when plant will reach at design capacity

$$P_n = P_0 + n\bar{x}$$

$$n = \frac{40000 - 28000}{800} = 15 \text{ years}$$

Q.2 **What is meant by 'design period' and 'population forecast'? Describe the 'incremental increase' method of future population forecast of a city, stating its advantages.**

Solution:

Design Period : The number of years for which the system is to be adequate is called design period.

Population forecasting: Design of water supply and sanitation scheme is based on the projected population of a particular city, estimated for the design period. Any underestimated value will make system inadequate for the purpose intended, similarly overestimated value will make it costly.

The present and past population record for the city can be obtained for the census population record. After collecting these population figures, the population at the end of design period is predicted using various methods as suitable for that city considering the growth pattern followed by the city.

Incremental Increase method: This method is modification of arithmetical increase method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method, the increase in increment is considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase.

Hence, population after n^{th} decade is $P_n = P + nX + \left\{\frac{(n+1)n}{2}\right\} Y$

Where, P_n = Population after n^{th} decade
X = Average increase
Y = Incremental increase

- Advantages of incremental increase method:
  1. This method gives/predict more accurate value of population.
  2. This method embodies the advantage of arithmetic average method and geometrical average method.

Q.3 The population of a city at previous consecutive census year was 4,00,000, 5,58,500, 7,76,000 and 10,98,500. Calculate the anticipated population at the next census nearest to 5,000

Solution:

Since the method is not mentioned in the question, hence the question is solved by *incremental increase method*. This is done because

- This method gives results between the results given by the arithmetic increase method and the geometric increase method.
- The method is considered to be the best for any city, whether old or new.

Census year	Population	Population Increment	Incremented Increase
1	4,00,000		
		1,58,500	
2	5,58,500		59000
		2,17,500	
3	7,76,000		10,5000
		3,22,500	
4	10,98,500		
		$\bar{X} = \frac{\Sigma X}{3}$ = 232833.33	$\bar{Y} = \frac{\Sigma Y}{2}$ = 82000

$$P_n = P_0 + n \cdot \bar{X} + \frac{n(n+1)}{2}\bar{Y}$$

For $n = 1$

$$P_5 = P_0 + 1 \cdot \bar{X} + \frac{1(1+1)}{2}\bar{Y}$$

$$= 10,98,500 + 232833.33 + 82000 = 1413333.33$$

∴ The anticipated population at the next census to the nearest 5000 would be 1415000.

Q.4 Compute the 'fire demand' for a city of 2 lac population by any two formulae including that of the National Board of Fire Underwriters.

Solution:

(i) The rate of fire demand as per **National Board of Fire Underwriters formula** for a central congested city whose population is less than or equal to 2 lakh is given by

$$Q = 4637\sqrt{P}(1 - 0.01\sqrt{P})$$

where Q is amount of water required in litres per minute and P is population in thousands

$$Q = 4637\sqrt{200}\left[1 - 0.01\sqrt{200}\right] = 56303.08 \text{ litres per minute}$$

$$= \frac{56303.08 \times 60 \times 24}{10^6}\text{MLD} = 81.08 \text{ MLD}$$

(ii) Kuichling's formula,

$$Q = 3182\sqrt{P} = 3182\sqrt{200}$$

$$= 45000.28 \text{ litres per minute} = 64.8 \text{ MLD}$$

(iii) Freeman Formula,

$$Q = 1136\left[\frac{P}{10} + 10\right]$$

$$= 1136\left[\frac{200}{10} + 10\right] = 34080 \text{ litres per minute} = 49.0752 \text{ MLD}$$

(iv) Buston's formula,

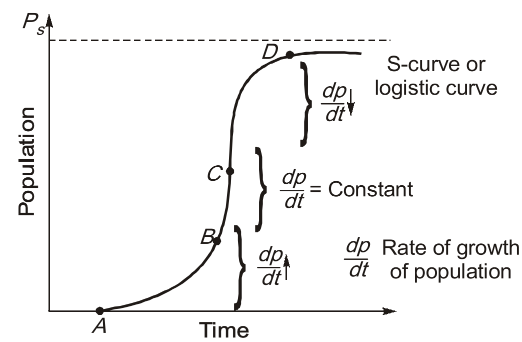
$$Q = 5663\sqrt{P} = 5663\sqrt{200}$$
$$= 80086.91 \text{ litres per minute} = 115.33 \text{ MLD}$$

Q.5 Explain any three methods of estimating the future population of a city. What are their relative merits?

Solution:

Population forecasting: General population growth curve with respect to time is given by following method:

1. **Arithmetic increase method:** In this method rate of growth of population is assumed to be constant i.e. for region BC. for which $\frac{dp}{dt}$ = Constant, i.e., population increases by same amount in a given time duration.



2. **Geometric increase method (compound/uniform increase method):** In this method rate of growth of population is assumed constant but population is compounded for this given rate to compute population in future.
3. **Incremental increase method:** In this method, rate of growth of population is not assumed to be constant. Rate of growth of population may increase or decrease. In this method average incremental increase in increase of population is also considered.
4. **Merits of different forecasting methods:**
   (a) Population forecasted by geometric increase method is maximum in comparison to that computed by arithmetic or increment increase method.
   (b) Population forecasted with arithmetic increase method is minimum in comparison to geometric increase method and incremental increase method.
   (c) Geometric increase method is generally recommended for young cities and arithmetic increase method for old ones.

Q.6 Compute the population of the year 2000 and 2006 for a city whose population in the year 1930 was 25000 and in year 1970 was 47000. Make use of geometric increase method.

Solution:

The growth rate can be computed by,

$$r = \sqrt[n]{\frac{P_2}{P_1}} - 1 = \sqrt[4]{\frac{47000}{25000}} - 1 = 0.17095 = 17.095\% \text{ per decade}$$

Now, using
$$P_n = P_o\left(1 + \frac{r}{100}\right)^n, \text{ we have}$$

$$P_{2000} = P_3 \text{ (i.e., after 3 decades from 1970 onwards)}$$

$$= P_{1970}\left(1 + \frac{r}{100}\right)^3 = 47000(1 + 0.17095)^3 = 75459$$

and
$$P_{2006} = P_{3.6}$$
$$= P_{1970}(1 + 0.17095)^{3.6} = 47000(1 + 0.17095)^{3.6} = 82954$$

Q.7 A city has following recorded population :

1951	50000
1971	110000
1991	160000

Estimate: (i) the saturation population, and (ii) expected population in 2011. (Use Logistic Curve Method)

Solution:

Given data: n = 20 years, P_0 = 50000, P_1 = 110000, P_2 = 160000

$$\text{Saturation population, } P_S = \frac{2P_0P_1P_2 - P_1^2(P_0+P_2)}{P_0P_2 - P_1^2}$$

$$\Rightarrow \quad P_S = \frac{2\times 50000\times 110000\times 160000 - (110000)^2(50000+160000)}{50000\times 160000 - (110000)^2}$$

$$\simeq 190488$$

$$P_t = \frac{P_s}{1+\left(\frac{P_s-P_o}{P_o}\right)e^{(-kP_st)}} = \frac{P_s}{1+\left(\frac{P_s-P_o}{P_o}\right)e^{nt}}$$

(where $n = -kP_s$)

$$n = \frac{1}{t_1}\ln\left[\frac{P_o(P_s-P_1)}{P_1(P_s-P_o)}\right] = \frac{1}{20}\ln\left[\frac{50000(190488-110000)}{11000(190488-50000)}\right] = -0.0673$$

$$\therefore \quad P = \frac{190488}{1+2.80976\times e^{-0.0673\times 60}} = 181496$$

Q.8 In a town, it has been decided to provide 200 litres per head per day in the 21st century. Estimate the domestic water requirements of this town in the year AD 2000 by projecting the population of the town by incremental increase method:

Year	1940	1950	1960	1970	1980
Population	2,37,98,624	4,69,78,325	5,47,86,437	6,34,67,823	6,90,77,421

Solution:

Thy given population data is analysed, as shown in table below:

Year (1)	Population (2)	Increase in population (3)	Increment over the increase, i.e. incremental increase (4)
1940	2,3798,624		
1950	4,69,78,325	2,31,79,701	(–) 1,53,71,589
1960	5.4786,437	78,08,112	(+) 8,73,274
1970	6,34,67,823	86,81386	(–) 30,71,788
1980	6,90,77,421	5609,598	
Total		4,52,78,797	(–) 1,75,70,103
Average per decade		$\bar{x}$ = 1,13,19,699	$\bar{y} = (-)\frac{1,75,70,103}{3}$ = (–) 58,56,701

Expected population at the end of year 2000 (i.e. after 2 decades from 1980)

$$= P_2 = P_0 + 2.\bar{x} + \frac{2 \times 3}{2}.\bar{y}$$

$$= 6,90,77,421 + 2(1, 13,19,699) - 3(58,56,701) = 7,41,46,716$$

∴ Water requirement in AD 2,000 @ 200 *l*/head/d

$$= \frac{200 \times 7,41,46,716}{10^6} \text{M}l\text{/day} = 14,829 \text{ MLD}$$

Q.9 What do you mean by the term per Capita Demand? How is it estimated? The population of a locality as obtained from census record is as follows:

Year	1970	1980	1990	2000	2010
Population	15000	20000	24500	29500	32500

Estimate the population of the locality in 2040 by Arithmetic increase, geometric increase, incremental increase and rate of decrease of methods.

Solution:

Per capita demand is the annual average amount of daily water required by one person and includes the domestic use, industrial use and commercial use, public use, water thefts etc.

It is estimated as,

$$\text{Per capital demand (in } l\text{/c/d)} = \frac{\text{Total yearly water requirement of city}}{365 \times \text{Design population}}$$

Arithmetic increase method: $P_n = P_0 + n \cdot \bar{x}$

$$\bar{x} = 4.375 = \frac{P_{1970} + P_{1980} + P_{1990} + P_{2000} + P_{2010}}{5}$$

$$P_{2040} = P_{2010} + 3 \cdot \bar{x}$$

∴ $P_{2040} = [32.5 + 3 \times 4.375] \times 10^3 = 45625$

Year	Population (in 10^3)	Increase in Pop. (in 10^3)	Growth rate	Incremental Increase	% Decrease in growth rate
1970	15			–	–
1980	20	5	$\frac{5}{15} \times 100 = 33.3\%$	–	–
1990	24.5	4.5	22.5%	–0.5	10.8%
2000	29.5	5	20.41%	0.5	2.09%
2010	32.5	3	10.17%	–2	10.24%
		$\bar{x} = 4.375$	$r = \sqrt[4]{33.3 \times 22.5 \times 20.41 \times 10.17}$	$\bar{y} = -0.6667$	$r' = 7.71\%$

Geometric increase method: $r = (33.3 \times 22.5 \times 20.41 \times 10.17)^{1/4} = 19.86\%$

$$P_n = P_0\left(1 + \frac{r}{100}\right)^n$$

or, $$P_{2040} = P_{2010}\left(1+\frac{19.86}{100}\right)^3$$

or, $$P_{2040} = 32.5\times 10^3\,(1+0.1986)^3$$

∴ $$= 55963.67 \simeq 55964$$

Incremental increase method: $$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}\cdot\bar{y}$$

$$P_{2040} = P_{2010} + 3\bar{x} + \frac{3\times 4}{2}\times\bar{y}$$

$$= \{32.5 + 3\times 4.375 + 6\times(-0.6667)\}\times 10^3$$

∴ $$P_{2040} = 41624.8 \simeq 41625$$

Rate of decrease method: $$P_1 = P_0 + \left(\frac{r_0 - r'}{100}\right)\times P_0$$

$$P_{2020} = P_{2010} + \frac{(10.17-7.71)}{100}\times P_{2010} = 33299.5$$

$$P_{2030} = P_{2020} + \frac{(10.17-2\times 7.71)}{100}\times P_{2020} = 31551.28$$

$$P_{2040} = P_{2030} + \frac{(10.17-3\times 7.71)}{100}\times P_{2030} = 27462.23 \simeq 27463$$

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ENGINEERING HYDROLOGY

CONVENTIONAL PRACTICE SETS

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1 CHAPTER

Introduction

Q.1 The average surface area of a reservoir in the month of June is 20 km^2. In the same month, the average rate of inflow is 10 m^3/s, outflow rate is 15 m^3/s, monthly rainfall is 10 cm, monthly seepage loss is 1.8 cm and the storage change is 16 million m^3. What is the evaporation (in cm) in that month?

Solution:

Let 'x' cm evaporation takes place in month of June.

$$\text{Total inflow} = I + P$$

$$= \left(\frac{10 \times 30 \times 24 \times 60 \times 60}{20 \times 10^6} \times 100\right) + 10 = 139.6 \text{ cm}$$

$$\text{Total outflow} = Q + S + E$$

$$= \left(\frac{15 \times 30 \times 24 \times 60 \times 60}{20 \times 10^6} \times 100\right) + 1.8 + x = 196.2 + x \text{ cm}$$

As total outflow is more than total inflow, therefore depression in storage takes place.

Depression in storage

$$= -\frac{16 \times 10^6}{20 \times 10^6} \times 100 = -80 \text{ cm}$$

$$\Rightarrow \quad 139.6 - (196.2 + x) = -80$$

$$-x = -80 + 56.6$$

$$\therefore \quad x = 23.4 \text{ cm}$$

Q.2 A catchment area of 140 km^2 received 120 cm of rainfall in a year. At the outlet of the catchment the flow in the stream draining the catchment was found to have an average rate of 2.0 m^3/s for 3 months, 3.0 m^3/s for 6 months and 5.0 m^3/s for 3 months. (i) What is the runoff coefficient of the catchment? (ii) If the afforestation of the catchment reduces the runoff coefficient to 0.50, what is the increase in the abstraction from precipitation due to infiltration, evaporation and transpiration, for the same annual rainfall of 120 cm?

Solution:

(i) $$P = \frac{120}{100} \times 140 \times 10^6 = 168 \text{ Mm}^3$$

$$R = [2 \times 3 + 3 \times 6 + 5 \times 3] \times 30 \times 24 \times 3600$$

$$= 101.088 \text{ Mm}^3$$

$\therefore$ Runoff coefficient, $$k = \frac{R}{P} = \frac{101.088}{168} = 0.6017$$

(ii) Increase in abstraction $= (0.6017 - 0.5) \times 168 = 17.09$ Mm^3

Q.3 What is hydrological cycle? How does it keep balance between water of earth and moisture in the atmosphere? What is the importance of hydrological cycle?

Solution:

Hydrological cycle is the cyclic movement of water from oceans to atmosphere , from atmosphere to land and from land back to the oceans.

It contains basic continuous processes listed below:

(i) Evaporation

(ii) Precipitation

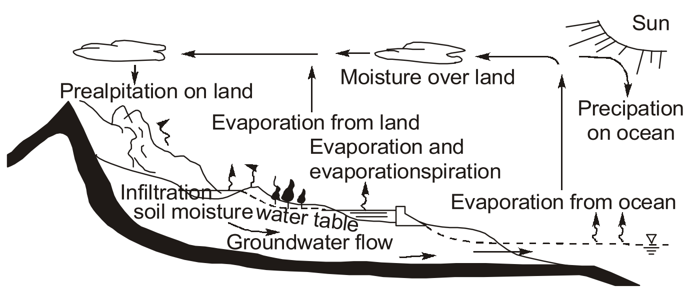
(iii) Runoff

Process of hydrological cycle starts with oceans. Water in oceans, gets evaporated due to heat energy provided by solar radiation and forms water vapour. This water vapour moves upwards to higher altitudes forming clouds. Most of the clouds condense and precipitate in any form like rain, hail, snow, sleet. And a part of clouds is driven to land by winds.

Precipitation, while falling to the ground, some part of it evaporates back to atmosphere. Portion of water that reaches the ground, enters the earth's surface infiltrating various strata of soil and enhancing the moisture content as well as water table. Vegetation sends a portion of water from earth's surface back to atmosphere through the process of transpiration. Once water percolates and infiltrates the earth's surface, runoff is formed over the land, flowing through the contours of land heading towards river and lakes and finally joins into oceans after many years. Some amount of water is retained as depression storage.

Further again the process of this hydrological cycle continues by blowing of cool air over ocean, carrying water molecules, forming into water vapour then clouds getting condensed and precipitates as rainfall. Similarly, then water gets percolated into soil, increasing water table then formation of runoff waters heading towards water bodies. Thus the cyclic process continues.

Thus hydrological cycle helps in providing freshwater in terms of rainfall, recharge groundwater, maintain appropriate moisture in the atmosphere keeping the balance between water of ocean, atmosphere and land and maintaining circulation of water in biosphere.



Q.4 A river reach had a flood wave passing through it. At a given instant, the storage of water in the reach was estimated as 15.5 ha.m. What would be the storage in the reach after an interval of 3 hours if the average inflow and outflow during the time period are 14.2 m^3/s and 10.6 m^3/s respectively.

Solution:

Given data:

$$\Delta S = 15.5 \times 10^4 \text{ m}^3$$

$$\text{Inflow} = 14.2 \times 60 \times 60 \times 3 = 153360 \text{ m}^3$$

$$\text{Outflow} = 10.6 \times 3600 \times 3 = 114480 \text{ m}^3$$

$$\Delta S' = 155000 + (153360 - 114480) = 193880 \text{ m}^3 = 19.388 \text{ ha.m}$$

Q.5 A catchment has four sub-areas. The annual precipitation and evaporation from each of the sub-areas are given in table below:

Assume that there is no change in the groundwater storage on an annual basis. Calculate for the whole catchment the values of annual average (i) precipitation, and (ii) evaporation. What are the annual runoff coefficients for the sub-areas and for the total catchment taken as a whole?

Sub-area	Area (Mm^2)	Annual precipitation (mm)	Annual evaporation (mm)
A	10.7	1030	530
B	3.0	830	438
C	8.2	900	430
D	17.0	1300	600

Solution:

(i) Average annual precipitation $= \dfrac{(10.7\times1030+3\times830+8.2\times900+17\times1300)}{(10.7+3+8.2+17)} = 1105.167$ mm

(ii) Average annual evaporation $= \dfrac{(10.7\times530+3\times438+8.2\times430+17\times600)}{(10.7+3+8.2+17)} = 532.416$ mm

Runoff coefficient $k_A = \dfrac{1030-530}{1030} = 0.485$

$$k_B = \frac{830-438}{830} = 0.472$$

$$k_C = \frac{900-430}{900} = 0.52$$

$$k_D = \frac{1300-600}{1300} = 0.538$$

For whole catchment average runoff coefficient

$$= \frac{1105.167-532.416}{1105.167} = 0.518$$

Q.6 A catchment area of 140 km^2 received 120 cm of rainfall in a year. At the outlet of the catchment, the flow in the stream draining the catchment was found to have an average rate of (i) 1.5 m^3/s for the first 3 month, (ii) 2.0 m^3/s for 6 months and (iii) 3.5 m^3/s for the remaining 3 months. (a) What is the runoff coefficient of the catchment? (ii) If the afforestation of the catchment reduces the runoff coefficient to 0.35, what is the increase in the abstraction from precipitation due to infiltration, evaporation and transpiration for the same annual rainfall of 120 cm?

Solution:

(i) Before afforestation

Given data: Consider a period $= \Delta t = 1$ year

Input volume to the catchment through precipitation,

$$V_i = 140\times10^6\times\left(\frac{120}{100}\right) = 168\ Mm^3$$

Runoff = Output volume = $V_o = (1.5\times3)+(2\times6)+(3.5\times3)$

$= 27\ Mm^3$ month

$$= 27\left(\frac{365}{12}\right)\times24\times60\times60 = 70.956\times10^6\ m^3 = 70.956\ Mm^3$$

Runoff coefficient $= \dfrac{70.956}{168.0} = 0.4224$

Abstraction volume = 168.0 – 70.956 = 97.044 Mm^3

(ii) After Afforestation

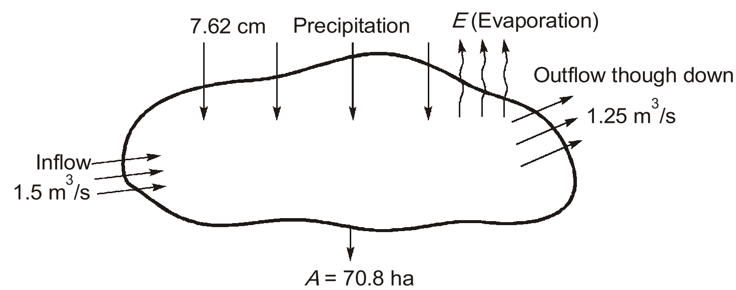
Runoff = 0.35 × 168 = 58.8 Mm^3

New abstraction volume = 168.0 – 58.8 = 109.2 Mm^3

Increase in abstraction = 109.20 – 97.044 = 12.156 Mm^3

Q.7 For a lake of 70.8 ha surface area, the inflow was 1.5 m^3/s in certain 30 day month. The dam on lake regulates the outflow (discharge) from the lake to 1.25 m^3/s in that month. If the recorded precipitation in that month was 7.62 cm and storage volume increased by an estimated 6,50,000 m^3. What is the estimated evaporation in m^3 and cm.? Assume no water infiltrates out of bottom (and sides) of that lake.

Solution:



$$\Delta S = +6{,}50{,}000 \text{ m}^3$$

the problem finds its solution in water budget equation,

$$\Sigma I\Delta t - \Sigma Q\Delta t = \Delta s$$

Here Δt = 1 month or 30 days

Input (+) → Inflow (I), → Precipitation (P)

Out (–) → Outflow/discharge (Q), → evaporation (E)

$$P + I - Q - E = \Delta S$$

$$P = (+)\frac{7.62}{100} \times 70.8 \times 10^4 = \mathbf{5.394 \times 10^4 \text{ m}^3}$$

$$I = (+)\ 1.5 \times 86400 \times 30 = 38{,}88{,}000 \text{ m}^3$$

$$Q = (-)\ 1.25 \times 86400 \times 30 = 32{,}40{,}000 \text{ m}^3$$

$$\Delta S = (+)\ 6{,}50{,}000 \text{ m}^3$$

$$E = (-)?$$

Putting all in equation of water budget,

$$5.394 \times 10^4 + 388.8 \times 10^4 - 324 \times 10^4 - E = 65 \times 10^4$$

$$\therefore \quad E = 5.194 \times 10^4 \text{ m}^3$$

In terms of depth,

$$E = \frac{5.194 \times 10^4}{70.8 \times 10^4} \times 100 \text{ (in cm)} = \mathbf{7.336 \text{ cm}}$$

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