Concepts and Applications in Agricultural Engineering

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International Book Distributing Co.
(Publishing Division)

Published by

INTERNATIONAL BOOK DISTRIBUTING CO.
(Publishing Division)
Khushnuma Complex Basement
7, Meerabai Marg (Behind Jawahar Bhawan)
Lucknow 226 001 U.P. (INDIA)
Tel. : 91-522-2209542, 2209543, 2209544, 2209545
Fax : 0522-4045308
E-Mail : ibdco@airtelbroadband.in

First Edition 2007

ISBN 978-81-8189-139-6

Composed & Designed at :
Panacea Computers
3rd Floor, Agrawal Sabha Bhawan
Subhash Mohal, Sadar Cantt. Lucknow-226 002
Phone : 3127082, 2480875
E-mail : prasgupt@rediffmail.com

Printed at:
Salasar Imaging Systems
C-7/5, Lawrence Road Industrial Area
Delhi - 110 035
Tel. : 011-27185653, 9810064311

To

the students of

Agricultural Engineering

-N.B. Dash

-M.K Mohanty

Preface

In the branch of Agricultural Engineering, there is a need for a book exclusively dealing with various concepts and their applications in a crystal clear manner. So, an effort has been made to prepare this book entitled "Concepts and Applications in Agricultural Engineering, Volume-I" to meet the demand of students, teachers, research scholars in Agricultural Engineering education.

The book will be useful immensely to the students preparing for GATE examination in Agricultural Engineering to carry out their postgraduate study at IITs and other Agricultural Engineering Institutes. The book will also be helpful to the aspirants competing for JRF, ARS, SRF and IFS examinations in the branch of Agricultural Engineering and also serve the purpose of reference book.

The book broadly consists of two parts - concepts and applications. In the first part of concepts, the chapters of three major disciplines of Agricultural Engineering having critical and confusing concepts are analyzed innovatively. In the second part of application, it has been tried to present the solution of 17 years of GATE questions in Agricultural Engineering. This application part will also fulfill one of the perpetual needs of the student community to have a book extensively dealing with solved examples in Agricultural Engineering. In this section, readers will find applications of various concepts, discussed in this book and use of many other new concepts to solve numerous problems.

No attempt has been made to make this volume bulky; rather the portion of the book dealing with conceptual analysis includes only those concepts, which are confusing and difficult to understand. It is expected that the theoretical analysis of this book will sharpen the ingenious power of the readers and help them to solve problems quickly. Moreover, many problems are solved in different ways, which will help the readers in understanding and applying the concepts properly. Overall, this book is designed not only to make the readers able to grasp the concepts easily but also to solve the problems quickly and effectively.

Attractions

- Analysis of only confusing concepts and critical theories
- Solution to 17 years of GATE questions
- Innovative analysis and unique style of representation

Although utmost care has been taken to make the present volume free of error, still there may be some kind of errors in this book. Therefore, we will sincerely acknowledge if the readers will send suggestions to improve this first volume. Finally, we envisage this attempt as an important step in removing hurdles in the path of popularization of Agricultural Engineering. We hope that it will fire imaginations and ability of many Agricultural Engineers in the profession to produce such innovative works in future.

19th April, 2006

Mr. Nikunja Bihari Dash
Dr. Mahendra Kumar Mohanty

Acknowledgement

We are thankful to Prof. D. K. Das, Prof. S. C. Pradhan, and Dr. N. Mohapatra of College of Agricultural Engineering and Technology, O.U.A.T, Bhubaneswar for their initial help and encouragement during preparation of the manuscript for this book. We are also thankful to Dr. S.N.Mohanty, Dean, C.A.E.T for his help and suggestion in timely preparation of the manuscript.

We express our indebtedness to Prof B.C. Mal, Prof. S. N. Panda, Prof. A. K. Datta and Dr. H. Raheman of Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur for their valuable suggestions to improve the quality of the book.

Mr. Nikunja Bihari Dash is especially thankful to his seniors Subrat Kumar Mohanty, Mrutyunjay Padhiary, Santosh K. Prusty, Jatindra Kumar Sahu and Sridhar Patra for their valuable suggestions to improve the book. Mr. Dash is also thankful to his friends Murali Mohan Bebbartta, Kumar Ashis, Akhyaya Kumar Tripathy, Uddeeptabh Mishra, Sujit Kumar Mongaraj, Ajay Kumar Roul, Sitesh kumar Parida, Jayadeep Kumar Sethy and many others for their direct as well as indirect help and support during preparation of the manuscript for this book. Our heartfelt appreciation is also due to Ashok, Saswat and Manas and students of C.A.E.T for their help and encouragement in editing the book.

We are also thankful to many others whose seen and unseen contribution played a role in bringing this book to its present shape. Finally, we are grateful to Almighty God without whose grace this book would have been only a distant dream.

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PART 1
CONCEPTS

Chapter 1

Soil and Water Conservation Engineering

1.1 Bunding

Broadly, the bunds can be categorised in 2 types (1) contour bund (2) graded bund. When the bunds are constructed along (on) the contour, they are known as *counter bunds* and when a grade (slope) is provided to the bunds in addition to their natural land slope they are known as *graded bunds*.

Contour bund design

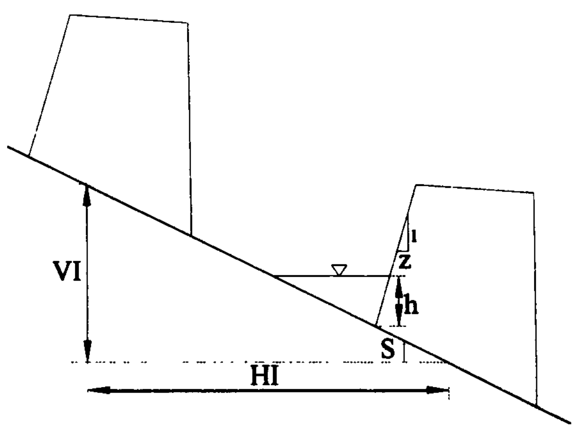

Fig.1.1 Contour bund

$$R_V = [A] \times P_e = [HI \times L_B] \times P_e \tag{1.1.1}$$

$$S_V = [A_w] \times L_B = \left[\frac{h^2}{2}(Z + \frac{100}{S})\right] \times L_B \tag{1.1.2}$$

$$R_e = R_V - S_V \tag{1.1.3}$$

Notations

R_V = run off volume of water, m^3

S_V = storage volume of water behind the bund, m^3

R_e = excess run off to be disposed , m^3

A = area of watershed between two bunds, m^2

P_e = excess rainfall, also known as *run off*, *m*

HI = horizontal interval between two bunds, *m*

L_B = length of the bund behind which water is stored, *m*

A_w = cross-sectional area of water behind the bund, m^2

= storage area required for water behind the bund

h = depth of water stored behind the bund, *m*

Z = side slope of the bund i.e. H: V

S = land slope, *percentage*

Note

- HI can be calculated from the following formula

$$\frac{VI}{HI} = \frac{S}{100} \tag{1.1.4}$$

- P_e can be calculated from either of the following 2 formulae

$$P_e = P - f \tag{1.1.5}$$

$$P_e = P \times c \tag{1.1.6}$$

Notations

VI = vertical interval between two bunds, *m*

HI= horizontal interval between two bunds, *m*

P = rainfall

f = infiltration

c = runoff coefficient

Calculation for depth of water stored, h

Case 1: When side slope (Z) is not neglected

Runoff volume of water to be stored = Storage volume of water behind the bund

$$\Rightarrow HI \times L_B \times P_e = \frac{h^2}{2}\left(Z + \frac{100}{s}\right) \times L_B$$

$$\Rightarrow h = \sqrt{\frac{2HI(P_e)}{\left(Z + \frac{100}{S}\right)}} \tag{1.1.7}$$

Note :

- HI, P_e, h are in meter

Case 2: When side slope (z) is neglected

$$h = \sqrt{2 \times VI \times P_e} \qquad (1.1.8)$$

Dimensions of contour bund

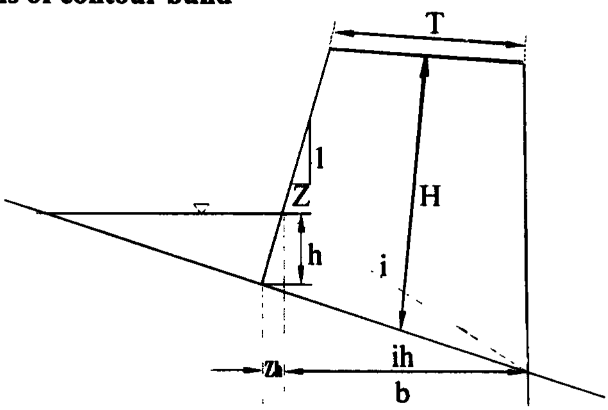

Fig.1.2 Dimensions of contour bund

- Total height of bund, H = h + depth of flow over weir + free board
- Base width of bund, b = h (Z + i),
  where i = slope of seepage line (phreatic line)
- Top width of bund, T = b -2ZH
- Cross sectional area of bund, A_B= (b+T) H/2
- Volume of earthwork, $V_B = A_B$ x L_B

Quantity Required	Contour bunding (Main Bund)	Bunding (Total bund)
Length / ha	10,000 / HI	(10,000 / HI) x 1.3
Earthwork / ha (m^3)	Length / ha x (b+T) H/2	Length / ha x (b+T) H/2
Area lost / ha	Length / ha x b	Length / ha x b

Note:

- In case of bunding the factor 1.3 counts for side bund and lateral bund in addition to the main counter bund

- Area lost (%) = area not available for cultivation (%)

$$= \frac{area\ lost}{original\ area} \times 100 = \frac{L \times b}{L \times HI} \times 100 = \frac{b}{HI} \times 100 \qquad (1.1.9)$$

- Area lost/ha = Area lost (%) x 100

1.2 Terracing

Bench Terracing

D = vertical drop, also known as *vertical interval*, VI
D/2 = depth of cut
W = width of terrace
W/2 = width of cut
S = land slope (%)

(a) Vertical cut

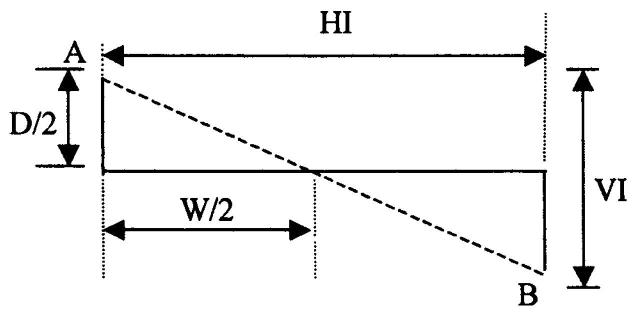

Fig.1.3 Vertical cut for bench terracing

(i) $$\frac{D/2}{W/2} = \frac{S}{100} \qquad (1.2.1)$$

(ii) Length/ha = $$\frac{10{,}000}{HI} \qquad (1.2.2)$$

Total length = Length / ha x Area

Methods to calculate HI

(a) HI = W

(b) $$\frac{VI}{HI} = \frac{S}{100}$$

(iii) Earthwork / ha (m^3) = $$\frac{1}{8} WD \times length / ha \qquad (1.2.3)$$

(iv) Percentage area lost $= \dfrac{AB - W}{AB} \times 100$

$$= \frac{\sqrt{D^2 + W^2} - W}{\sqrt{D^2 + W^2}} \times 100 \qquad (1.2.4)$$

Note

- Area lost (%) = area not available for cultivation (%)

$$= \frac{area\,lost}{original\,area} \times 100 = \frac{width\,lost}{original\,width} \times 100$$

$$= \frac{original\,width - width\,available}{original\,width} \times 100$$

(b) Batter (riser) slope of 1:1 (H: V)

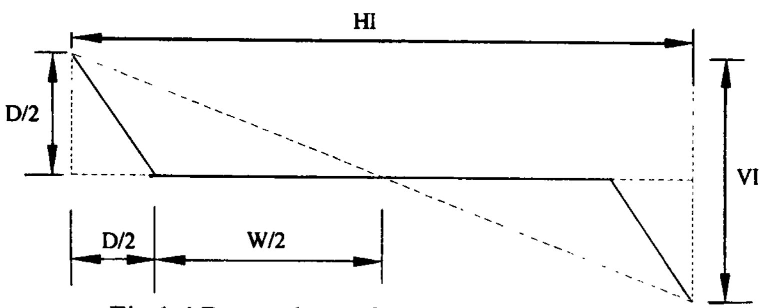

Fig.1.4 Batter slope of 1:1 for bench terracing

(i) $$\frac{D/2}{D/2 + W/2} = \frac{S}{100} \qquad (1.2.5)$$

(ii) Length/ha $= \dfrac{10{,}000}{HI}$ (1.2.6)

Methods to calculate HI

(a) HI = W + D

(b) $\dfrac{VI}{HI} = \dfrac{S}{100}$

(i) Earthwork/ha (m^3) $= \dfrac{1}{8} WD \times Length\,/\,ha$ (1.2.7)

(ii) Percentage area lost $= \dfrac{S+200}{\dfrac{200}{S}+\dfrac{S}{100}}$ (1.2.8)

(c) Batter (riser) slope of 1/2:1 (H: V)

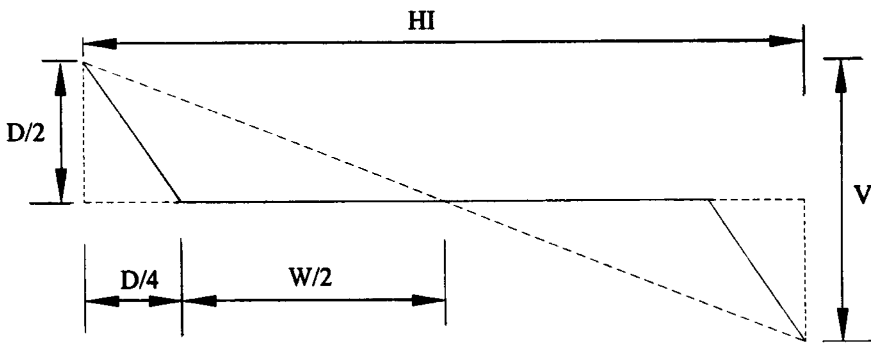

Fig.1.5 Batter slope of 1/2:1 for bench terracing

(i) $\dfrac{D/2}{D/4+W/2}=\dfrac{S}{100}$ (1.2.9)

(ii) Length / ha $= \dfrac{10{,}000}{HI}$ (1.2.10)

Total length = Length / ha x Area

Methods to calculate HI

(a) HI = W + D/2

(b) $\dfrac{VI}{HI}=\dfrac{S}{100}$

(iii) Earthwork/ha (m^3) $= \dfrac{1}{8}WD \times Length/ha$ (1.2.11)

(iv) Percentage area lost $= \dfrac{S+100}{\dfrac{200}{S}+\dfrac{S}{100}}$ (1.2.12)

1.3 Water Requirement of Crops

Net irrigation requirement

Water depth needed to bring the soil moisture upto field capacity is known as *net irrigation requirement* or *field moisture deficiency* or *soil moisture deficiency of the field.*

Methods to calculate net irrigation requirement
Method 1

$$d = \frac{(m_{fc} - m_{bi})}{100} \times \rho_d \times D \qquad (1.3.1)$$

$$= \frac{M_{fc} - M_{bi}}{100} \times D \qquad (1.3.2)$$

Notations
d = net irrigation requirement, *cm*
m_{fc} = moisture content at field capacity; *%, db*
m_{bi} = moisture content before irrigation; *%, db*
M_{fc} = moisture content at field capacity; *%, vb*
M_{bi} = moisture content before irrigation; *%, vb*
D = depth of root zone, *m*
$\rho_d = M_d / V =$ dry bulk density of soil, also known as *apparent specific gravity of soil, gm/cm^3*

Note:
- db → dry weight basis
- vb → volume basis

Method 2

$d = d_{fc} - d_{bi}$ (1.3.3)

where

d_{fc} (cm) = AMHC x D (cm) (1.3.4)

AMHC= M_{fc} (%, vb)

$= m_{fc}$ (%, db) x $\rho_d (gm/cm^3)$ (1.3.5)

= WHC (%, db) x $\rho_d (gm/cm^3)$

Notations
d_{fc} = depth of water in root zone at field capacity (cm)
d_{bi} = depth of water in root zone before irrigation (cm)
AMHC = apparent moisture holding capacity
WHC = water holding capacity

Water requirement of crops

WR = ET + AL+ SN (1.3.6)

WR = IR + ER + S (1.3.7)

Notations

WR = water requirement of crops

ET = evapotranspiration requirement of crops

AL = application loss of water

SN = special needs of water eg. percolation need for leaching etc.

IR = irrigation requirement of crops

ER = effective rainfall

S = surface profile contribution

From equation (1.3.6) and (1.3.7)

IR = WR – ER – S

= (ET +AL + SN) – ER – S

= (ET – ER – S) + SN + AL (1.3.8)

= CIR + SN + AL (1.3.9)

= NIR + AL (1.3.10)

$$\therefore IR = \frac{NIR}{E_a} = \frac{d}{E_a} = IR\ (at\ field) = FIR$$

$$\text{IR (at source)} = \frac{FIR}{E_c} \qquad (1.3.11)$$

From equations (1.3.8) and (1.3.9)

CIR = ET – ER – S (1.3.12)

From equations (1.3.8) and (1.3.10)

NIR = ET + SN – ER – S (1.3.13)

Notations

CIR = consumptive irrigation requirement

NIR = net irrigation requirement

FIR = field irrigation requirement

E_a = water application efficiency

E_c = water conveyance efficiency

Note:

- Irrigation requirement, IR, is otherwise known as *gross irrigation requirement* or simply as *GIR*

1.4 Rainfall and Infiltration Analysis

Rainfall excess, P_e

Rainfall excess = rainfall – interception – depression storage – infiltration.

Note:

- Interception loss and depression storage both combinedly known as *initial basin loss*. Initial basin loss is otherwise known as *initial basin recharge* or *basin loss* or simply as *initial loss*. Most of times, interception loss and depression storage are considered negligible. So **rainfall excess = rainfall – infiltration.**
- Interception loss, depression storage and infiltration loss are combinedly known as *potential infiltration*

Analytically, Rainfall excess (m) = $\dfrac{area\ of\ DRH\ (m^3)}{area\ of\ catchment\ (m^2)}$

$$\begin{aligned}\text{Area of DRH } (m^3) &= \sum Direct \text{ runoff volume } (m^3)\\ &= \sum DRH \text{ ordinates } (m^3/s) \times \text{time interval } (s)\\ &= \sum Direct \text{ runoff } (m^3/s) \times \text{time interval } (s)\\ &= \sum (Runoff - Baseflow) \times \text{ time interval } (s)\end{aligned}$$

Notations

DRH = direct runoff hydrograph

Note:

- Direct runoff depth is also known as *effective rainfall* or *rainfall excess* or *supra rainfall*

Infiltration capacity

The maximum rate at which a soil is capable of absorbing water is known as *infiltration capacity.*

Infiltration rate

The actual rate at which water enters a particular soil mass is known as *infiltration rate.*

Infiltration Indices

(1) W_{index}

$$W_{index} = \frac{\sum P - \sum R}{\sum t} = \frac{\sum (I.t) - \sum R}{\sum t} \tag{1.4.1}$$

Notations

$\sum P = total$ rainfall = summation of the individual rainfalls

$\sum R = \sum direct$ runoff = total direct runoff

$= \sum excess$ rainfall = effective rainfall

$\sum t$ = total time of rainfall

t = individual time of rainfall

I = individual rainfall intensity

$= \dfrac{individual\ rainfall\ increment}{individual\ time\ increment}$

Note:

- Direct runoff (surface runoff) and runoff are 2 different concepts
- Runoff = Direct runoff + Base flow (Groundwater inflow)

(2) $\varnothing_{index}$

$$\phi_{index} = \frac{\sum P_e - \sum R}{\sum t_e} = \frac{\sum (I_e t_e) - \sum R}{\sum t_e} \qquad (1.4.2)$$

Notations

$\sum P_e = \sum$ Rainfall for periods where I > ϕ_{index}

I_e = Individual rainfall intensity for periods where I > ϕ_{index}

t_e = Individual time period of rainfall where I > ϕ_{index}

If I > ϕ_{index}, then $\sum t_e$ = total time of excess rainfall.

Steps for calculation of ϕ_{index}

Step 1: calculate W_{index} by using the equation (1.4.1)

Step 2: calculate individual rainfall intensity, I

Step 3: If all I > W_{index} then $\phi_{index} = W_{index}$

Step 4: otherwise calculate P_e by using I_e and t_e

Step 5: calculate ϕ_{index} by using the equation (1.4.2)

1.5 Fundamentals of Soil Mechanics

Fundamental relations

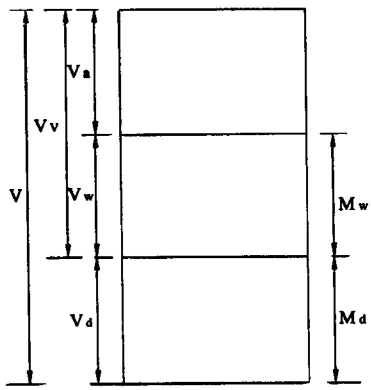

Fig. 1.6 Cross-section of a soil mass showing fundamental relations

$V = V_v + V_d = (V_w + V_a) + V_d$ (1.5.1)
$M = M_w + M_d$ (1.5.2)

Notations
V = total volume of the soil mass
V_v = volume of voids in the soil mass
V_w = volume of water in the soil mass
V_d = volume of solid particles in the soil mass
V_a = volume of air in the soil mass
M = total mass of the soil or wet mass of the soil mass
M_w = mass of water in the soil mass
M_d = mass of solid particles in the soil mass

$$w = \frac{M_w}{M_d} \tag{1.5.3}$$

Water content, w, is also known as *moisture content* or *gravimetric water content* or *mass wetness.*

Wet bulk density, ρ

Wet bulk density is also known as *wet density* or *moist density* or *soil density* or *apparent specific gravity for moist soil* or simply known as *bulk density.*

$$\rho = \frac{M}{V} = \frac{total\ mass\ of\ soil\ mass}{total\ volume\ of\ soil\ mass} \tag{1.5.4}$$

Dry bulk density, ρ_d

Dry bulk density is also known as *dry density* or *apparent specific gravity for dry soil.*

$$\rho_d = \frac{M_d}{V} = \frac{mass\ of\ solid\ particle}{total\ volume\ of\ soil\ mass} \tag{1.5.5}$$

Thus, dry bulk density accounts for void space *between* the particles and internal pores (air) *within* solid particles are not taken into account.

Note:

- Dry bulk density, ρ_d, and apparent specific gravity, G_m, are often used synonymously.

Solid density, ρ_S

Solid density is also known as *particle density* or *true density* or *real density* or *absolute density.*

$$\rho_s = \frac{M_d}{V_d} = \frac{mass\ of\ solid\ particles}{volume\ \ of\ solid\ particles} \tag{1.5.6}$$

Thus, solid density accounts for presence of internal pores (air) within solid particles, unlike dry bulk density.

Specific gravity, G

Concepts

- Specific gravity is known as *true specific gravity* or *absolute specific gravity* because it includes determination of volume of solid, V_d, and excludes determination of volume of voids, V_v
- As only volume of solid, V_d, is determined excluding volume of soil mass, V, specific gravity is also referred to as *specific gravity of soil solid.*
- It is also known as *relative density* because it represents ratio of solid density, ρ_s and water density, ρ_w

Methods for calculation of specific gravity

(1) CGS unit method

$$\text{Specific gravity} = \frac{solid\ density}{water\ density}$$

$$\text{i.e. } G = \frac{\rho_s}{\rho_w} = \frac{\rho_s}{1} = \rho_s = \frac{M_d}{V_d} \qquad (1.5.7)$$

Note:

- In CGS unit ρ_w (mass of water / volume of water) = 1

(2) SI unit method 1

$$\text{Specific gravity} = \frac{unit\ weight\ of\ soil\ solid}{unit\ weight\ of\ water}$$

$$\text{i.e. } G = \frac{\gamma_s}{\gamma_w} = \frac{\rho_s \times g}{\gamma_w} = \rho_s = \frac{M_d}{V_d} \qquad (1.5.8)$$

Note:

- In SI unit $g = \gamma_w = 9.81$

(3) SI unit method 2

$$G = \frac{\gamma_s}{\gamma_w} = (\frac{W_d}{V_d}) / \gamma_w \qquad (1.5.9)$$

Note

- W_d = weight of soil solid

(4) Water displacement method

$$G = \frac{mass\ of\ soil\ solid(M_d)}{volume\ of\ water\ displaced\ by\ it}$$

$$= \frac{mass\ of\ soil\ solid(M_d)}{mass\ of\ water\ displaced\ by\ it}$$

Note:

- $G\ (\text{of any gas}) = \dfrac{density\ of\ the\ gas}{density\ of\ air}$

$$= \frac{mass\ of\ the\ gas}{mass\ of\ air\ of\ equal\ volume}$$

- G (of any liquid) = $\dfrac{density\ of\ the\ liquid}{density\ of\ water}$

$$= \frac{mass\ of\ the\ liquid}{mass\ of\ water\ of\ equal\ volume}$$

Apparent Specific Gravity, G_m

Concepts

- When specific gravity is referred to that of soil mass as a whole, it is known as *apparent specific gravity.*
- Apparent specific gravity is also known as *mass specific gravity* or *bulk specific gravity* because it refers to specific gravity of soil mass or of bulk of soil.

Apparent specific gravity = $\dfrac{apparent\ density}{water\ density}$

Types

As there are 3 types of apparent densities for three types of soil eg. for dry soil, moist soil and saturated soil, hence there are 3 types of corresponding apparent specific gravities which can be determined as follows

Methods for determination of apparent specific gravity for dry soil

Method-1

$$G_{md} = \frac{\gamma_d}{\gamma_w} = \frac{(\frac{W_d}{V})}{\gamma_w} \qquad (1.5.10)$$

Notations

G_{md} = apparent specific gravity for dry soil

γ_d = dry unit weight

W_d = weight of soil solid

Method-2

$$G_{md} = \frac{\gamma_d}{\gamma_w} = \frac{(\frac{G}{1+e})\gamma_w}{\gamma_w} = \frac{G}{1+e} \qquad (1.5.11)$$

Methods for determination of apparent specific gravity for moist soil

Method 1

$$G_{mm} = \frac{\gamma}{\gamma_w} = \frac{\frac{W}{V}}{\gamma_w} \qquad (1.5.12)$$

Notations

G_{mm} = apparent specific gravity for moist soil

γ = bulk unit weight, also known as *moist unit weight*

W = total weight of soil mass

Method 2

$$G_{mm} = \frac{\gamma}{\gamma_w} = \frac{(\frac{G+es_r}{1+e})\gamma_w}{\gamma_w} = \frac{G+es_r}{1+e} \qquad (1.5.13)$$

Notations

e = void ratio of soil

S_r = degree of saturation

Methods for determination of apparent specific gravity for saturated soil

Method 1

$$G_{ms} = \frac{\gamma_{sat}}{\gamma_w} = (\frac{Wsat}{V}) / \gamma_w \qquad (1.5.14)$$

Notations

G_{ms} = apparent specific gravity for saturated soil

γ_{sat} = saturated unit weight of the soil mass

W_{sat} = saturated weight for the soil mass

Method 2

$$Gms = \frac{\gamma_{sat}}{\gamma_w} = \frac{(\frac{G+e}{1+e})\gamma_w}{\gamma_w} = \frac{G+e}{1+e} \qquad (1.5.15)$$

Note:

$$\gamma = (\frac{G+eS_r}{1+e})\gamma_w \qquad (1.5.16)$$

$$\gamma_d = (\frac{G}{1+e})\gamma_w, \quad S_r = 0 \qquad (1.5.17)$$

$$\gamma_{sat} = (\frac{G+e}{1+e})\gamma_w, S_r = 1 \qquad (1.5.18)$$

Void ratio, e

Void ratio is also known as *relative porosity.*

$$e = \frac{V_v}{V_d} \qquad (1.5.19)$$

Porosity, n

Porosity is variedly known as *void fraction* or *percentage void* or *percentage pore space* or *drainable porosity* or *interparticle porosity.*

$$n = 1 - \frac{\rho_d}{\rho_s} = 1 - \frac{M_d / V}{M_d / V_d} = 1 - \frac{V_d}{V} = \frac{V - V_d}{V} = \frac{V_v}{V} \qquad (1.5.20)$$

1.6 Groundwater Hydrology

Darcy's law

$$\frac{Q}{t} = q = AV = A(Ki) = AK(\frac{\Delta h}{\Delta L}) \qquad (1.6.1)$$

Notations

Q = total quantity of fluid flow in time t

q = discharge per unit time, also known as *rate of flow*

V = mean velocity of flow variedly known as *average velocity or apparent velocity* or *discharge velocity* or *superficial velocity* of flow

K = hydraulic conductivity, also known as *coefficient of permeability* or simply as *permeability*

i = hydraulic gradient

Δh = change in hydraulic head when fluid covers a distance of ΔL

Flow head, h

$$h = h_w + Z + \frac{V^2}{2g} \tag{1.6.2}$$

Notations

h = flow head also known as *hydraulic head* or *hydraulic potential*

$h_w = \frac{P}{\gamma_w}$ = piezometric head or *pressure head*

Z = position head, also known as *gravitational head* or *potential head* or *datum head* or *elevation head.*

$\frac{V^2}{2g}$ = velocity head or *kinetic head*

Note:

- Position head is taken as positive when considered upward from point of consideration and negative when considered downward from point of consideration
- Most of time velocity head is considered negligible

Porosity, n

Methods to calculate porosity

Method 1

$$n = \frac{V}{V_a} = \frac{Ki}{(\Delta L / \Delta t)} = \frac{K(\Delta h / \Delta L)}{(\Delta L / \Delta t)} \tag{1.6.3}$$

Notations

V_a = actual velocity, also known as *true velocity* or *seepage velocity* or *percolation velocity*

Δt = time taken by fluid to cover a distance of ΔL

Method 2

$AV = A_v V_a$

$$\Rightarrow \frac{V}{V_a} = \frac{A_v}{A} = n \tag{1.6.4}$$

Notations

A = total cross-sectional area through which fluid flows

A_v= area of void through which fluid flows

Method 3

$$n = \frac{V}{V_a} = \frac{Ki}{K_p i} = \frac{K}{K_p} \tag{1.6.5}$$

where, K_p = coefficient of percolation

Method 4

$$n = n_c + n_{nc} \tag{1.6.6}$$

where, $n_c = F\gamma_d$ (1.6.7)

Notations

n_c= capillary porosity
n_{nc} = non-capillary porosity
F = field capacity moisture content
γ_d = dry unit weight of soil

Method 5

$$n = S_y + S_r \tag{1.6.8}$$

where,

$$S_y = \frac{V_y}{V} \times 100 \tag{1.6.9}$$

$$S_r = \frac{V_r}{V} \times 100 \tag{1.6.10}$$

$$\therefore n = S_y + S_r = \frac{V_y}{V} + \frac{V_r}{V} = \frac{V_v}{V} \tag{1.6.11}$$

Notations

S_y = specific yield, also known as *effective porosity* or *drainable volume*
S_r = specific retention
V_y = volume of water an aquifer material will yield when drained by gravity
V = total volume of aquifer material.

1.7 Flow Through Pipe

Laminar flow through pipe

Laminar flow of liquid through pipe has the following characteristics:
(1) Reynold number, Re < 2100

(2) Coefficient of function, $f = \dfrac{16}{R_e}$

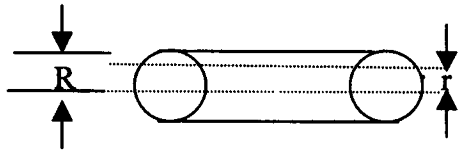

Fig. 1.7 Flow of liquid through pipe

$$V_r = \frac{\Delta P R^2}{4\mu L}\left(1 - \frac{r^2}{R^2}\right) \quad (1.7.1)$$

$$V_{max} = \frac{\Delta P R^2}{4\mu L} \quad (1.7.2)$$

$$V = \frac{\Delta P R^2}{8\mu L} = \frac{\Delta P D^2}{32\mu L} \quad (1.7.3)$$

Notations

V_r = velocity of flow at a distance 'r' from centre of the pipe
V_{max} = maximum velocity of flow, occurs at centre of the pipe i.e. when r = 0
V = mean or average velocity of flow through the pipe
μ = coefficient of viscosity
R = radius of the pipe
L = length of the pipe for pressure drop ΔP (i.e. $P_1 - P_2$)
D = diameter of the pipe

Relation between V_r and V_{max}

$$V_r = V_{max}\left(1 - \frac{r^2}{R^2}\right)$$

Relation between V and V_{max}

$$V = \frac{V_{max}}{2}$$

Equation (1.7.3) is known as *Hagen – Poiseuille equation.*

Pressure drop, ΔP

Pressure drop in laminar flow through the pipe can be calculated from any of the following equations (1.7.4) or (1.7.5) or (1.7.6) depending upon the situations.

From equation (1.7.3), we can obtain:

$$\Delta P = \frac{32\mu v L}{D^2} \tag{1.7.4}$$

$$\Delta P = \gamma\, h_f = \rho g h_f \tag{1.7.5}$$

Notations

γ = unit weight of fluid flowing through the pipe

h_f = frictional headless through pipe

Again using *concept of coefficient of friction*

$$f = \frac{Shear\ stress\ at\ surface}{Kinetic\ energy} = \frac{F/A}{\frac{1}{2}\rho V^2} = \frac{\frac{\Delta P(\pi R^2)}{2\pi RL}}{\frac{1}{2}\rho v^2} = \frac{\Delta P.R}{L\rho v^2}$$

$$\therefore\ \Delta P = \frac{L\rho v^2 f}{R} \tag{1.7.6}$$

Notations

F = drag force

A = surface area upon which drag force acts

P = density of fluid flowing through the pipe

Friction Factor

Comparing equations (1.7.4) and (1. 7.6)

$$f = \frac{16}{(\frac{\rho D V}{\mu})} = \frac{16}{\mathrm{Re}} \tag{1.7.7}$$

$$\text{And } f' = 4f = 4 \times \frac{16}{\mathrm{Re}} = \frac{64}{\mathrm{Re}} \tag{1.7.8}$$

Notations

f = coefficient of friction, also known as *Darcy's roughness coefficient* or *fanning friction factor*

f' = 4f = friction factor, also known as *Darcy's friction factor*

Again comparing equations (1.7.5) and (1.7.6), frictional head loss through pipe can be calculated as follows:

$$h_f = \frac{4fLv^2}{2gD} = \frac{f'LV^2}{2gD} \qquad (1.7.9)$$

Note

- Darcy's friction factor = 4 × fanning friction factor
- The term *fanning friction factor* is more frequently used in chemical and food engineering textbooks whereas the term *Darcy's friction factor* is mostly used in civil and mechanical engineering textbooks
- Value of 'f' should be obtained from Moody's diagram

Turbulent flow through Pipe

For turbulent flow through the pipe, Reynold number, Re > 4000

Relation between V, V_r, V_{max}

$$V_r = V_{max}\left(1 - \frac{r}{R}\right)^{1/7} \qquad (1.7.10)$$

$$V = 0.8V_{max} \qquad (1.7.11)$$

Notations

V_r = velocity of flow at a distance 'r' from centre of the pipe
V_{max} = maximum velocity of flow, occurs at centre of the pipe i.e. when r = 0
V = mean or average velocity of flow through the pipe
R = radius of the pipe

Note:

Equation (1.7.10) repesents relation between V_r and V_{max} & equation (1.7.11) represents relation between V and V_{max} and equation (1.7.10) is known as *Blassius* $1/7^{th}$ power law.

Pressure drop

Pressure drop in turbulent flow through the pipe can be calculated from either of the following equations (1.7.12) or (1.7.13)

$$\Delta P = f\left(\frac{4fl}{D}\right)\frac{v^2}{2} \qquad (1.7.12)$$

$$\Delta P = \rho g h_f \qquad (1.7.13)$$

From equations (1.7.12) and (1.7.13) frictional headloss, h_f, through the pipe can be obtained as follows:

$$h_f = \frac{4fLv^2}{2gD} \tag{1.7.14}$$

Moody's diagram

Moody's diagram is a log-log plot of 'f' vs. 'Re' for different values of '*R/K*' or '*K/D*'

Notations

R/K = relative smoothness
K/D = relative roughness
R = radius of the pipe
D = diameter of the pipe (inside diameter)
K = average height of the pipe wall roughness

Note

Moody's diagram is used to describe the flow conditions other than laminar flow. For laminar flow region (Re < 2100), Moody's diagram is explained by the equation f = 16/Re and is not influenced by the surface roughness, k. According to Moody's chart, fanning friction factor, f never equals to zero.

General Flow through pipe

Chezy's equation

Chezy's equation for flow through the pipe is given by the following equation

$$V = C\sqrt{RS} \tag{1.7.15}$$

Notations

V = mean velocity of flow through the pipe.
C = Chezy's roughness coefficient
R = hydraulic radius
S = hydraulic slope or *hydraulic gradient*, also known as *channel slope* or *bed slope* or *longitudinal slope*

Manning's equation

$$V = \frac{1}{n} R^{2/3} S^{1/2} \tag{1.7.16}$$

Comparing equation (1.7.15) with equation (1.7.16)

$$C = \frac{1}{n} R^{1/6} \tag{1.7.17}$$

Darcy-Weisbach equation

$$V = \sqrt{\frac{2gRS}{f}} \qquad \therefore C = \sqrt{\frac{2g}{f}} \qquad (1.7.18)$$

$$\text{Also } V = \sqrt{\frac{8gRS}{f'}} \qquad \therefore C = \sqrt{\frac{8g}{f'}} \qquad (1.7.19)$$

Bazin's equation

$$V = \frac{157.6}{1.81 + \frac{k}{\sqrt{R}}}(\sqrt{RS}) \qquad \therefore C = \frac{157.6}{1.81 + \frac{k}{\sqrt{R}}} \qquad (1.7.20)$$

Kutter's equation

$$V = \frac{\frac{1}{n} + 23 + (\frac{0.00155}{S})}{1 + (23 + \frac{0.00155}{S})\frac{n}{\sqrt{R}}}(\sqrt{RS})$$

$$\therefore C = \frac{\frac{1}{n} + 23 + \frac{0.00155}{S}}{1 + (23 + \frac{0.00155}{S})\frac{n}{\sqrt{R}}} \qquad (1.7.21)$$

where, $S = \frac{h_f}{L}$ and $h_f = \frac{4fLV^2}{2gD}$

Notations

h_f = frictional head loss through the pipe

L= length of the slope

f = coefficient of friction

f' = friction factor

D = diameter of the pipe

n = Manning's roughness coefficient.

k = Bazin's constant

1.8 Flow in Open Channel

Flow nature
Laminar flow, Re < 500
Turbulent flow, Re > 2000
Transient flow, Re $= [500 - 2000]$

Discharge, $Q = AV$ (1.8.1)

where, $V = C\sqrt{RS}$ (1.8.2)

Or, $V = \frac{1}{n} R^{2/3} S^{1/2}$ (1.8.3)

Channel Conveyance, K

$Q = K\sqrt{S}$ (1.8.4)

Comparing equations (1.8.1), (1.8.2), (1.8.3) & (1.8.4)

$K = AC\sqrt{R} = \frac{1}{n} AR^{2/3}$ (1.8.5)

Hydraulic jump
- When a given flow changes from a flow depth, h, such as $h < d_c$ to a flow depth, h, such as $h > d_c$, then this phenomenon is known as *hydraulic jump*. Here d_c is known as *critical depth*.
- By this process energy due to velocity is converted into energy of elevation and some energy is lost as friction through turbulence.
- Hydraulic jump is made to occur within downstream portion of the structure and thus velocity is reduced to a non-erosive level in the sub-critical range.
- When inflow is at critical depth, then Froude number, F = 1 and $h = d_c$. So no hydraulic jump occurs.

Nature of flow

Conditions	$F = \frac{V}{\sqrt{gd}}$	Type of flow
$h = d_c$	$F = 1$	Critical
$h > d_c$	$F < 1$	Subcritical
$h < d_c$	$F > 1$	Supercritical

Note:

- The notations h and d are used synonymously meaning the same *flow head* or *flow depth*

Nature of hydraulic jump

$$\text{Supercritical flow} \xrightarrow{\textit{Hydraulic Jump}} \text{Subcritical flow}$$

Value of F	Type of hydraulic jump
$F_1 = 1$	no jump, critical flow
$F_1 = 1\text{-}1.7$	undular jump
$F_1 = 1.7 - 2.5$	weak jump
$F_1 = 2.5 - 4.5$	oscillating jump
$F_1 = 4.5 - 9$	steady jump
$F \geq 9$	strong jump

Note:

- Subcritical flow is also known as *tranquil* or *streaming flow.*
- Supercritical flow is also known as *shooting* or *rapid* or *torrential flow.*

Again $d_2 = \frac{d_1}{2}(\sqrt{1+8F_1^2} - 1)$ (1.8.6)

$$F_1 = \frac{V_1}{\sqrt{gd_1}} \quad (1.8.7)$$

Notations

d_2 = depth after hydraulic jump, also known as *sequent depth* or *theoretical tail water depth*

d_1 = depth before hydraulic jump, also known as *initial depth*

F_1 = Froude number of incoming flow

V_1 = velocity of incoming flow

Loss of energy in hydraulic jump

$$H_L = E_1 - E_2 = (d_1 + \frac{V_1^2}{2g}) - (d_2 + \frac{V_2^2}{2g}) \quad (1.8.8)$$

$$q = V_1 d_1 = V_2 d_2 \quad (1.8.9)$$

Using equations (1.8.8) and (1.8.9) we can get

$$H_L = \left(\frac{d_2 - d_1}{4d_2 d_1}\right) \quad (1.8.10)$$

Notations

H_L = loss of energy in hydraulic jump of standing wave

E_1 & E_2 = specific energy before jump and after jump respectively

$d_2 - d_1$ = depth of hydraulic jump

Energy Head

$$\text{Total energy head} = Z + h + \frac{V^2}{2g}$$

$$\text{Specific energy head, } h_e = h + \frac{V^2}{2g} = h + h_a$$

$$\therefore\ h_e = h + h_a = h + \frac{V^2}{2g} = h + \frac{Q^2}{A^2 \times 2g} = h + \frac{Q^2}{2b^2h^2g} = h + \frac{q^2}{2h^2g} \quad (1.8.11)$$

Notations

Z = elevation head
h = flow depth or *flow head*
V = mean velocity of flow, also known as *approach velocity of flow*
h_e = specific energy head
h_a = approach velocity head
A = area of channel (rectangular)
b = channel width (top width)
Q = total discharge
q = discharge per unit width of channel

Note:

- The notations h_e and E are used synonymously meaning the same *specific energy head* or simply *specific energy.*

Critical Depth, d_c

A given quantity of water may flow at two depths having same energy head in an open channel. When these depths coincide the energy head is minimum and corresponding depth is termed as *critical depth.*

$$d_c = \sqrt[3]{\frac{Q^2}{b^2 g}} = \frac{2}{3} h_e \quad (1.8.12)$$

The equation (1.8.12) holds good for rectangular channel but for triangular channel following expression is used

$$d_c = \sqrt[5]{\frac{2Q^2}{g}} = \frac{4}{5} h_e \qquad (1.8.13)$$

Critical Velocity, V_c

Velocity of flow in channel corresponding to critical depth is known as *critical velocity*.

$$V_c = \sqrt{g \times d_c} \qquad (1.8.14)$$

Critical Flow, Q_{max}

The flow corresponding to critical depth is known as *critical flow*. In other word, at critical depth maximum flow occurs and this flow is known as critical flow.

$$Q_{max} = AV_c = (bd_c) \times (\sqrt{gd_c}) \qquad (1.8.15)$$

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Chapter 2

Farm Machinery and Power

2.1 Field capacity and Force analysis

Field capacity, FC

$$\text{FE} = \frac{AFC}{TFC} = \frac{nW_AV}{nW_TV} = \frac{nW_TV - overlap}{nW_TV} \tag{2.1.1}$$

Notations:

FE = field efficiency
AFC = actual field capacity, also known as *effective field capacity*
TFC = theoretical field capacity
n = number of plough bottoms
W_A = actual width of cut
W_T = theoretical width of cut, also known as *design width of cut* or *rated width of cut*
V = actual velocity of travel, considered same as the theoretical velocity of travel
K = percentage width utilized

Methods to determine actual field capacity

Method 1

$$\text{FE}=\frac{\text{AFC}}{\text{TFC}}=\frac{1/\text{T}_\text{A}}{1/\text{T}_\text{T}}=\frac{\text{T}_\text{T}}{\text{T}_\text{A}}=\frac{\text{T}_\text{T}}{\text{T}_\text{e}+\text{T}_\text{a}+\text{T}_\text{h}}=\frac{\text{T}_\text{T}}{\frac{\text{T}_\text{T}}{\text{K}}+\text{T}_\text{a}+\text{T}_\text{h}} \tag{2.1.2}$$

Note:

When the T_a and T_h are negligible equation (2.1.2) transforms as follows:

$$\text{FE} = \frac{T_T}{T_T / K} = \text{K} \tag{2.1.3}$$

Method 2

$$\text{AFC}=\frac{\text{actual area covered}}{\text{actual time taken}}$$

Notations:
T_A = time taken per hectare
T_T = theoretical (ideal) time taken per hectare
T_e = effective operating time per hectare
T_a = time lost per hectare which is proportional to area e.g. turning time
T_h = time lost per hectare which is not proportional to area e.g. time for filling, emptying

Unit draft

Unit draft, $L_u = L/A$ (2.1.4)

Notations

L = draft
A = cross sectional area of cut

Note

For rectangular furrow, A = width x depth
For triangular furrow, A = ½ (top width) x depth
For trapezoidal furrow, A = ½ x (top width + bottom width) depth

Forces acting on tillage tools

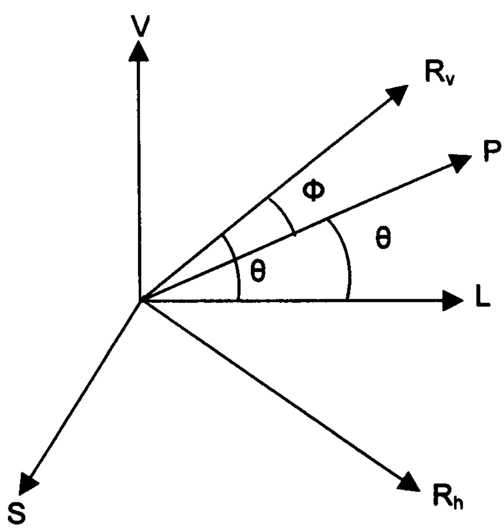


Fig. 2.1 Forces acting on a tillage tool

Notations

P = pull force
  = resultant pull exerted by tractor or by bullock upon the implement

R = soil reaction force
  = resultant of useful and parasitic soil forces exerted by tractor or by bullock upon the implement

R_v = vertical component of soil reaction force

R_h = horizontal component of soil reaction force

θ = inclination of pull force with horizontal

ϕ = direction of pull force with R_v

Case 1: *When useful and practice forces can't be determined separately*

Draft, $L = (P\cos\phi)\cos\theta$ (2.1.5)

= Longitudinal and directional component of R

Vertical component, $V = (P\cos\phi)\sin\theta$ (2.1.6)

Side force, $S = (P\sin\phi)\cos\theta$ (2.1.7)

= Lateral component of R, also known as *landside force*

$$R_V = \sqrt{L^2 + V^2}$$

$$= \sqrt{(P\cos\phi\cos\theta)^2} + \sqrt{(P\cos\phi\sin\theta)^2} = p\cos\phi \qquad (2.1.8)$$

$$R_h = \sqrt{L^2 + S^2}$$

$$= \sqrt{(Pcos\phi\, cos\theta)^2} + \sqrt{(Psin\phi\, cos\theta)^2} = P\cos\theta \qquad (2.1.9)$$

$$R = \sqrt{R_V{}^2 + R_h{}^2} \qquad (2.1.10)$$

Note:

P_v, P_h are useful forces

W, F, and f are parasitic forces

Case 2: *When useful forces and parasitic forces can be determined separately*

$$R_V = W - P_V = W - P\sin\theta \qquad (2.1.11)$$

$$R_h = P_h - F - f = P\cos\theta - F - f \qquad (2.1.12)$$

$$R = \sqrt{R_V{}^2 + R_h{}^2}$$

$$\tan\theta = \frac{R_V}{R_h} \qquad (2.1.13)$$

Notations:
P_v = vertical component of pull
P_h = horizontal component of pull
F = frictional force
f = rolling resistance force
W = weight of the implement

Note:
- P_v can be determined from $\sum V = 0$ i.e. summation of vertical forces = 0
- P_h can be determined from $\sum H = 0$ i.e. summation of horizontal forces = 0
- Another useful concept used in solving such type of problems is $\sum M = 0$ i.e. Summation of moments acting at a particular convenient point on tillage implement = 0

2.2 Sowing and Planting

Device for metering single seed
- Horizontal plate planter
- Vertical plate planter

(I) Calculation of spacing between seeds along the row, L
Case 1:Horizontal plate planter

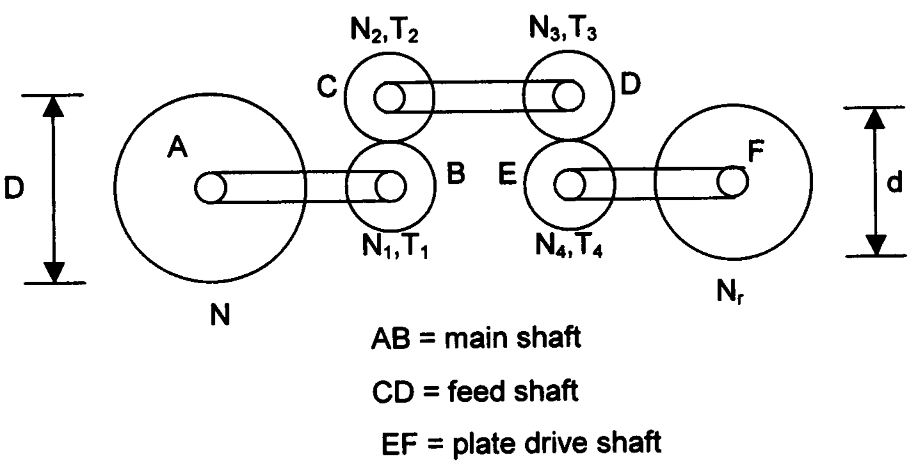


Fig. 2.2 Horizontal plate planter

Speed ratio between plate drive shaft and main drive shaft

$$= \frac{N_r}{N} = \frac{N_4}{N} = \frac{T_1 T_3}{T_2 T_4} = \frac{\text{Product of tooth on driver gears}}{\text{Product of tooth on driven gears}} \quad (2.2.1)$$

Spacing between seeds along row, L is given by

$$L = \frac{\pi DN}{nN_r} = \frac{V}{nN_r} \quad (2.2.2)$$

Notations

N = rpm of ground wheel

D = diameter of ground wheel

N_r = rpm of rotor

d = diameter of rotor

V = velocity of ground wheel

n = number of cells on rotor

Proof

In 1 revolution rotor drops n number seeds

Number of revolutions to drop 1 seed = $1/n$

Corresponding number of revolutions of ground wheel = $N/n \,.\, N_r$

In 1 revolution distance covered by ground wheel = π D

In N/n.N*r* revolution distance covered by ground wheel= πDN / n.Nr

$$\therefore L = \frac{\pi DN}{nN_r} = \frac{V}{nN_r}$$

Case 2: Vertical plate planter

$$L = Vt = \frac{\pi d}{n}\left(\frac{V}{V_p}\right) \quad (2.2.3)$$

Notations:

V= velocity of travel

V_p= peripheral velocity of plate planter

Note:

- Velocity of travel can be referred to as *velocity of ground wheel* or *forward travel speed of planter* or *velocity of planting*
- Peripheral velocity of plate planter otherwise can be referred to as *peripheral velocity of rotor* or *linear cell speed* or *linear plate speed*

Proof

t = time to cover peripheral distance between two consecutive cells of rotor

= time gap between falling of seeds from consecutive cells of the rotor

= peripheral distance between two consecutive cells of rotor ÷ V_p

= $\frac{\pi d}{n} / V_p$

$$L = Vt = \frac{\pi d}{n}\left(\frac{V}{V_p}\right)$$

Correlation between equation (2.2.2) and (2.2. 3) is as follows

$$L = \frac{V}{nN_r} = \frac{V}{\pi d N_r} \times \frac{\pi d}{n} = \frac{V}{V_p}\left(\frac{\pi d}{n}\right) \tag{2.2.4}$$

(II) Calculation of velocity of travel, V

$$\frac{V}{V_p} = \frac{\pi DN}{\pi d N_r} = \frac{\pi D}{\pi d}\left(\frac{T_2 T_4}{T_1 T_3}\right) \tag{2.2.5}$$

(III) Calculation of number of plants required per hectare

$$x = \frac{nE}{LS} \times 10{,}000 \tag{2.2.6}$$

Notations:

x = number of plants required per hectare

n = number of seeds per hill

E = emergence rate

L x S = area required per each hill

L = plant to plant distance or hill to hill distance in a row

S = row to row distance

(IV) Vertical plate planter with rotor mechanism

Case 1: When the rotor turns in same direction as ground wheel

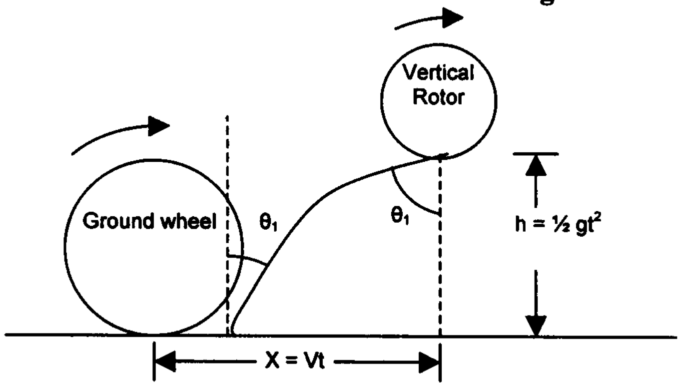


Fig. 2.3 Vertical plate planter with rotor turning in same direction as ground wheel

Horizontal distance covered, $X = Vt$ (2.2.7)

Vertical falling distance, $h = \frac{1}{2} gt^2$ (2.2.8)

$$X = V\sqrt{\frac{2h}{g}} \tag{2.2.9}$$

$$\theta_1 = \tan^{-1}(X/h) \tag{2.2.10}$$

$$V = V_G - V_R \tag{2.2.11}$$

Notations:

V = net velocity of travel

V_G = velocity of ground wheel

V_R = velocity of rotor, also known as *peripheral velocity of rotor*

θ_1 = angle made by the seeds with vertical when striking the ground

Case 2: When a rotor turns in opposite direction as ground wheel

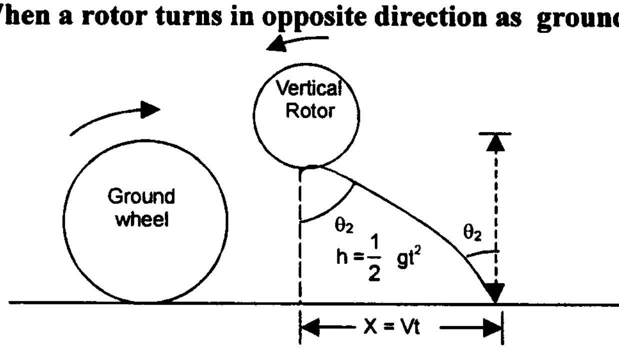


Fig. 2.4 Vertical plate planter with rotor turning in opposite direction as ground wheel

Horizontal distance covered, $X = Vt$
Vertical falling distance, $h = \frac{1}{2} gt^2$

$$X = V\sqrt{\frac{2h}{g}}$$

$V = V_G + V_R$ (using concept of relative velocity)
$\theta_2 = \tan^{-1} (X/h)$

Notations:
V = net velocity of travel
V_G = velocity of ground wheel
V_R = velocity of rotor, also known as *peripheral velocity of rotor*
θ_2 = angle made by the seeds with vertical when striking the ground

2.3 Sprayer and Chaff Cutter

Sprayer

Flow rate of spray material

$$\dot{m} = \rho Q = \rho\,(AR_v) = \rho\,(nSVE)\,R_v = (SVE)\,R_m \qquad (2.3.1)$$

Notations:
$\dot{m}$ = mass flow rate of spray material, *kg/min*
ρ = density of spray material, *kg/m³*
Q = volumetric flow rate, *m³/min*
A = area covered by sprayer, *m²/min*
R_v = volumetric application rate, *m³/m²*
n = number of nozzles
S = spacing between nozzles, *m*
V = velocity of travel of sprayer, *m/min*
E = spraying efficiency of sprayer
R_m = mass application rate, *kg/m²*

When coefficient of discharge through orifice, C_d is considered

$$\dot{m} = C_d \rho Q \qquad (2.3.2)$$

Analysis of flow rate in a sprayer

$$R_m = \rho R_v \qquad (2.3.3)$$
$$A = n\,SVE \qquad (2.3.4)$$
$$Q = nq \qquad (2.3.5)$$
$$q = aV' = \pi/4\, d^2 \times V' \qquad (2.3.6)$$

Notations:

n = number of nozzles
q = discharge per nozzle
a = area of each nozzle
V' = velocity of water through nozzle

Mass flow rate of liquid

$$G = \rho V' \tag{2.3.7}$$

where

G = mass flow rate or *mass velocity* or *mass flux per nozzle, kg /m²-min*

Chaff Cutter

Capacity of a chaff cutter

$$\dot{m} = \rho Q = \rho VA = \rho\,(NLn)\,(WH) \tag{2.3.8}$$

Notations

$\dot{m}$ = theoretical maximum capacity of chaff cutter, *kg/min*
ρ = density of feed material, *kg/m³*
Q = volumetric flow rate of feed material, *m³/min*
V = linear speed of cutterhead, *m/min*
= linear speed of feed mechanism
= rate of advance of material through throat
A = cross sectional area of throat, *m²*
N = rotational speed of cutterhead, *rpm*
L = theoretical length of cut, *m*
= amount of advance of feed mechanism between cuts of two consecutive knives
n = number of knives on cutterhead
W = width of throat = minimum width of opening at feed rolls
H = height of throat, *m*
= maximum operating clearance between upper and lower feed rolls

Velocity analysis in chaff cutter

$$V = NLn \tag{2.3.9}$$

$$V' = \pi D'N' \tag{2.3.10}$$

Notations:

V = linear speed of cutterhead
V' = peripheral velocity of feed rolls
D' = diameter of feed rolls

N' = rpm of feed rolls

Also V = V'

$\Rightarrow$ NLn = π D'N'

When feed rolls are of different diameter and different rpm

$$NLn = \frac{\pi D_1' N_1' + \pi D_2' N_2'}{2} \quad (2.3.11)$$

Notations:

D_1' and D_2' = diameter of two feed rolls

N_1' and N_2' = rpm of two feed rolls

$$V^p = \pi D N \quad (2.3.12)$$

V_p = peripheral velocity of cutter head, m/s

D = diameter of cutter head or fly wheel, *m*

Theoretical length of cut

$$L = \frac{2\pi r_i \tan\alpha}{n} \quad (2.3.13)$$

Notations:

L = theoretical length of cut

r_i = distance of inner edge of throat from fly wheel center

α = clearance angle between knife support assembly and plane of rotation

Analysis for kinetic energy & power in a chaff cutter

Kinetic energy of flywheel in one revolution = ½ MV^2 = ½ M $(\omega r)^2$

$$= \tfrac{1}{2} M (2\pi Nr)^2 = \tfrac{1}{2} M r^2 \omega^2 = \tfrac{1}{2} I \omega^2 \quad (2.3.14)$$

Power required (consumed) to drive flywheel, $P = \tfrac{1}{2}\, m\, V_p^2$ (2.3.15)

Also power consumed to drive flywheel, P = 2 π NT

$$= 2\pi NT\,(F.r) = 2\pi N\,(A_o \Gamma)\, r \quad (2.3.16)$$

Notations:

T = torque required to drive the flywheel, *N.m*

A_o = effective cut area of fodder, m^2

Γ = dynamic shear stress of fodder, N/m^2

F = force required to cut per revolution, *N*

r = effective radius of knife rotation, *m*

2.4 Fuel and Combustion

Volumetric efficiency, η_v

Case 1: For a cylinder

$$\eta_v = \frac{V_A}{V_S} = \frac{m_A}{\rho_A \times V_S} \qquad (2.4.1)$$

Notations:

V_A = actual volume of air taken into cylinder, *m^3*

V_s = swept volume of air inside cylinder, *m^3*

m_A = air compressed during compression, kg

ρ_A = ambient air density, also known as *density of air at inlet*, *kg/m^3*

Methods to calculate ρ_A

Method 1: $\rho_A = \dfrac{m}{V} = \dfrac{P}{RT}$ (2.4.2)

Method 2: $\rho_A = 1/$ specific volume, m^3/kg (2.4.3)

Note:

- R = 8.31 *KJ/ kgmole-K*
- m, V, P, T represents mass, volume, Pressure and temperature of ambient air respectively

Case 2: For an engine

(a) For liquid fuel or fuel of CI engine

Volumetric efficiency (η_v) can be calculated from the following formula

$$\frac{A}{F} = \frac{\dot{A}}{\dot{F}} = \frac{Q_A \times \rho_A}{\dot{F}} = \frac{(\eta_V \times Q_e) \times \rho_A}{\dot{F}} \qquad (2.4.4)$$

Notations:

$\dfrac{A}{F}$ = air to fuel ratio

$\dot{A}$ = air taken in or *mass flow rate of air, kg/min*

$\dot{F}$ = fuel consumed or *mass flow rate* of fuel, *kg/min*

Q_A = air taken in or *volumetric flow rate* of air, *m^3/min*

Q_e = engine displacement, *m^3/min*

ρ_A = ambient air density, *kg/m^3*

(b) For gaseous fuel or fuel of SI engine

$$\frac{A}{F} = \frac{Q_A}{Q_F} = \frac{Q_{A+F} - Q_F}{Q_F} = \frac{\eta_V Q_e - Q_F}{Q_F} = \frac{\eta_V Q_e}{Q_F} - 1 \qquad (2.4.5)$$

Q_F = fuel consumed, m^3/min
Q_{A+F} = air-fuel mixture taken in, m^3/min

Break Horsepower, BHP

BHP = p Q_e = p (LAn.N) (2.4.6)
p = break mean effective pressure (BMEP)

Indicated Horsepower, IHP

IHP = P Q_e = P (LAnN) (2.4.7)
P = indicated mean effective pressure (IMEP)

Break Thermal Efficiency, BTE

Break thermal efficiency is variedly known as *engine thermal efficiency* or *net engine efficiency* or *thermal efficiency* or simply as *efficiency*. *Conceptually,*

$$\text{BTE} = \frac{\textit{heat actually used}}{\textit{heat input}}$$

$$= \frac{\textit{actual work output}}{\textit{heat input}}$$

$$= \frac{\textit{actual work output per unit time}}{\textit{heat input per unit time}}$$

$$= \frac{BHP}{Fuel\ HP} \qquad (2.4.8)$$

$$= \frac{BHP}{\dot{F} \times \text{CV}} \qquad (2.4.9)$$

$$= \frac{BHP}{\frac{Kg}{hr} \times \frac{Kcal}{Kg}}$$

$$= \frac{641 \frac{Kcal}{hr}}{\frac{Kg}{BHP-hr} \times \frac{Kcal}{Kg}}$$

$$= \frac{641 \frac{Kcal}{hr}}{SFC \times CV} \qquad (2.4.10)$$

Note:

- 1 HP = 641 Kcal/Kg
- SFC = specific fuel consumption
- unit of SFC = Kg / HP-hr (for liquid fuel)
  = m^3 / HP-hr (for gaseous fuel)
- CV = calorific value of fuel
- F = fuel consumed or mass flow rate of fuel

Indicated Thermal Efficiency,ITE

Indicated thermal efficiency is also known as *indicated engine efficiency*
Conceptually,

$$\text{ITE} = \frac{indicated\ work\,(output)}{heat\ input} = \frac{IHP}{Fuel\ HP} = \frac{IHP}{\dot{F} \times CV} \qquad (2.4.11)$$

Mechanical Efficiency, ME

$$ME = \frac{BTE}{ITE} = \frac{BHP}{IHP} = \frac{BMEP}{IMEP} \qquad (2.4.12)$$

Relative Efficiency

$$\text{Relative efficiency} = \frac{indicated\ thermal\ efficiency}{air\ standard\ efficiency} = \frac{actual\ ITE}{ideal\ ITE} \qquad (2.4.13)$$

where

$$Air\ standard\ efficiency,\ ASE = \frac{Net\ work\ done}{heat\ input}$$

$$= \frac{|W_{by}| - |W_{on}|}{Q_{in}} \qquad (2.4.14)$$

$$= \frac{|Q_{in}| - |Q_{out}|}{Q_{in}} \qquad (2.4.15)$$

For otto cycle: $ASE = 1 - \frac{1}{r^{k-1}}$ (2.4.16)

For diesel cycle: $ASE = 1 - \frac{1}{r^{k-1}}\left[\frac{c^k - 1}{k(c-1)}\right]$ (2.4.17)

Note:
- W_{by}, W_{on} refers to work done by the system and work done on the system respectively
- Q_{out} = -ve, Q_{in} = + ve, W_{on} = -ve, W_{by} = + ve

The general formula for combustion of hydrocarbons is given by

$C_x H_y + (x + y/4)\, O_2 \rightarrow x\, CO_2 + y/2\, H_2O$ (2.4.18)

2.5 Traction Analysis

Drawbar pull

– Drawbar pull, P, is variedly known as *net pull* or *net tractive capacity* or *draft capacity* or *pull used for useful work* or simply as *pull*

Conceptually,

$P = F - TF$ (2.5.1)

$\Rightarrow PV_a = F\, V_t - TF\, V_a$

$\Rightarrow$ drawbar power = axle power – towed power

$\Rightarrow$ net tractive power = gross tractive power – rolling resistance power

Notations

F = force of traction or *soil thrust* in direction of motion, also known as *gross tractive force* or simply *tractive force*

TF = towed force, also known as *motion resistance*

V_a = actual travel velocity, also known as *forward travel velocity*

V_t = theoretical travel velocity

Theoretical travel velocity, V_t

$V_t = \omega\, r = (2\pi N)r = 2\pi\, N\, (D/2) = \pi DN$ (2.5.2)

Notations:

r = rolling radius of wheel

D = wheel diameter

$F = AC + W \tan\phi$ (2.5.3)

Notations:

A = area sheared by the equivalent wheel or by the track
= bl (for track/crawler type tractor)
= 0.78 bl (for wheel / rubber tyre / pneumatic tyre tractor)

W = weight on the equivalent wheel or on the track.

C = cohesion, *N/cm²*

ϕ = angle of internal friction

Force analysis

$$P = F - TF \quad (2.5.4)$$

$$\Rightarrow \frac{P}{W} = \frac{F}{W} - \frac{TF}{W}$$

$$\Rightarrow \mu = \mu_g - \rho \quad (2.5.5)$$

Notations:

W = dynamic weight on equivalent wheel

μ = coefficient of traction, also known as *net coefficient of traction*

μ_g = gross traction coefficient

ρ = rolling resistance coefficient, also known as *motion resistance ratio*

$$\mu = 0.75\,(1 - e^{-0.3\,C_n S}) \quad (2.5.6)$$

$$\rho = \frac{1.2}{C_n} + 0.04 \quad (2.5.7)$$

$$C_n = \frac{CI(bd)}{W} \quad (2.5.8)$$

Notations:

W = dynamic weight on each individual wheel
= dynamic weight on equivalent wheel ÷ 2

CI = cone index, *N/cm²*

S = slip (in decimal)

C_n = wheel numeric (per wheel)

b = width of tire (rim)

d = diameter of tire (rim)

Note:

- Width of tire is also known as *sectional width* or *sectional thickness*
- Equations (2.5.6) & (2.5.7) apply to single wheel

Dynamic weight

Dynamic weight is also known as "true tire load"

Conceptually,
Dynamic weight = static weight distribution on rear wheel + weight of implement + weight transfer from front wheel
Physically,
Dynamic weight, W, means net load on wheels (i.e. on the equivalent wheel) during pull condition and static *weight* means load on wheel in rest condition.

Equivalent wheel
In two dimensional analysis, the 2 wheels on rear axle of tractor are replaced by a single wheel having equivalent force properties as that of 2 wheels. Likewise the 2 wheels on front axle are also replaced by another single wheel. These 2 single wheels, one at rear axle and another at front axle are known as equivalent wheels at the respective axles.

Net coefficient of traction, μ

$$\mu = \frac{P.V_a}{T.W} = \frac{horizontal\, drawbar\, pull(p\cos\alpha)}{dynamic\, weight\, on\, rear\, wheel}$$

Tractive Efficiency, TE

$$TE = \frac{drawbar\, power}{axle\, power} \qquad (2.5.9)$$

$$= \frac{P.V_a}{T.W} \qquad (2.5.10)$$

$$= \frac{P.V_a}{(F.r)(\frac{V_t}{r})}$$

$$= \frac{P.V_a}{F.V_t} \qquad (2.5.11)$$

$$= \frac{P}{F}(1-S) \qquad (2.5.12)$$

$$= \frac{P/W}{F/W}(1-S)$$

$$= \frac{\mu}{\mu_g}(1-s) \qquad (2.5.13)$$

$$= \frac{\mu}{\mu+\rho}(1-S) \tag{2.5.14}$$

Notations:
T = wheel torque
r = rolling radius

Slip, S

When wheels are rotating but not moving ahead this condition is known as slip

Methods to calculate slip

Method 1

In terms of velocity:

$$\text{Slip} = \frac{V_t - V_a}{V_t} = 1 - \frac{V_a}{V_t} \tag{2.5.15}$$

Method 2

To cover a particular distance:

$$\text{Slip} = \frac{N_1 - N_0}{N_0} \tag{2.5.16}$$

Method 2

To register a particular rpm:

$$\text{Slip} = \frac{L_0 - L_1}{L_0} \tag{2.5.17}$$

In other words slip is the difference between ideal distance a wheel should move and the distance actually moved by the wheel. So slip is also known as *travel reduction.*

Notations

N_0, N_1 = rpm without and with slip respectively
L_0, L_1 = distance covered without and with slip respectively

Skid

When wheels are sliding i.e. moving ahead along the road but not rotating this condition is known as skid e.g. sudden application of brakes the rotating wheels. Thus, this is just opposite condition to that of slip. Mathematically,

$$\text{Skid} = \frac{V_a - V_t}{V_t} = \frac{V_a}{V_t} - 1 \tag{2.5.18}$$

Relationship between slip and skid

$V_a = V_t(1 - \text{slip})$
$V_a = V_t(1 + \text{skid})$

where, $V_t = \pi DN$

2.6 Mechanics of Tractor Chassis

Analysis of forces acting on a tractor:

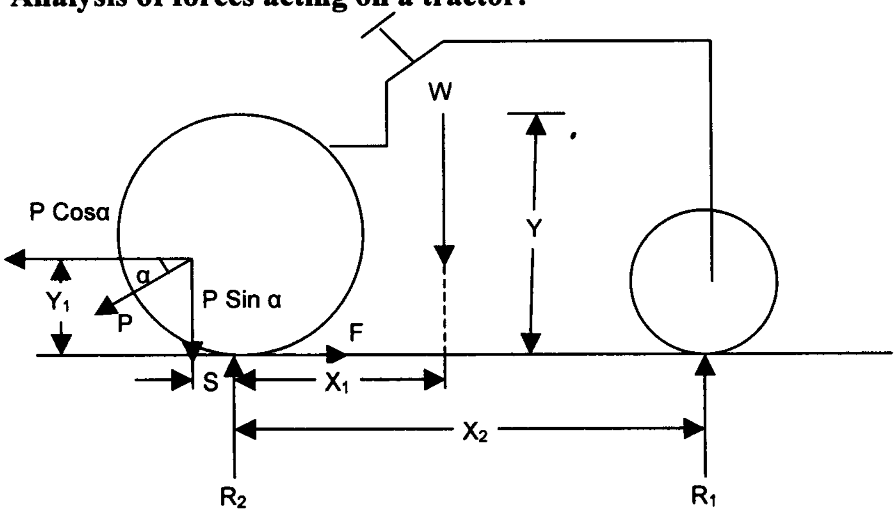


Fig.2.5 Forces acting on a tractor in pull condition

Notations:

P = pull force acting on the tractor
α = angle of inclination of pull with horizontal
R_1 = normal reaction force at front wheel
R_2 = normal reaction force at rear wheel
W = weight.of tractor acting through centre of gravity of tractor
X_1 = perpendicular distance between R_2 & W
X_2 = perpendicular distance between R_1 & R_2

Weight Transfer

(a) In rest condition

$R_1 + R_2 = W$ (2.6.1)

$W.X_1 = R_1X_2$ (2.6.2)

Solving (2.6.1) and (2.6.2) simultaneously:

$$R_1 = \frac{WX_1}{X_2} \quad \text{and} \quad R_2 = W\left(1 - \frac{X_1}{X_2}\right)$$

(b) When implement is attached and pulled

Referring to the figure 2.5

$R_1 + R_2 = W + P \sin \alpha$ (2.6.3)
$WX_1 = P \cos \alpha \, Y_1 + P \sin \alpha \, S + R_1 \, X_2$ (2.6.4)

Solving (2.6.3) and (2.6.4) simultaneously:

$$R_1 = \frac{WX_1}{X_2} - \left(\frac{P \cos\alpha \mathbf{Y}_1 + p \sin\alpha . S}{X_2} \right) \tag{2.6.5}$$

This amount $\left(\frac{P \cos\alpha \mathbf{Y}_1 + p \sin\alpha . S}{X_2} \right)$ in equation (2.6.5) by which upward reaction at front wheel decreases due to pulling of attached implement is popularly known as *weight transfer.*

Note:

- $\frac{WX_1}{X_2}$ = Static weight distribution on front wheel in pull condition
- $\frac{P \cos\alpha Y_1 + P \sin\alpha S}{X_2}$ = Weight transfer (2.6.6)

$= \frac{PY_1}{X_2}$ (when pull is parallel to ground)

Conditions:

Case 1: weight transfer $= \frac{WX_1}{X_2} \Rightarrow R_1 = 0$

$\Rightarrow$ Front wheel will leave the ground

Case 2: weight transfer $> \frac{WX_1}{X_2} \Rightarrow R_1$ = negative

$\Rightarrow$ Overturning / toppling about rear wheel

Case 3: weight transfer $< \frac{WX_1}{X_2} \Rightarrow R_1$ = positive

$\Rightarrow$ Stable condition

Dynamic weight

Solving equation (2.6.3) and (2.6. 4) simultaneously we can get

$$R_2 = W\left(1 - \frac{X_1}{X_2}\right) + P \sin\alpha + \left(\frac{P \cos\alpha . Y_1 + P \sin\alpha . S}{X_2} \right) \tag{2.6.7}$$

Note:
This equation (2.6.7) represents the mathematical expression for dynamic weight on rear wheel (i.e. R_2) in pull condition.
Here,

$W\left(1-\frac{X_1}{X_2}\right)$ = Static weight distribution on rear wheel in pull condition

$P\sin\alpha$ = weight of implement in rear wheel

$\left(\frac{P\cos\alpha.Y_1 + P\sin\alpha.S}{X_2}\right)$ = weight transfer

How to use in problems

Case 1:

When in clear words the static weight division on rear wheel and front wheel are given then Dynamic weight on rear wheel, R_2 = static weight on rear wheel (given) + weight of implement + weight transfer

Case 2:

When static weight division on rear wheel and front wheel are not given then to get dynamic weight on rear wheel, R_2, use equation (2.6.7) directly.

Summary

The effects of pulling implement are:

1. To add implement weight to rear wheels
2. To transfer some weight from front wheels to rear wheels

Motion of a tractor on level ground

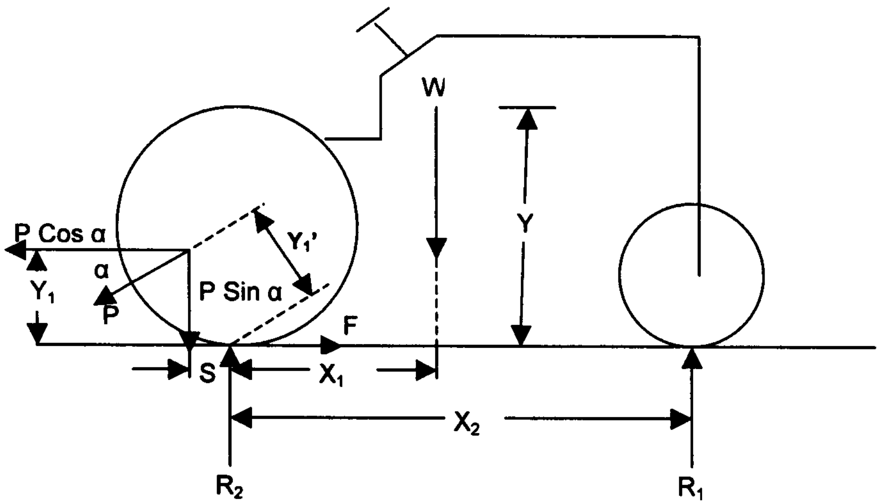


Fig. 2.6 Forces acting on a tractor on level ground

Analysis of motion of a tractor on level ground

$F = AC + R_2 \tan \phi$ (2.6.8)

Force balance

$R_1 + R_2 = W + P \sin \alpha$ (2.6.9)

$F = P \cos \alpha + TF_r = P \cos \alpha + R_2 \rho$ (2.6.10)

Momentum balance

Concept : Unstabilizing moment = Stabilizing moment

Case 1

When pull is parallel to horizontal ground

$R_1X_2 + PY_1 = WX_1$ (2.6.11)

Case 2

When pull is inclined with horizontal ground

(a) When pull is resolved into two components

$R_1X_2 + P \cos \alpha Y_1 + p \sin \alpha s = WX_1$ (2.6.12)

(b) When pull is measured from rear wheel contact point

$R_1 X_2 + P Y_1 = W X_1$ (2.6.13)

Notations:
Y_1 = perpendicular distance between the hitch point and ground surface
Y_1' = perpendicular distance between the hitch point and rear wheel contact point
S = perpendicular distance between the hitch point and rear wheel centre point
ρ = rolling resistance coefficient, also known as *motion resistance ratio*
ϕ = angle of internal friction

Motion of a tractor up a slope

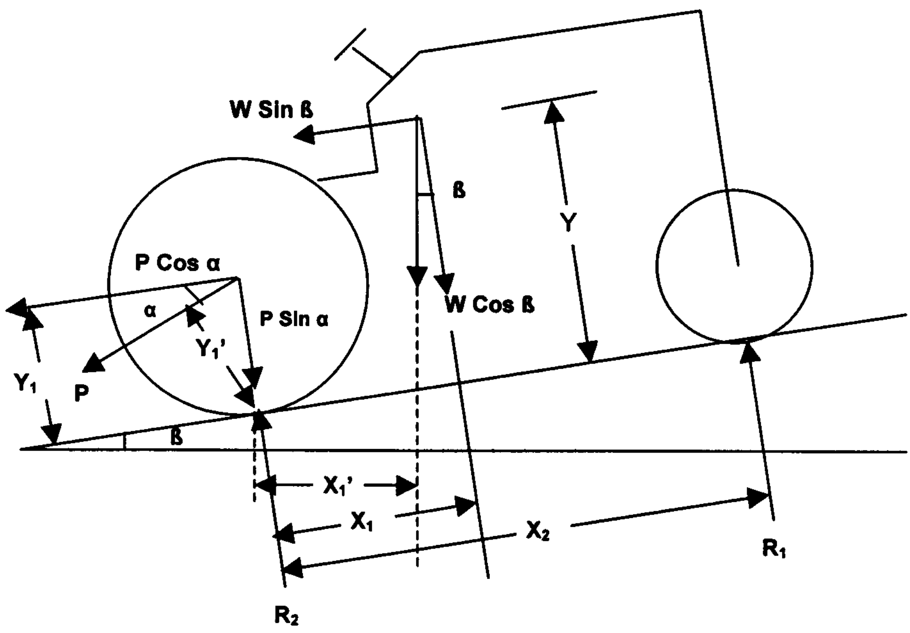


Fig.2.7 Forces acting on a tractor when in motion up a slope

Notations:
Y = perpendicular distance between centre of gravity and ground surface.
β = angle of the slope upon which tractor is moving up the slope
X_1 = perpendicular distance between reaction at rear wheel R_2 and W cos β

X_1' = perpendicular distance between rear wheel contact point and point where weight 'W' meets ground.

Analysis of motion of a tractor up a slope

$F = AC + R_2 \tan \emptyset$ (2.6.14)

Force balance:

$R_1 + R_2 = W \cos \beta + P \sin\alpha$ (2.6.15)

$F = W \sin \beta + P \cos\alpha$ (2.6.16)

Momentum balance:

Concept : Unstabilizing moment = Stabilizing moment

Case 1

When pull is parallel to ground

$R_1X_2 + PY_1 + W \sin\beta\, Y = W \cos\beta . X_1$ (2.6.17)

Case 2

When pull is inclined with horizontal

(a) When pull is resolved into 2 components

$R_1 X_2 + P \cos\alpha . Y_1 + P \sin\alpha . S + W \sin \beta Y = W \cos \beta X_1$ (2.6.18)

(b)When pull is measured from rear wheel contact

$R_1X_2 + PY_1' = WX_1'$ (2.6.19)

2.7 Power Transmission in Tractor

Steps in power transmission in a tractor

Piston cylinder

$\downarrow$

Connecting rod

$\downarrow$

Crank shaft

$\downarrow$

Clutch

$\downarrow$

Gear box

$\downarrow$

Bevel pinion

↓

Ring gear

↓

Rear half axle

↓

Final drive

↓

Bull gear

↓

Rear wheel

Note:

- Bevel pinion and ring gear are parts inside differential
- Ring gear is known as *crown gear* or *crown wheel*
- Final drive gear is known as *final gear*
- Bull gear is known as *final drive*
- Differential is known as *final differential unit.*

Schematic diagram of power flow

Engine

↓

$\boxed{2\pi N_e T_e}$

↓

Gear box

↓

$\boxed{2\pi N_G T_G}$

↓

Bevel pinion

↓

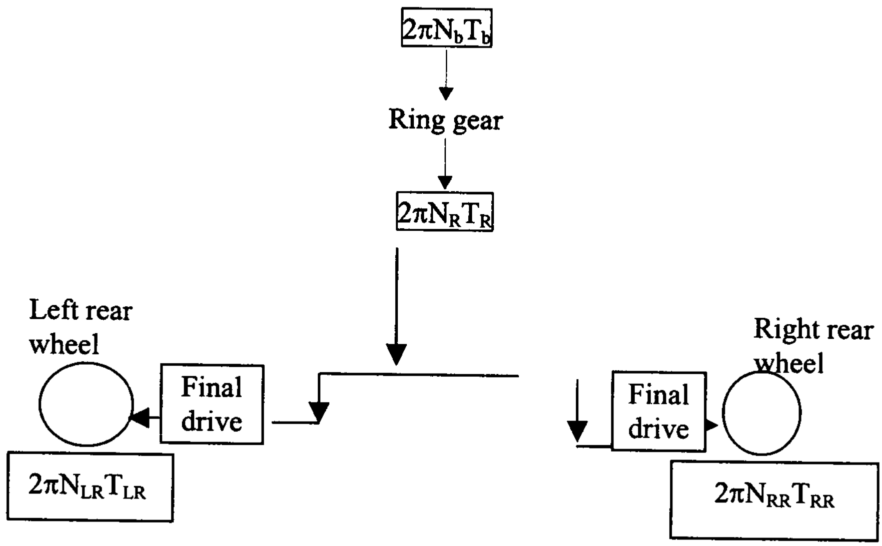


Fig. 2.8 Schematic diagram of power flow in a tractor

Equations:

$2\pi N_G T_G = 2\pi N_e T_e \times \eta_G$ (2.7.1)

$2\pi N_R T_R = 2\pi N_b T_b \times \eta_D = 2\Pi N_G T_G \times \eta_D$ (2.7.2)

Using equation (2.7.1) and (2.7.2)

$2\pi N_R T_R = 2\pi N_e T_e \times \eta_G \times \eta_D$ (2.7.3)

Notations:

N_e = rpm of engine
T_e = torque produced at engine
N_G = rpm at gear box
T_G = torque produced at engine
N_R = rpm at ring gear
T_R = torque at ring gear
N_{LR} = rpm at left rear wheel
T_{LR} = torque at left rear wheel
N_{RR} = rpm at right rear wheel
T_{RR} = torque at right rear wheel
$2\pi N_e T_e$ = power out put from engine
$2\pi N_G T_G$ = power out put from gear box
$2\pi N_b T_b$ = power out put from bevel pinion
$2\pi N_R T_R$ = power out put from ring gear
$2\pi N_{LR} T_{LR}$ = power at left rear wheel
$2\pi N_{RR} T_{RR}$ = power at right rear wheel
η_G = efficiency of power transmission through gear box
η_D = efficiency of power transmission through differential

Gear ratio

Gear ratio of tractor is also known as gear *reduction* in tractor.
Gear ratio of tractor = *gear ratio of gear box* X *gear ratio of differential* X *gear ratio of final drive* $= \frac{N_e}{N_G} \times \frac{N_G}{N_R} \times \frac{N_R}{N_{RR}}$ (2.7.4)

$$= \frac{Ne}{N_{RR}} = \frac{rpm\ at\ engine}{rpm\ at\ right\ rear\ wheel}$$

Note:

- RPM at right rear wheel is assumed to be same as that of left rear wheel
- Gear ratio or *gear reduction* through gear box is known as *reduction in transmission gear*

Mathematical analysis of power transmission

Straight travel of tractor

In case of straight travel of tractor, differential is not used

a) when no gear reduction at final drive

Here rpm of left and right rear wheels remain same as that of ring gear RPM, N_R but torque of ring gear, T_R become equally divided among left and right rear wheels i. e.

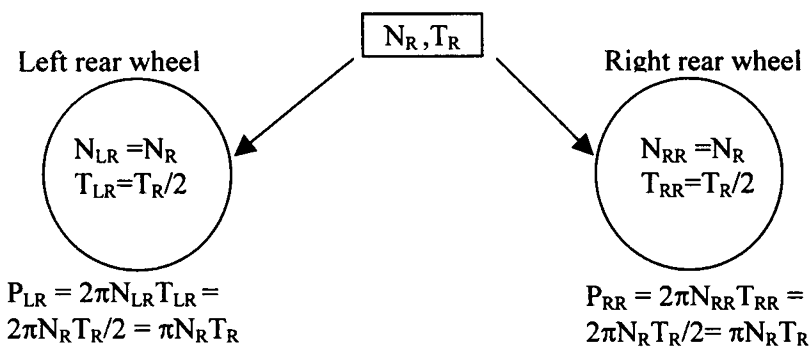
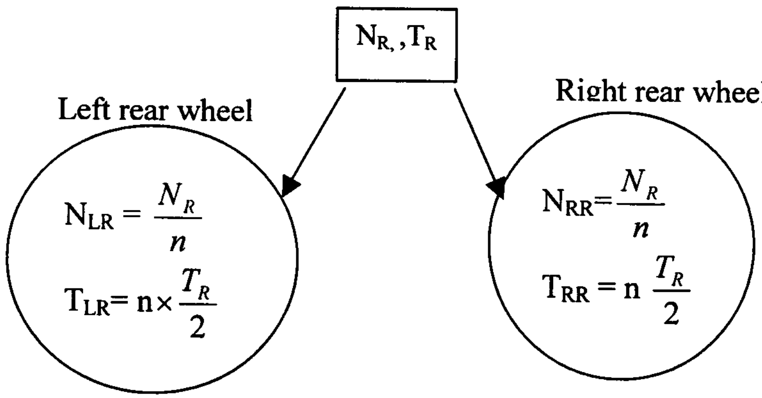


Fig. 2.9 Power distribution at rear wheels for straight travel of tractor

Power at both the rear wheels = $P_{LR} + P_{RR} = \pi N_R T_R + \pi N_R T_R = 2\pi N_R T_R$
Power at ring gear = $2\pi N_R T_R$
$\therefore$ Power is conserved

(b) **With gear reduction by a factor 'n' at final drive:**
In addition to previous case here due to gear reduction by a factor 'n' RPM at both left and right rear wheels become reduced by a factor 'n' and torque at respective wheels became 'n' times e.g.



$$P_{LR} = 2\pi N_{LR}\, T_L = 2\pi \times \frac{N_R}{n} \times \left(n \times \frac{T_R}{2}\right) = \pi\, N_R T_R$$

$$P_{RR} = 2\pi N_{RR}\, T_{RR} = 2\pi \times \frac{N_R}{n} \times \left(n \times \frac{T_R}{2}\right) = \pi\, N_R T_R$$

Fig.2.10 Power distribution at rear wheels with gear reduction

Power at both the rear wheels = $P_{LR} + P_{RR} = \pi N_R T_R + \pi N_R T_R = 2\pi N_R T_R$
Power at ring gear = $2\, \pi N_R T_R$
Power is conserved

2.8 Pumps and Motors

Schematic Diagram for flow of fluid and power

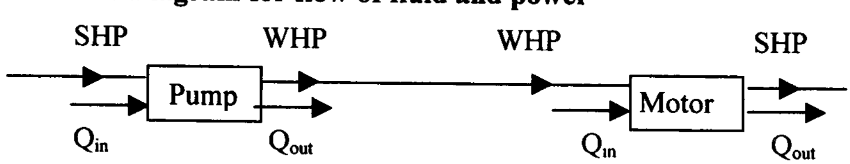


Fig. 2.11 Schematic diagram for flow of fluid and power in pumps and motors

Pump

$$\eta_v = \frac{Q_{out}}{Q_{in}} = \frac{Q_{out}}{DN} = \frac{Q_{ac}}{Q_{th}} \tag{2.8.1}$$

$$\eta_{oa} = \eta_v \times \eta_T \tag{2.8.2}$$

$$\eta_{oa} = \frac{Power_{out}}{Power_{in}} = \frac{Power_{th}}{Power_{ac}} = \frac{WHP}{SHP} = \frac{\Delta P Q_{out}}{2\pi NT} \tag{2.8.3}$$

Motor

$$\eta_v = \frac{Q_{out}}{Q_{in}} = \frac{DN}{Q_{in}} = \frac{Q_{th}}{Q_{AC}} \tag{2.8.4}$$

$$\eta_{oa} = \eta_v \times \eta_T \tag{2.8.5}$$

$$\eta_{oa} = \frac{Power_{out}}{Power_{in}} = \frac{Power_{ac}}{Power_{th}} = \frac{SHP}{WHP} = \frac{2\pi NT}{\Delta P Q_{in}} \tag{2.8.6}$$

Notations::

SHP	=	shaft horse power (input power to pump and output power from motor)
WHP	=	water horse power (output power from pump and input power to motor)
Q_{in}	=	input flow of water to both pump and motor
Q_{out}	=	output flow of water from both pump and motor
$Power_{th}$	=	theoretical power
$Power_{ac}$	=	actual power
η_v	=	volumetric efficiency
η_T	=	torque efficiency , also known as *mechanical efficiency*
η_{oa}	=	overall efficiency
D	=	displacement volume, m^3 *per revolution*
N	=	rpm
ΔP	=	pressure drop across pump or motor, N/m^2
T	=	torque, *N.m*

Chapter 3

Food Processing Engineering

3.1 Kinetics of Microbial Growth

D value

D value, also known as *decimal reduction time* is the *time required to reduce the number of microorganisms by a factor 10.* More clearly, it is the time required for 90% reduction in the original number of microorganisms. It can also be defined as the *time required for one log cycle reduction in the original number of microorganisms.*

Mathematically,

$$t = \frac{1}{k}\ln\left[\frac{N_0}{N}\right] \tag{3.1.1}$$

$$\Rightarrow D = \frac{1}{k}\ln\left[\frac{N_0}{N_0/10}\right] = \frac{1}{k}\ln 10$$

$$\Rightarrow D = \frac{2.303}{k} \tag{3.1.2}$$

Combining equation (3.1.1) and (3.1.2)

$$t = D\log_{10}(N_0/N) \tag{3.1.3}$$

Notations:
N_0 = initial spore load, also known as *contamination level*
N = sterility level

12 D value

12 D value is the minimum heating time or process time required to reduce the number of microorganisms by a factor 10^{12}. It is also known as *time required for 12 log cycle reduction* or simply *12 – D reduction* in original number of microorganisms.

12 log cycle reduction means: 1 survival out of 10^{12} number of microorganisms

i.e. $\dfrac{N_0}{N} = 10^{12}$

i.e. probability of survival of microorganisms = 1 in 10^{12}

Thus, it is also known as *99.9999999999 % inactivation of micro-organisms.*

Half life period

Half life period is the time period during which number of microorganisms is reduced by a factor 2

$$\text{i.e. } t = \frac{1}{k}\ln\left(\frac{N_0}{N}\right) \tag{3.1.4}$$

$$\Rightarrow t_{1/2} = \frac{1}{k}\ln\left(\frac{N_0}{N_0/2}\right) = \frac{1}{k}\ln 2$$

$$\Rightarrow t_{1/2} = D\log_{10} 2 \tag{3.1.5}$$

F value

F value is known as the *processing time* or *thermal death time*. It is defined as the *time required in accomplishing the stated reduction in population of microorganisms*. It is usually denoted by F_T^Z where subscript indicates process temperature and superscript indicates the Z value for the microorganisms. So either changing Z or T or both, changes the F value.

Note:

- 121°C (250°F) is the reference temperature for sterilization and 65.6°C (150°F) is the reference temperature for pasteurization. So, for sterilization the values of *F and* D at 121°C are termed as F_0 and D_0 respectively. Likewise for pasteurization the values of F & D at 65.6°C are termed as F_0 and D_0 respectively.
- F_{121}^{10} or F_{250}^{18} is known as *reference thermal death time* and is denoted by the symbol F_0.

Q_{10} value

Q_{10} value is defined as the number of times a reaction rate changes with 10^0 change (either decrease or increase) in temperature i.e. if a reaction rate doubles with 10^0 change in temperature then $Q_{10} = 2$

$$\therefore \frac{k_1}{k_2} = Q_{10}^{\left(\frac{T_1 - T_2}{10}\right)} \tag{3.1.6}$$

Notations:

k_1, k_2 = reaction rate constants at temperature T_1 and T_2 respectively.

Z value

Z value is known as *thermal resistant constant.* It is defined as *the temperature change needed to change the microbial inactivation by a factor 10.* Generally, Z value is used to represent increase in temperature for increasing death rate by a factor 10. In other words, it is defined as *the temperature range for 10:1 change in the D value or F value.* It can also be defined as *the increase in temperature for 90% reduction in the D value* or *decimal reduction time*

$$\therefore \frac{k_1}{k_2} = 10^{\left(\frac{T_1 - T_2}{Z}\right)} \tag{3.1.7}$$

Parent equations

$$\frac{D_{T2}}{D_{T1}} = 10^{\left(\frac{T_1 - T_2}{Z}\right)} \tag{3.1.8}$$

$$\Rightarrow \frac{D_T}{D_0} = 10^{\left(\frac{T_0 - T}{Z}\right)}$$

Notations:

D_T, D_{T1}, D_{T2} are decimal reduction times at temperatures T, T_1 and T_2 respectively.

Likewise,

$$\frac{F_{T2}}{F_{T1}} = 10^{\left(\frac{T_1 - T_2}{}\right)} \tag{3.1.9}$$

$$\Rightarrow \frac{F_T}{F_0} = 10^{\left(\frac{T_0 - T}{Z}\right)}$$

Notations:

F_T, F_{T1} and F_{T2} are thermal death times at temperatures T, T_1, T_2 respectively.

Also, we know

$$t = D \log \frac{N_0}{N}$$

$$\Rightarrow \frac{t}{D} = \log \frac{N_0}{N}$$

$$\Rightarrow \frac{F}{D} = \log \frac{N_0}{N}$$

$$\Rightarrow \frac{F_T}{D_T} = \log \frac{N_0}{N} \qquad (3.1.10)$$

$$\Rightarrow \frac{F_0}{D_0} = \log \frac{N_0}{N}$$

Notations:

F_0 and D_0 are reference thermal death time and reference decimal reduction time respectively.

Lethal rate and Lethality

We know, $\frac{F_T}{F_0} = 10^{\left(\frac{T_0 - T}{z}\right)}$

$$\Rightarrow \frac{F_0}{F_T} = 10^{\left(\frac{T - T_0}{z}\right)} \qquad (3.1.11)$$

Here, $\frac{F_0}{F_T}$ is known as *lethal rate* and F_0 is known as *lethality*

∴ Lethality = F_T X lethal rate

Physical meaning of F_0 and F_T

Physically, F_0 is the process time at 121^0C (*250^0F*) that will produce same degree of sterilization (known as *equivalent lethality*) as the given process at its temperature *T*. It implies F_0 is the equivalent heating time for the process at a temperature of 250^0F. Likewise F_T is the equivalent heating time for the process at a temperature of T ^{0}F.

Sterilizing Value

Sterilizing value represents the number of log cycles required to accomplish the stated reduction in population of microorganisms.

Mathematically,

Sterilizing value = $\log \frac{N_0}{N}$

$$\therefore t = D\log\frac{N_0}{N} = \mathrm{D} \times \text{number of log cycles}$$

$$= \mathrm{D} \times \text{sterilizing value} \qquad (3.1.12)$$

Note:

It is important to note that for conversion of a particular temperature between 'C' and 'F', the equation C = (F-32)/1.8 is used. But for conversion of range of temperature between 'ΔC' and 'ΔF', the equation $\Delta C = \Delta F/1.8$ is used.

The parent equation for kinetics of microbial death

$$\frac{D_{T2}}{D_{T1}} = \frac{F_{T2}}{F_{T1}} = \frac{k_1}{k_2} = 10^{\left(\frac{T_1-T_2}{Z}\right)} = Q_{10}^{\left(\frac{T_1-T_2}{10}\right)} = e^{\frac{E_a}{R}\left(\frac{1}{T_2}-\frac{1}{T_1}\right)} \qquad (3.1.13)$$

Notations:

E_a = activation energy

R = universal gas constant

3.2 Drying of grain

Thin layer drying

Rate of Drying ($\dot{W}$)

$$\dot{W} = \frac{IMC - FMC}{t} \qquad (3.2.1)$$

Where,

$$IMC = \frac{W_i m_i}{100} = \frac{W_d M_i}{100} = W_d X_i \qquad (3.2.2)$$

$$FMC = \frac{W_f m_f}{100} = \frac{W_d M_f}{100} = W_d X_f \qquad (3.2.3)$$

Where,

$W_d = IMC - W_i$

Notations:

$\dot{W}$ = rate of water evapouration, kg/hr

IMC = initial moisture content, kg

FMC = finial moisture content after 't' hour, kg

W_d = amount of dry matter in the product, kg

W_i = initial mass of the product, kg

W_f = final mass of the product after 't' hour, kg

m_i = initial moisture content, % wet basis
m_f = final moisture content after 't' hour, % wet basis
M_i = initial moisture content, % dry basis
M_f = final moisture content after 't' hour, % dry basis
X_i = initial moisture content, kg/kg dry basis
X_f = final moisture content after 't' hour, kg/kg dry basis

Vapour pressure and moisture content

P_v = vapour pressure of moisture in grain, also known as *grain vapour pressure*

P_s = vapour pressure of pure liquid at surface in equilibrium, also known as *saturated vapour pressure*

Condition 1:
$P_v < P_s$, then environment for 100% humidity (H) exists and this moisture is known as *bound moisture*

Condition 2:
$P_v = P_s$, then environment for 100% relative humidity (ø) exists and this moisture is known as *unbound moisture*

Condition 3:
$P_v > P_s$, then environment for moisture removal exists i.e. only this moisture can be removed from the product and this moisture is known as *free moisture* or *moisture content above equilibrium*

Methods to calculate constant drying rate, R_c

Method 1

$$R_c = \frac{W_d}{A}\left(\frac{X_1 - X_2}{t_c}\right) \qquad (3.2.4)$$

Notations:
R_c = constant drying rate, kg/hr-m^2
W_d = weight of dry solid, kg
A = wet surface area, m^2
X_1 = initial moisture content, kg/kg dry basis
X_2 = final moisture content, kg/kg dry basis
t_c = constant drying rate period, hr

Equation (3.2.4) satisfies when $X_2 < X_c$ but when $X_2 = X_c$

$$R_c = \frac{W_d}{A} = \left(\frac{X_1 - X_c}{t_c} \right) \tag{3.2.5}$$

Here, Xc = critical moisture content, kg/kg dry basis

Method 2

When temperature is driving force:

$$R_c = \frac{\dot{W}}{A} = \frac{q}{A\lambda_w} = \frac{hA(T-T_w)}{A\lambda_w} = \frac{h(T-T_w)}{\lambda_w} \tag{3.2.6}$$

Notations:

$\dot{W}$ = total constant drying rate, kg/hr
λ_w = latent heat of vapourization at T_w
q = rate of heat transfer
T = dry bulb temperature of air
T_w = wet bulb temperature of air, also known as *psychrometric wet bulb temperature of air*

Note:

$T_w = T_s$ (for moist air)
$T_w < T_s$ (for dry air)
$T_s < T$ (for both)

Here, Ts = adiabatic saturation temperature of air, also known as *thermodynamic wet bulb temperature of air.*

Method 3

When humidity is driving force::

$$R_c = \frac{\dot{W}}{A} = \frac{q}{A\lambda_\omega} = \frac{K_y M_B A\lambda_\omega (H_w - H)}{A\lambda_\omega}$$

$$= K_y M_B (H_w - H) = K_g (H_w - H) \tag{3.2.7}$$

Notations:

K_y = mass transfer coefficient, kg-mol/hr-m^2
M_B = molecular mass of water vapour = 18
K_g = mass transfer coefficient, kg/hr-m^2
H_w = humidity at temperature, T_w
H = humidity at temperature, T

Note:

$K_g = K_y M_B$ and $K_g' = K_y' M_A$

Thus unit of pressure (P) is mm of Hg, then units of K_y' and K_g' are kg-mol/hr-m^2 and kg/hr-m^2 respectively and when unit of 'P' is atmosphere then units of Ky' and Kg' are kg-mol/hr-m^2-atm and kg/hr-m^2-atm respectively.

Grain drying and grain dryer

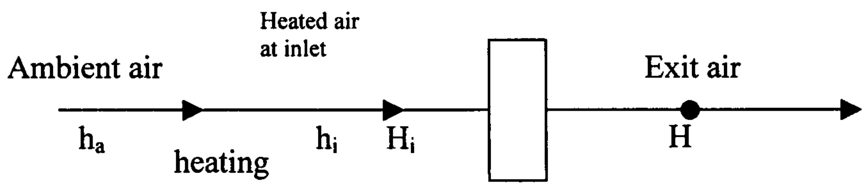


Fig. 3.1 Flow of air in a grain dryer

$$Q_s = \dot{A}(h_i - h_a) = \dot{A}[C_p(T_i - T_a)] = \left(\dot{V}\big/V_H\right)[C_p(T_i - T_a)] \tag{3.2.8}$$

$$Q_r = \dot{W}\lambda = [\dot{A}(H_e - H_i)]\lambda = \left[\left(\dot{V}\big/V_H\right)(H_e - H_i)\right]\lambda \tag{3.2.9}$$

Notations:

Q_s = rate of heat supply to ambient air, kJ/hr

Q_r = rate of heat removal from heated air in evapourating water inside dryer, kJ/hr

$\dot{A}$ = mass flow rate of dry air, kg/hr

h_i = enthalpy of heated air at inlet of dryer, kJ/kg

h_a = enthalpy of ambient air, kJ/kg

C_p = specific heat of dry air, kJ/kg-k

T_i = temperature of heated air at inlet of dryer, k

T_a = temperature of ambient air, k

$\dot{V}$ = volumetric flow rate of dry air, m^3/kg

V_H = specific volume of dry air, m^3/kg

$\dot{W}$ = rate of water evapouration, kg/hr

λ = latent heat of evapouration of water, kJ/kg

H_i = humidity of heated air at inlet of dryer, kg/kg

H_e = humidity of air at exit of dryer, kg/kg

Thermal efficiency of dryer

Thermal efficiency is also known as *overall thermal efficiency* of the dryer.

Methods to calculate thermal efficiency of dryer

Method 1

$$TE = \frac{Q_u}{Q_i} = \frac{\dot{W}}{\dot{F}C} \tag{3.2.10}$$

where,

$$\dot{W} = \frac{W_d}{t}\left(\frac{M_i - M_f}{100}\right) = \frac{W_d}{t}(X_i - X_f) \tag{3.2.11}$$

$$\dot{F}C = \dot{A}(\Delta h) = \dot{A}(h_i - h_a) \tag{3.2.12}$$

Notations:

Q_u = heat utilized in evapourating water, kJ/kg
Q_i = heat input for evapouration of water, kJ/kg
λ = latent heat of evapouration of water, kJ/kg
$\dot{W}$ = rate of water evapouration, kg/hr
$\dot{F}$ = rate of fuel consumption, kg/hr
C = calorific value of fuel, kJ/kg
W_d = amount of dry matter in grain, kg
t = time of drying, hr
M_i = initial moisture content, % dry basis
M_f = final moisture content, % dry basis
X_i = initial moisture content, kg/kg dry basis
X_f = final moisture content, kg/kg dry basis
$\dot{A}$ = mass flow rate of dry air, kg/hr
h_i = enthalpy of heated air at inlet of dryer, kJ/kg
h_a = enthalpy of ambient air, kJ/kg

Method 2

$$TE = \left(1 - \frac{R}{100}\right) \times HUF \tag{3.2.13}$$

Notations:

R = radiation loss in % of total temperature drop in the dryer

HUF = heat utilization factor of dryer

Methods to calculate HUF
Method 1

$$HUF = \frac{\text{heat utilized}}{\text{heat supplied}}$$

$$= \frac{\text{air temperature decreased during drying}}{\text{air temperature increased for drying}} = \frac{t_2 - t_3}{t_2 - t_1} \qquad (3.2.14)$$

Method 2
HUF = 1 – COP
Notations:
COP = coefficient of performance of dryer
t_1 = temperature of ambient air
t_2 = temperature of heated air flowing into dryer
t_3 = temperature of exit air from dryer

3.3 Psychrometry

Psychrometry
Study of water vapour or moisture is known as *psychrometry*

Humidity, H
Humidity is also known as specific humidity or *absolute humidity* or *humidity ratio* or simply as *moisture content*
Methods to calculate humidity
Method 1

$$\text{Humidity, H} = \frac{m_v}{m_a} \qquad (3.3.1)$$

Notations:
m_v = mass of water vapour, kg
m_a = mass of dry air, kg

Method 2

$$H = 0.622\frac{P_v}{P_a} = 0.622\frac{P_v}{P - P_v} \qquad (3.3.2)$$

Notations:
P_v = partial pressure of water vapour

P_a = partial pressure of dry air
P = total pressure of moist air, also known as *atmospheric pressure* or *barometric pressure* = 101.3 kPa
Note:

- Method-1 provides a mass basis definition of humidity but some authors also have given volume basis definition humidity as follows,

$$H = \frac{\text{mass of water vapor, kg}}{\text{volume of air, m}^3}$$

Saturation humidity, H_s
Saturation humidity is also known as *humidity of saturated air* or *maximum humidity.*

$$H_s = 0.622\left(\frac{P_s}{P-P_s}\right) \tag{3.3.3}$$

Notations:
P = total pressure of moist air, also known as *atmospheric pressure*
P_s = partial pressure of saturated air at dry bulb temperature, also known as *saturation pressure of water vapour at dry bulb temperature* or vapour pressure of pure water

Percentage humidity, H_p
Percentage humidity is also known as *degree of saturation* of moist air.

Methods to calculate percentage humidity
Method 1

$$H_p = \frac{m_v}{m_{vs}} \tag{3.3.4}$$

m_v = mass of water vapour in a given mass of dry air, kg
m_{vs} = mass of water vapour when same mass of dry air is saturated, kg

Method 2

$$H_p = \frac{H}{H_s} \tag{3.3.5}$$

where,

$$H = \frac{P_v}{P-P_v} \text{ and } H_S = \frac{P_s}{P-P_s}$$

Relative humidity, ø

Relative humidity is also known as *percentage relative humidity*

Methods to calculate relative humidity

Method 1

$$\phi = \frac{m_v}{m_s} \quad (3.3.6)$$

Notations:

m_v = mass of water vapour in a given volume of moist air

m_s = mass of water vapour when same volume is saturated at same temperature

Method 2

$$\phi = \frac{P_v}{P_s} \quad (3.3.7)$$

Notations:

Pv = partial pressure of water vapour

P_s = saturation pressure of water vapour

Method 3

$$\phi = \frac{X_v}{X_s} \quad (3.3.8)$$

Notations:

X_v = mole fraction of water vapour in a given mass of moist air

X_s = mole fraction of water vapour when same mass is saturated

Humid heat, C_S

Humid heat = heat required to raise the temperature of 1 kg of dry air plus its accompanying water vapour by 1^0C

= specific heat of 1 kg of dry air + specific heat of accompanying water vapour

= 1.005 kJ/kg-k + 1.88 H kJ/kg-k

∴ Humid heat = 1.005 kJ/kg-k + 1.88 H kJ/kg-k (3.3.9)

Enthalpy, h

Enthalpy is also known as *heat content* or *specific enthalpy.*

Enthalpy, h = heat content of 1 kg of dry air plus its accompanying water vapour

= heat content of 1 kg of dry air + [heat content of water vapour]

= sensible heat of 1 kg of dry air + [sensible heat of water vapour + latent heat of water vapour]
$= 1.005\ (T-T_0) + [1.88\ (T-T_0)\ H + H\lambda_0]$
$= \{1.005\ (T-T_0) + 1.88\ (T-T_0)\ H\} + H\lambda_0$ (3.3.10)
= {sensible heat of mixture} + latent heat of mixture

If datum temperature of 0^0C is considered, as generally done, then $T_0 = 0$

$\therefore$ Enthalpy, $h = [1.005\ T + 1.88\ HT] + H\lambda_0$
$= [1.005 + 1.88\ H]\ T + H\lambda_0$
$= C_s\ T + H\lambda_0$

$\therefore$ *Enthalpy,* $h = C_s\ T + H\lambda_0$ *kJ/kg* (3.3.11)

Note:

- λ_0 = latent heat of water vapour at T_0 (i.e. at 0^0C) = 2501 kJ/kg
- Heat capacity is also known as *specific heat*

Humid volume, V_H

Humid volume is also known as *specific volume*

Physically,

Humid volume = total volume of 1 kg of dry air plus its accompanying water vapour

Mathematically,

$\therefore\ V_H = (0.00283 + 0.00456\ H)\ (t + 273)\ m^3/kg$ (3.3.12)

3.4 Analysis of Boiling

Analysis of change of state of any liquid (or water) can be expressed with the help of three types of diagrams.

- Pressure – enthalpy (P - h) diagram
- Pressure – volume (P - V) diagram
- Temperature – entropy (T - S) diagram

But P – h diagram is most useful in this respect and it is a bell shaped curve.

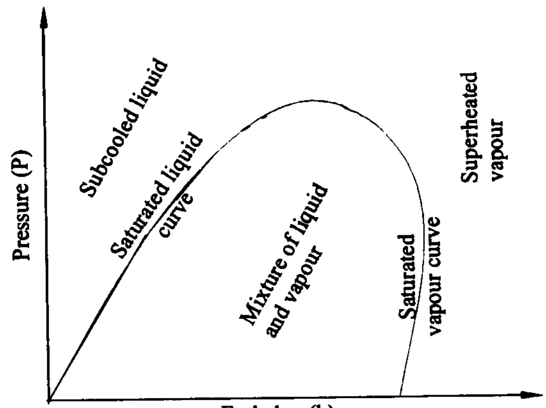


Fig 3.2 P – h diagram for change of state of liquid

Subcooled liquid

When at saturation pressure the temperature of liquid is lowered below boiling temperature (i.e. saturation temperature) then the liquid is known as subcooled liquid e.g. at pressure of 1 atmosphere if temperature of water is lowered below 100^0C then this is known as subcooled water.

Note: *Saturation temperature* is the temperature at which vapourization takes place at a given pressure and saturation pressure is the pressure corresponding to saturation temperature of the liquid.

Saturated liquid

When a substance occurs as liquid at its saturation temperature and pressure it is called as saturated liquid. Here water is in equilibrium with its vapour.

Saturated vapour

When a substance occurs as vapour at its saturation temperature and saturation pressure, it is called as saturated vapour. Here water is in equilibrium with steam.

Superheated vapour

When temperature of vapour is greater than saturation temperature at the existing pressure, it is called as superheated vapour

Note: The terms *vapour* and *water vapour* are used synonymously.

Wet steam

Steam produced with water particles as a result of heating saturated liquid is known as wet steam. Thus wet steam is a mixture of liquid and vapour at boiling temperature as some liquid is converted into vapour by absorbing latent heat of vapourization i.e. wet steam = water vapour + water particles. Wet steam is also known as *partially saturated water vapour.*

Dry steam

Steam produced with all the water particles being converted into vapour as a result of heating saturated liquid is known as dry steam. It is also known as *dry saturated steam* or *saturated water vapour* or *water vapour* or simply as *vapour*

Boiling

Boiling occurs when the vapour pressure of the water is equal to the total pressure above the water surface e.g. at 100^0C, vapour pressure of water is equal to 1 atmosphere. Thus at a combination of 100^0C temperature and 1 atmospheric pressure water will boil. Likewise at 105^0C temperature, vapour pressure of water is equal to 1.2 atmospheres. Thus, at a combination of 105^0C temperature and 1.2 atmospheric pressure water will also boil.

Dryness fraction, x

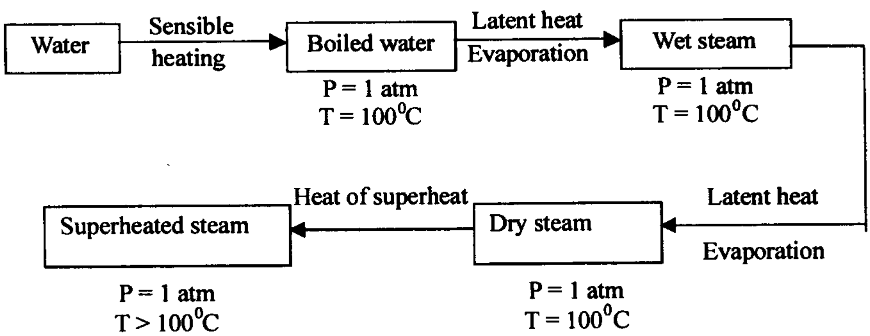
Dryness fraction is also known as *steam quality*. It is defined as the extent to which phase change from saturated liquid stage to saturated vapour stage has progressed.

$$\therefore \text{Dryness fraction} = \frac{\text{weight of dry steam}}{\text{weight of wet steam}}$$

$$= \frac{\text{weight of dry steam}}{\text{weight of dry steam } + \text{ weight of water}}$$

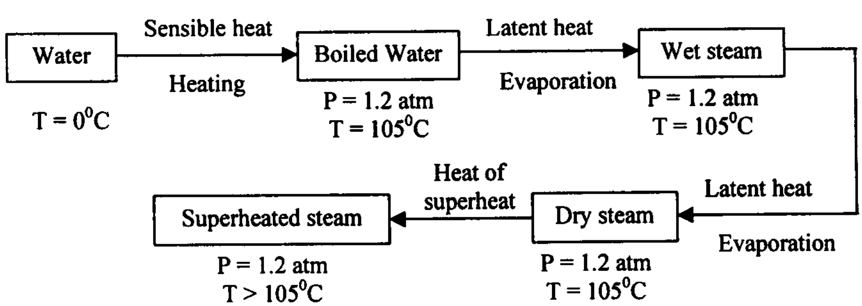
Heat Analysis

Case 1:



- Sensible heat of 1 kg of boiled water at 100^0C and 1 atmosphere pressure = $mCp\Delta T = 1\times 4.187 \times 100 = 419$ kJ/kg
- Latent heat of 1 kg of steam at 100^0C and 1 atmospheric pressure = 2257 kJ/kg
- Total heat = 2676 kJ/kg

Case 2:



- Sensible heat of 1 kg of boiled water at 105^0C and 1.2 atmospheric pressure = $mCp\Delta T = 1 \times 4.22 \times 105 = 443$ kJ/kg
- Latent heat of 1 kg steam at 105^0C and 1.2 atmospheric pressure = 2241 kJ/kg
- Total heat = 2684 kJ/kg

From the above two case studies it is important to note that:

- Specific heat of any liquid varies with boiling temperature (i.e. saturation temperature) of the liquid.
- Boiling temperature of any liquid varies directly with pressure i.e. if pressure is increased above 1 atmosphere then boiling temperature of water is increased above 100^0C and if pressure is decreased below 1 atmosphere then boiling temperature of water is decreased below 100^0C.
- As pressure increases
  - Boiling temperature of liquid increases
  - Sensible heat increases & latent heat decreases
  - Total heat increases

Physical quantities	Boiled water	Wet steam	Dry steam	Superheated steam
Pressure	1 atm	1 atm	1 atm	1 atm
Temperature	100^0C	100^0C	100^0C	> 100^0C
State	Only liquid	Liquid – Vapour mixture	Only vapour	Only vapour
Enthalpy (h)	h_c	$h_w = h_c + x\lambda$ $= h_c + x\,(h_s - h_c)$	$h_s = h_c + \lambda$ $(\Theta\ x = 1)$	$h_{sup} = h_c + \lambda + e_{sup}$
Specific volume	–	$xV_s + (1-x)\,V_w$	V_s $(\Theta\ x = 1)$	$V_s \times \left(T_{sup}/T_s\right)$

Notations:

h_c = enthalpy of condensate
h_w = enthalpy of wet steam
h_s = enthalpy of dry steam
h_{sup} = enthalpy of superheated steam
V_s = specific volume of dry steam
V_w = specific volume of liquid
e_{sup} = heat of superheat = C_p (steam) × ($T_{sup} - T_s$)
T_{sup} = temperature of superheated steam
T_s = temperature of dry steam
$T_{sup} - T_s$ = degree of superheat
x = dryness fraction, also known as *steam quality*
λ = latent heat of steam

Note:

- Total heat (or heat content) of any state is known as *enthalpy* of that state.
- Sensible heat is also known as *liquid heat* or *total heat of water*
- Boiled water is also known as *saturated water* or *condensate.*

3.5 Milling

Sphericity, ø

Sphericity is also known as *sphericity shape factor* or simply as *shape factor*

Methods to calculate sphericity

Method 1

$$\phi = \frac{S_s}{S_p} = \frac{\pi D_p^{\ 2}}{S_p} \tag{3.5.1}$$

Notations:

S_s = surface area of a sphere having same volume as the particle

S_p = actual surface area of the particle

For large particles (i.e. diameter > 1mm):

D_p = diameter of the sphere having the same volume as that of the particle, also known as *equivalent diameter of the particle* or *geometric mean diameter of the particle*

For fine particles (i.e. Diameter < 1mm):

D_p = sieve analysis diameter, also known as *nominal diameter* of the particle

Method 2

$$\phi = \frac{D_i}{D_c} \tag{3.5.2}$$

Notations:

D_i = diameter of largest circle inscribing the particle

D_c = diameter of smallest circle circumscribing the particle

Method 3

$$\phi = \frac{D_p}{D_c} = \frac{\left(\frac{\pi}{6} lbt\right)^{\frac{1}{3}}}{\left(\frac{\pi}{6} l^3\right)^{\frac{1}{3}}} = \frac{(lbt)^{\frac{1}{3}}}{l} \qquad (3.5.3)$$

Notations:
l = length of particle, also known as *longest length* of the particle
b = breadth of particle, also known as *intermediate length* of the particle
t = thickness of particle, also known as *smallest length* of the particle

CLEANING

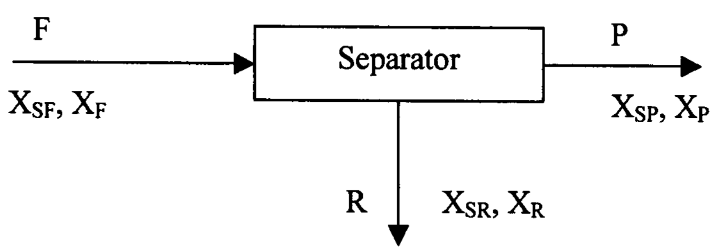


Fig.3.3 Separation activity in a separator

Total material balance:
total material in = total material out

$$\therefore F = P + R \qquad (3.5.4)$$

Total solid balance:
Total solid in = Total solid out

$$\therefore F.X_{SF} = P.X_{SP} + R.X_{SR} \qquad (3.5.5)$$

Desired material balance:
total desired material in = total desired material out

$$\therefore F.X_F = P.X_P + R.X_R \qquad (3.5.6)$$

Notations:
F = amount of feed into separator
P = amount of product (i.e. overflow material)
R = amount of rejected (i.e. underflow material)
X_{SF} = mass fraction of solid in feed
X_{SP} = mass fraction of solid in product,

X_{SR} = mass fraction of solid in rejected
X_F = mass fraction of desired material in feed,
X_P = mass fraction of desired material in product
X_R = mass fraction of desired material in rejected
Note:
When desired material is liquid or oil then

$$X_{SF} + X_F = 1 \tag{3.5.7}$$

$$X_{SP} + X_P = 1 \tag{3.5.8}$$

$$X_{SR} + X_R = 1 \tag{3.5.9}$$

Cyclone separator

Inside cyclone separator, particles are acted upon by 2 forces i.e. centrifugal force and gravitational force. Centrifugal force helps in separating out air-borne materials i.e. lighter products at top of cyclone from heaver particles which are discharged at the bottom of the cyclone.

$$F_C = \frac{MV^2}{R} \tag{3.5.10}$$

$$W = Mg \tag{3.5.11}$$

$$S = \frac{F_C}{W} = \frac{V^2}{Rg} \tag{3.5.12}$$

Notations:
F_C = centrifugal force
W = weight of particle
R = radius of cyclone
V = entrance velocity
S = separation factor, also known as *performance factor*
M = mass of particle
Note:
Separation factor, S, represents *cyclone efficiency* or *separation efficiency* of cyclone separator. It is related to other factors as follows

$S \alpha L$
$S \alpha V$
$S \alpha M$
$S \alpha D_P$
$S \alpha 1/R$
$S \alpha 1/D_e$

Notations:
L = length (height) of cyclone

V = Entrance velocity of particles
D_P = Size (diameter) of particle
R = radius of cyclone, also known as *radius of rotation of particles*
D_e = outlet (exit) duct diameter of cyclone

3.6 Evaporator

Single Effect Evaporator

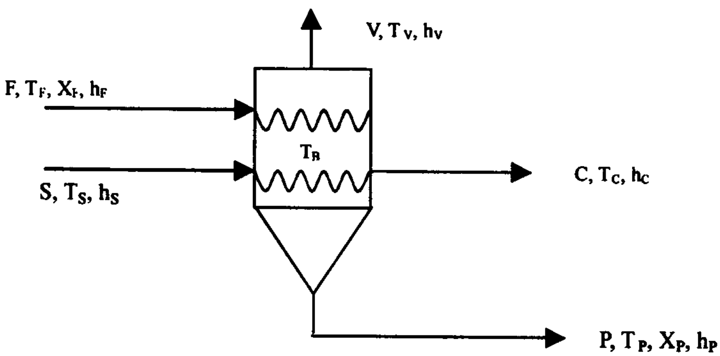


Fig.3.4 Evapouration in a single effect evaporator

Mass balance:
$F = P + V$ (3.6.1)
Solid balance:
$F.X_F = P.X_P$ (3.6.2)
Heat balance:
$F.h_F + S.h_S = P.h_P + V.h_V + C.h_C$ (3.6.3)
$F.h_F + S.h_S - C.h_C = P.h_P + V.h_V$
$F.h_F + S\,(h_S - h_C) = P.h_P + V.h_V$
$F.h_F + S\lambda = P.h_P + V.h_V$ 3.6.3 (a)
$F.h_F + Q = P.h_P + V.h_V$ 3.6.3 (b)
Note:

- $C = S$, $T_C = T_S$, $T_B = T_V = T_P$
- $h_F = C_{PF}\,(T_F - 0)$, T_F in centigrade
  $= C_{PF}\,(T_F - 273)$, T_F in kelvin
- $h_P = C_{PP}\,(T_P - 0)$, T_P in centigrade
  $= C_{PP}\,(T_P - 273)$, T_P in kelvin

Note:
It is important to note that h_F, h_P, must be calculated assuming datum

temperature as 0^0C as given above. It is erroneous to take boiling temperature of liquid (T_B) as datum temperature.

Notations:

F, S = amount of feed and steam entering evaporator

P, V, C = amount of product, vapour and condensate leaving evaporator

h_V = enthalpy of saturated steam at a temperature T_V

h_F = enthalpy of feed at temperature T_F

h_C = enthalpy of condensate at temperature T_C

h_P = enthalpy of product at a temperature T_P

X_F = mass fraction of solid in feed

X_P = mass fraction of solid in product

C_{PF}, C_{PP} = specific heat of feed and product respectively

λ = latent heat of steam at temperature T_S

Q = heat transfer in evaporator

Multiple effect evaporator

To recover and reuse much of latent heat of vapour that is being wasted in single effect (single stage) evaporator, multiple effect evaporator is used.

Forward Feed Triple Effect Evaporator

It is used when feed is hot

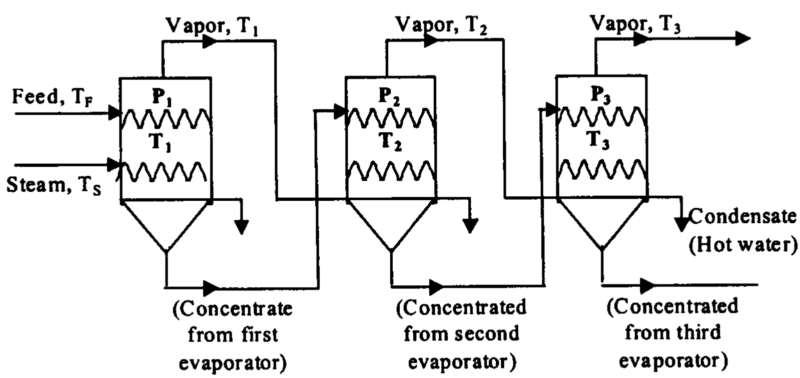


Fig.3.5 Evapouration in a forward feed triple effect evaporator

Mechanism

Vapour generated in first evaporator enters heating section of second evaporator and condenses there. It implies that heat is removed (known as heat vapourization) from the entering vapour which condenses inside second evaporator. Then this heat is transferred into boiling liquid of second evaporator to vapourize them. Thus heat is transferred from condensing vapour of first evaporator to boiling liquid of second evaporator. It is possible when second evaporator is at lower temperature (hence at lower pressure) than the first evaporator. Thus there exists a temperature gradient (hence a pressure gradient) along flow line from first evaporator to second evaporator. i.e. $T_2 < T_1$ and $P_2 < P_1$. Likewise $T_3 < T_2$ and $P_3 < P_2$ and vapour undergoes exactly same process by passing from second to third evaporator as from first to second evaporator.

Analysis

The volume changes occur as a vapour passes from one evaporator to next evaporator. Consequently,

- Temperature decreases
  ⇒ Pressure decreases
  ⇒ Boiling point decreases
  ⇒ Vacuum increases
- Specific steam consumption decreases
  ⇒ Steam economy increases

Note:

1. Specific steam consumption = steam consumed / water evaporated
2. Steam economy = water evapourated / steam consumed.

Type of evaporator	**Steam economy**
Single effect evaporator	1 / 1 to 1.2
Double effect evaporator	1/0.6
Triple effect evaporator	1/0.4
Quadruple effect evaporator	1/0.3

Note:

- Steam economy in an 'n' effect evaporator = n × steam economy in single effect evaporator.
- Like vapour, feed also passes from one evaporator to the next evaporator as shown in figure and become concentrated gradually

The following changes occur as feed (solution) passes from one evaporator to the next evaporator.

- Concentration increases
  ⇒ Viscosity increases
  ⇒ Overall heat transfer decreases.
- Concentration increases
  ⇒ Osmotic pressure increases
  ⇒ Boiling point increases
- Volume increases

Note:
(1) Boiling point of feed solution increases as it passes from one evaporator to the next and this increase is known as boiling point rise or simply as "BPR".
(2) The following overall changes occur as both feed and vapour passes from one evaporator to the next evaporator.

- Processing cost decreases
- Capacity of evaporator decreases

Note:
Capacity of evaporator means amount of water evapourated in kg per hour

Calculation for triple effect evaporator

Referring to Fig.3.5 rate of heat transfer in all the 3 evaporator remained the same.

$\therefore Q_1 = Q_2 = Q_3$

$\Rightarrow A_1U_1\Delta T_1 = A_2U_2\Delta T_2 = A_3U_3\Delta T_3$

$$\Rightarrow A_1U_1(T_S - T_1) = A_2U_2(T_1 - T_2) = A_3U_3(T_2 - T_3) \quad (3.6.4)$$

Again temperature drop in multi effect (triple effect) evaporator is given by, ΔT.

$$\Delta T = \Delta T_1 + \Delta T_2 + \Delta T_3 = (T_S - T_1) + (T_1 - T_2) + (T_2 - T_3) = T_S - T_3 \quad (3.6.5)$$

But when BPR (boiling point rise) in each effect can't be neglected then

$$\Delta T = T_S - T_3 - (BPR_1 + BPR_2 + BPR_3) \quad (3.6.6)$$

Notations:
T_S = temperature of entering steam into evaporator
T_1, T_2, T_3 = boiling temperatures of liquid inside first, second and third evaporator respectively
BPR_1, BPR_2, BPR_3 = boiling point rise of liquid inside first, second and third evaporator respectively.

3.7 Water Activity

Water activity, a_w

Physically, water activity means *availability of water as solvent for reaction in food.*

Methods to calculate water activity

Method 1

When vapour pressures of water are available:

$$a_w = P_V/P_S \tag{3.7.1}$$

Notations:

Pv = partial pressure of water in the headspace of a product

Ps = saturated vapour pressure of water (at same temperature as that of Pv). It is also known as "vapour pressure of pure water"

Method 2

When equilibrium relative humidity of atmosphere is available

$$a_w = \frac{ERH}{100} \tag{3.7.2}$$

Notations:

ERH = equilibrium relative humidity of atmosphere in contact with product, %

Method 3

When osmotic pressure, π, of the medium is available:

$$\pi = -\frac{RT}{V_m} \times \ln(a_w) \tag{3.7.3}$$

where,

$a_w = X_w$ (for ideal solution)

$a_w = \gamma X_w$ (for real solution)

Notations:

R = 8.314 kJ/kg-mol-K

T = absolute temperature = t + 273 K

V_m = molar volume of water = 18 lit/kg-mol = 0.018 m^3/kg

γ = activity coefficient,

X_w = mole fraction of water

Method 4

When water activity of individual solution is available:

$$a_w = a_{w1}\, a_{w2} \tag{3.7.4}$$

Notations:

a_w = water activity of solution

a_{w1}, a_{w2} = water activities of two types of solute in a solution

Method 5

When moisture content of medium is high (i.e. above 90%):

$$\log_{10}\left(\frac{a_w}{X_w}\right) = -K(1 - X_w)^2 \tag{3.7.5}$$

where,

X_w = mole fraction of water = $\dfrac{\text{moles of water}}{\text{mole of water + moles of solution}}$

Notations:

K = 2.7 (for sucrose), K = 0.7 (for glucose and fructose)

Method 6

When moisture content of medium is low (i.e. below 90%):

$$\frac{a_w}{X_e(1-a_w)} = \frac{1}{X_m.C} + \frac{C-1}{X_m.C}(a_w) \qquad (3.7.6)$$

X_e = equilibrium moisture content, kg/kg (dry basis)

X_m = water strongly bound to material, also known as *monolayer water content*, kg/kg (dry basis)

C = a constant

PART 2
APPLICATIONS
(Solution of GATE Question Papers 1988-2005)

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Chapter **4**

Long Type Solution (1988-2002)

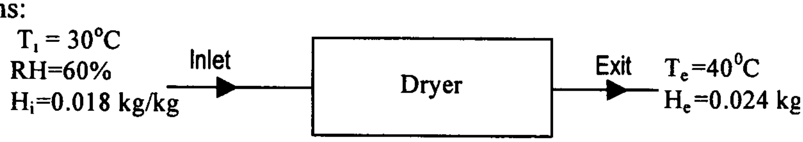
1988

(1) Atmospheric air at 30°C and 60 % relative humidity enters a grain dryer of 1 tonne/hr capacity at the rate of 0.8 m^3/s. Exhaust air temperature recorded is 40°C. Calculate

(a) rate of moisture removal in Kg/hr

(b) rate of fuel (husk) consumption in heating the air (calorific value of husk =3000 kcal/kg) with combustion efficiency of husk = 60 %

Ans:



(a)Volumetric flow rate of air through dryer, V = 0.8 m^3/s

Specific volume of dry air ,V_H = 0.88 m^3/kg

Moisture removed , $\Delta H = H_e - H_i = 0.024 - 0.018 = 0.006$ kg

$$\text{Mass flow rate of dry air (AG)} = \frac{\dot{V}}{V_H} = \frac{0.8}{0.88} = 0.91\ \frac{kg}{S}$$

Rate of moisture removal = $\dot{W}$=(AG) x ΔH = 0.91 x 0.006 = 19.63 kg/hr

(b) Rate of heat removal from heated air inside dryer, Q_r is given by

$$Q_r = W\lambda = 19.63 \times 2534.4 = 49750.27 \text{ kJ/hr}$$

$$\text{Gross heat removal from husk} = \frac{Q_r}{E}$$

$$= \frac{49750.27}{0.6} = 82917\ \frac{kJ}{hr} = 19742\ \frac{kcal}{hr}$$

$$\therefore \quad \text{Fuel required} = \frac{19742}{3000} = 6.58\frac{\text{kg}}{\text{hr}}$$ (Ans)

(2) A fan having an impeller diameter of 35 cm delivers 3m^3/min of air at a static pressure of 5 cm water when speed is 500 rpm and a power input of 4.5 KW. What will be (i) the speed and the static pressure if the same fan is made to deliver 4.5 m^3/min? (ii) the percentage increase in power to run the fan at this increased speed? (iii) the new fan size to deliver 4.5m^3/min if the speed is not allowed to deviate from 500 rpm ?

Ans:

$D_1 = 0.35$ m, $P_1 = 4.5$ kW, $Q_1 = 3$ m^3/min

$H_1 = 5$ cm of water, $N_1 = 500$ rpm, $Q_2 = 4.5$ m^3/min

$$\text{(i) } Q \;\alpha\; N \;\therefore \frac{N_2}{N_1} = \frac{Q_2}{Q_1}$$

$$\Rightarrow N_2 = \frac{N_1 Q_2}{Q_1} = \frac{500 \times 4.5}{3} = 750rpm$$

$$H \;\alpha\; N^2 \;\therefore \frac{H_2}{H_1} = \frac{N_2^2}{N_1^2}$$

$$H_2 = \frac{H_1 N_2^2}{N_1^2} = \frac{5 \times 750^2}{500^2} = 11.25 \text{ cm of water}$$

$$\text{(ii)} \quad P \;\alpha\; N^3 \;\therefore \frac{P_2}{P_1} = \frac{N_2^3}{N_1^3} \Rightarrow P_2 = P_1 \frac{N_2^3}{N_1^3}$$

$$\text{Percentage increase in Power} = \frac{P_2 - P_1}{P_1} = \frac{P_1 \dfrac{N_2^3}{N_1^3} - P_1}{P_1} = \frac{N_2^3}{N_1^3} - 1$$

$$= \frac{750^3}{500^3} - 1 = 2.375 = 237.5\ \%$$

(iii) Keeping N = constant

$$Q \;\alpha\; D^3 \;\therefore \frac{D_2^3}{D_1^3} = \frac{Q_2}{Q_1}$$

$$\Rightarrow D_2 = \sqrt[3]{\frac{Q_2}{Q_1}} \times D_1 = \sqrt[3]{\frac{4.5}{3}} \times 0.35 = 0.4 \text{ meter} \qquad \text{(Ans)}$$

(3) The performance of cyclones is governed by the facts that the particle diameter to be separated is inversely proportional to the square root of (i) particle density (ii) gas/air flow rate through the

cyclone. Also the particle diameter is directly proportional to the square root of the gas/air absolute viscosity. A cyclone was designed to separate particles up to 10μ diameter. Theoretically how many ways can you increase the cyclone efficiency so that the same cyclone would be effective in separating particle up to 5 μ diameter.

Ans:

Theoretically number of ways to increase cyclone efficiency when particle size reduces from 10μ diameter to 5 μ diameter are

(1) By increasing entrance velocity (V)
(2) By increasing length of cyclone (L)
(3) By decreasing radius of cyclone (R)
(4) By decreasing diameter of exit duct (D_e)

4(a) An orifice plate was designed for a pipe of 4" (100mm) internal diameter, the flow of air inside being 0.5 m^3/s. What should be the orifice diameter when the pressure drop across the orifice was limited to 20 cm of water? (Density of air at room temperature is 1.18Kg/m^3)

(b) Should the same conditions be applied to a venturimeter, do you expect that (i) $d_v > d_o$ (ii) $d_v = d_0$ (ii) $d_v < d_o$ where d_v and d_o are venturi and orifice diameters, respectively ? Reason your answer.

Ans:

$D_i = 100$ mm, $Q = 0.5\ m^3/s$, $H = 0.2$ m of water, $\rho_a = 1.18\ kg/m^3$

(a) $Q = AV = \pi/4\ d^2 \left(C_d\sqrt{2gh}\right)$

$$\Rightarrow 0.5 = \frac{\pi}{4} \times d^2 \times \left(0.62 \times \sqrt{2 \times 9.81 \times 0.2}\right)$$

$$\Rightarrow d = 72 \text{ cm}$$

(b) With same condition applied diameter of venturi (d_v) < diameter of orifice (d_0)

(as coefficient of discharge of venturimeter (C_{dv}) is greater than coefficient of discharge of orifice (C_{d0})

(5) A tractor is equipped with 4-cylinder four stroke engine and it develops 45 HP at 1200 rpm. Calculate :

(i) the torque developed in kg-m

(ii) the volume of fuel required for a single power impulse in any cylinder if the specific fuel consumption is 0.22 kg/hp/hr and specific gravity is 0.80

Ans:
n = 4 , power = 45 HP, N = 1200 rpm
(a) BHP = $2\pi NT$
$\Rightarrow$ 45 x 746 = 2πx (1200/60) x T
$\Rightarrow$ T = 27.23 kg.m.
(b) Specific fuel consumption, $F = 0.22 \text{kg} / \text{BHP} / \text{hr}$
Fuel density, ρ = G x 1000 = 0.8 x 1000 = 800 kg/m^3

$$\frac{F \times BHP}{\rho} = LAn\left(\frac{N}{2}\right)$$

$$\Rightarrow \frac{0.22 \times 45}{800} = (LA) \times 4 \times \left(\frac{1200}{2}\right) \times 60$$

$\Rightarrow$ LA = 85.93 mm^3 (Ans)

(6) An agronomist advised the farmer to apply 1.1 kg insecticide per hectare and the solution is to be obtained by mixing 0.9 kg of this insecticide in 90 liters of water. The rated delivery from each nozzle of a power sprayer was set to 0.5 liters/min at a pressure of 2.7 kg/cm^2. If the nozzles are spaced 60 cm apart find the forward speed of travel of sprayer for a pressure setting of 2.1 kg/cm^2.

Ans:
0.9 kg insecticide is applied in 90 litre of water
$\therefore$ 1.1 kg insecticide requires 110 litre of water
$\therefore$ R_v = 110 lit/ha = 1100 m^3/m^2
Q = 0.5 lit/min, P_1 = 2.7 kg/cm^2, P_2 = 2.1 kg/cm^2, S = 0.6 m
We know Q = AR_v = (nSVE) R_v

$$\therefore V = \frac{Q}{nSER_v} = \frac{0.5 \times 10^{-3}}{1 \times 0.6 \times 1100} = 75.75 \text{ m/min.}$$

Notations
Q = volumetric flow rate (m^3/min)
n = number of nozzles
q = Flow rate in single nozzle (m^3/min)
A = Area covered by sprayer (m^2/min)
R_v = Volumetric application rate (m^3/m^2)
S = Spacing between nozzles (m)
V = Velocity of travel of sprayer (m/s)
E = Spraying efficiency of a sprayer

Again V $\alpha\sqrt{p}$ $\qquad$ (Θ Q = AV and Q $\alpha\sqrt{\text{p}}$)

$$\frac{V_2}{V_1} = \sqrt{\frac{P_2}{P_1}} \Rightarrow \frac{V_2}{75.75} = \sqrt{\frac{2.1}{2.7}}$$

$\Rightarrow V_2 = 66.81$ m/min = 4 km/hr. (Ans)

(7) A three-bottom trailed type disc plow, each 66 cm diameter is adjusted to 46° disc angle and 20° tilt angle. Discs are mounted on a beam that makes an angle of 30° with the direction of motion. The consecutive distance between the discs is 50 cm. If the depth of plowing is 16 cm, calculate :
(a) Width of cut by each disc
(b) Total width of cut

Ans:

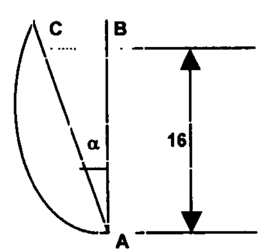
n = 3, D = 66 cm, $\alpha = 20^\circ$
$\beta = 30^\circ$, S = 50 cm, d = 16 cm, $\theta = 46^\circ$

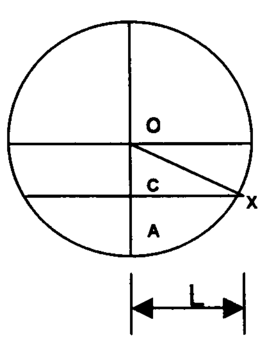
If AB = d = depth of cut

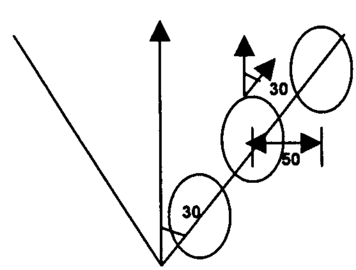
$$\cos\alpha = \frac{AB}{AC}$$

$$\Rightarrow \cos 20 = \frac{16}{AC}$$

$$\Rightarrow AC = \frac{16}{Cos 20} = 17.03\text{cm}$$







OA = OX = D/2 = 66/2 = 33 cm
CA = 17.03 cm
OC = 33 – 17.03 = 15.97 cm

$L = CX = \sqrt{33^2 - 15.97^2} = 28.878$ cm

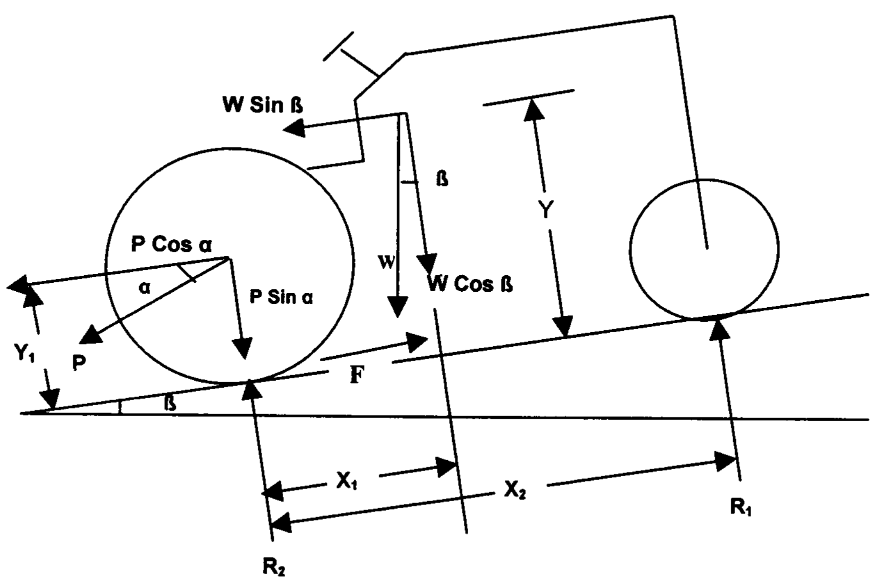
Width of cut by each disc = 2 L sin θ = 2 x 28.878 x sin 46 = 41.54 cm

(b)As plow is 3-bottomed then total width of cut = 41.54 + S cos (90-30) + Scos (90-30) = 41.54+50 cos(90-30)+50 cos (90-30)= 91.54 cm (Ans)

(8) A four-wheel tractor is plowing up a hill of 15° slope with three bottom 35 cm mould board plow at a speed of 4 km/hr. The tractor weighting 1500 kg has a wheel base of 240 cm and wheel trade of 115 cm. The C.G. is located 90 ahead of rear axle and 75 cm above the ground. The drawbar height is 40 cm. The line of pull of the implement makes an angle of 25° with the ground and is at a distance of 50 cm from the rear wheel contact point. Neglect rolling resistance. Assume : Cohesion coefficient = 0.15, Contact area =1650 cm^2, Angle of internal friction = 30°

Find : (a) reaction at the wheel (b) Pull (c) Tractive force.

Ans:



$\beta = 15^\circ$, $\alpha = 25^\circ$, $\phi = 30^\circ$, V = 4 km/hr, T = 115 cm

$X_2 = 240$ cm, , Y = 75 cm, $X_1 = 90$ cm, $Y_1 = 40$ cm,

S = 0, $Y_1' = 50$ cm, C = 0.15 kg/cm^2 ,W = 1500 kg

$F = AC + R_2 \tan\phi$ (1)

$R_1 + R_2 = W \cos\beta + P \cos\alpha$ (2)

$F = W \sin\beta + P \cos\alpha$ (3)
$W \cos\beta . X_1 = R_1 X_2 + P \cos\alpha \; Y_1 + W \sin\alpha \; Y$ (4)
Here 4 equations and 4 unknowns (F, R_2, R_1, P). Thus can be solved.
Solving equation (1) and (3)
$1650 \times 0.15 + R_2 \tan 30 = 1500 \sin 15 + P \cos 25$ (a)
$R_1 + R_2 = 1500 \cos 15 + P \sin 25$ (b)
$1500 \cos 15 \times 0.9 = R_1 \times 2.4 + P \cos 25 \times 0.4 + 1500 \times \sin 15 \times 0.75$ (c)
Now 3 equations and 3 unknown R_1, R_2, P
Thus solving equations a, b, c simultaneously
$P = 1156$ kg, $R_1 = 248.6$ kg, $R_2 = 1685.78$ kg
$\therefore F = 16500 \times .15 + 1685.78 \times \tan 30^\circ = 1221$ kg (Ans)

(9) A farmer desires to irrigate 10 hectares of land using a pump which operates 12 hours a day. The available moisture holding capacity of the soil is 20 cm per meter of depth. The depth of root zone is 1.2m. Irrigation is to be given when 50 percent of the available moisture is depleted. Assume conveyance efficiency is 65 percent, application clearly is 75 percent and peak rate of moisture use by the crop is 5 mm per day. Determine its depth of irrigation, irrigation period and horse power requirement if pumping plant efficiency is 60 percent and adequate stream is to be a supplied at a total head of 10 m.

Ans:
$A = 10$ ha, $E_a = 75$ %, $E_c = 65$ %, $E_p = 60$ %
$H = 12$ hrs/day, $H = 10$m, $D = 1.2$ m, $ET = 5$ mm/day
AMHC = 20 cm/m, Depletion = 50 %

$$AMHC = \frac{d_{fc}(cm)}{D(m)} \Rightarrow d_{fc} = 20 \times 1.2 = 24 \text{ cm}$$

(i) Depth of irrigation, $d = 0.5 \times 24 = 12$ cm
(ii) Irrigation Period, $F = d/ET = 120/5 = 24$ days

$$\text{(iii) } Q = \frac{Ad}{FHE} = \frac{10 \times 10^4 \times 0.12}{24 \times 12 \times 0.48} = 86.8 \frac{m^3}{hr}$$

Horsepower required, $HP = \gamma QH = 1000 \times 86.8 \times 10$ kg.m/hr=3.23 HP
(Ans)

(10) Find out the ordinates of runoff hydrograph resulting from a 9 hour normal rainfall amount of 2.5 cm, 3.5 cm and 2.5 cm at 3-hour intervals. The ordinates 3-hour unit hydrograph are given

below. Assume initial loss of 5mm,ø index = 5 mm/hr and base flow of $10m^3/s$.

Hours	0	03	06	09	12	15	18	21	24
Ordinates(cumeces)	0	90	200	360	450	350	260	100	130
Hours	27	30	33	36					
Ordinates (cumeen)	80	45	20	0					

Ans:

Total 9 hr storm = 2.5 + 3.5 + 2.5 = 8.5 cm

Initial loss = I_a = 5 mm , $ø_{index}$ = 5mm/hr, base flow = $10m^3/s$

DRH ordinates = ordinates of unit hydrograph X ER

RH ordinates = DRH ordinates + Base flow

$$ø_{index} = \frac{(P - I_a - R)}{t}$$

$$\Rightarrow 5 = \frac{85 - 5 - R}{9}$$

$\Rightarrow$ R = Effective rainfall, ER = 3.5 cm

Hours	0	3	6	9	12	15	18	21	24	27	30	33	36
Ordinates (m^3/s)	0	90	200	350	450	350	260	100	130	80	45	20	0
DRH ordinates (m^3/s)	0	315	700	1225	1575	1225	910	350	455	280	157.5	70	10
RH ordinates (m^3s)	10	325	710	1235	1585	1235	920	360	465	290	167.5	80	10

(11) Determine the size of each side of a square box inlet for a drop spillway to handle a peak flow of 3.2 cumeces over a fall of 1.5m if the energy head to fall ratio is not to exceed 0.6 at any time

Ans:

$Q_p = 3.2\ m^3/s$, H = 1.5m, he/H = 0.6

∴ he = 0.6 x H = 0.6 x 1.5 = 0.9 m.

∴ Head of flow, h= 2/3 he = 2/3 x 0.9 = 0.6 m

$Q = 1.77 \times L \times h^{3/2}$

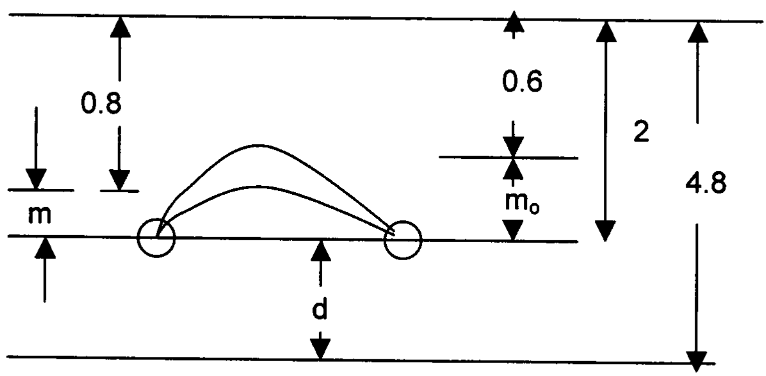
$\Rightarrow 3.2 = 1.77 \times L \times 0.6^{3/2}$

$\Rightarrow$ L = length of weir = 3.89 m

$\therefore\ l = L/3 = \dfrac{3.89}{3} = 1.3$ meter (Ans)

(12) Subsurface drains are to be constructed for lowering the water table from 0.6m to 0.2m below the ground level in 10 days. Tiles are to be placed 2m below the ground level. Impervious layer exits at 4.8m below the ground level. The drainable porosity is 8 percent and the hydraulic conductivity is 0.8m/day.What should be the spacing between the drains.

Ans:



$m_0 = 2 - 0.6 = 1.4$ m.
$m = 2 - 0.8 = 1.2$ m
$d = 4.8 - 2 = 2.8$ m
As per data given Van-schifgaarde equation is used. Thus

$$S^2 = \frac{9ktd}{f \times \ln(\frac{m_0(2d+m)}{m(2d+m_0)})} = \frac{9 \times 0.8 \times 10 \times 2.8}{0.08 \times \ln(\frac{1.4(2 \times 2.8 + 1.2)}{1.2(2 \times 2.8 + 1.4)})}$$

$\Rightarrow$S= 141.89m (Ans)

(13) Two pumping wells located 600m and 800m away from the observation well yielded 10 liters/sec and 20 liters/sec respectively. If the storage coefficient is 10^{-3} and transmissibility is 10 m^2/day,determine the drawdown at the observation well. Both wells are pumped for 25 days. The respective well functions are 4.04 and 4.48.

Ans:
r_1= 800m, Q_1= 10lit/s, r_2= 1000m, Q_2= 20lit/s
Storage coefficient = s = 10^{-3}, T = $10m^2$/day
$W(U_1) = 4.04$, $W(U_2) = 4.48$, t = 25days
Thus it is a case of unsteady flow in confined aquifer
∴ Using equation Q = 4πTS/W(U)
First pumping well

$$S = Q\,W\,(U_1)/(4\pi T) = \frac{10\times10^{-3}\times24\times3600\times4.04}{4\pi\times10} = 27.7m$$

Second pumping well

$$S = Q\,W\,(U_2)/(4\pi T) = \frac{20\times10^{-3}\times24\times3600\times4.48}{4\pi\times10} = 61.4m$$

∴ Drawdown in observation well = drawdown difference in 2 pumping wells = 61.4 – 27.7 = 33.7 m (Ans)

1989

(1) Velocity of 2 micron diameter fat globules inside a centrifuge operating at 5000 rev/min has been estimated to be 0.2 mm/sec. What will be the velocity of 1 micron diameter fat globules inside the same centrifuge operated at 6000 rev/min ?

Ans:
$D_1 = 2 \times 10^{-6}$ m, $D_2 = 1 \times 10^{-6}$ m, $N_2 = 6000$ rpm, $V_1 = 0.2$ mm/sec

$$V = \frac{D^2(\rho_s - \rho_f)\omega^2 R}{18\mu} \text{ and } \omega = 2\pi N$$

$$\therefore \frac{V_2}{V_1} = \frac{D_2^2 N_2^2}{D_1^2 N_1^2}$$

$$\Rightarrow \frac{V_2}{0.2} = \frac{(10^{-6})^2\times6000^2}{(2\times10^{-6})^2\times5000^2}$$

$\Rightarrow V_2 = 0.072$ mm/sec. (Ans)

(2) How many times will the power requirement of a centrifugal fan be increased when its speed is increased by 100 percent ?

Ans:

$P \alpha N^3$

$$\therefore \frac{P_2}{P_1} = \frac{N_2^3}{N_1^3} = \left(\frac{2N_1}{N_1}\right)^3 = 8 \qquad \text{(Ans)}$$

(3) A Newtonian fluid with a gauge pressure P flows in laminar regime through a tube having diameter 4 mm and length 50 cm. For the same volumetric flow rate find out the pressure required when the diameter of the tube has been increased to 5 mm and the length to 100 cm. The liquid is discharged to atmospheric pressure in both the cases.

Ans:

D_1 = 4 mm, L_1 = 50 cm, D_2 = 5 mm, L_2 = 100 cm

$\Delta P = (32\ \mu VL)/D^2$

$$\therefore \frac{\Delta P_2}{\Delta P_1} = \frac{L_2}{L_1} \times \frac{D_1^2}{D_2^2} = \frac{1}{0.5} \times \frac{4^2}{5^2} = 1.28$$

$\Rightarrow \Delta P_2 = 1.28\ \Delta P_1$

$$\therefore \text{Percentage increase} = \frac{\Delta P_2 - \Delta P_1}{\Delta P_1}$$

$$= \frac{1.28\Delta P_1 - \Delta P_1}{\Delta P_1} = -0.28 = 28\%\ \textit{decrease.}$$

(Ans)

(4) A liquid food flows through the inside pipe of a double pipe heat exchanger in turbulent regime. Steam is allowed to condense at the outside of the inner pipe and thus its wall temperature is maintained constant. At a certain flow rate of the liquid the heat transfer coefficient at the inside of the inner pipe has been found to be 1200 W/m^2 C. Estimate the heat transfer coefficient when the liquid flow rate through the pipe is doubled.

Ans:

$Q = AU\ \Delta T$, U_i = 1200 W/m^2-°C

When flow rate doubled, maintaining inner pipe wall temperature constant, then U_i became doubled

$\therefore U_i = 2 \times 1200 = 2400$ w/m^2-°C. (Ans)

(5) Assume that 2500 kJ of heat energy is required to convert 1 kg water to water vapour at 0°C. Assume that the specific heats of water, water vapour and air remains constant at 4.18. 1.88 and 1.0

kJ/kg°C respectively between 0°C and 50°C. Estimate the enthalpy (kJ/kg dry air) of atmospheric air containing 0.02 kg water vapour per kg dry air at 50°C.

Ans:

Enthalpy of atmospheric air: $h = C_s (T - T_0) + \Delta H$

$\Rightarrow h = (1.005 + 1.88\ H)(T - T_0) + \Delta H$

$\Rightarrow h = (1.005 + 1.88 \times 0.2)(50 - 0) + 2500 \times 0.02 = 102.13$ KJ/Kg (Ans)

(6) Five hours are required to dry a bed of vegetables in a tray dryer by warm air having $T_{db} = 60°C$, $T_{wb} = 50°C$, ($\lambda T_{wb} = 2383$ kJ/kg water). If the conditions of the air are now changed to $T_{db} = 50°C$, $T_{wb} = 45°C$ ($\lambda T_{wb} = 2395$ kJ/kg water), what will be the time required for drying ? Assume that the heat transfer coefficient on the surface of the vegetables has not changed. The symbols used are T_{db} : dry bulb temperature, T_{wb} : wet bulb temperature, λ : latent heat of vaporization of water.

Ans:

When temperature is driving force, drying rate

$$R = \frac{W}{A} = \frac{q}{A\lambda w} = \frac{hA(T - T_W)}{A\lambda\omega} = \frac{h(T - T_W)}{\lambda\omega}.$$

$$\therefore \frac{R_1}{R_2} = \frac{\dfrac{h(T_1 - T_{W1})}{\lambda\omega 1}}{\dfrac{h(T_2 - T_{W2})}{\lambda\omega 2}}.$$

But $W\& \alpha \ \frac{1}{t}$

$$\therefore \frac{t_2}{t_1} = \frac{\dfrac{h(T_1 - T_{W1})}{\lambda\omega 1}}{\dfrac{h(T_2 - T_{W2})}{\lambda\omega 2}}.$$

Given, $T_1 = 60°C, T_2 = 50°C, T_{WI} = 50°C, T_{W2} = 45°C$

$\lambda_{WI} = 2383$ kJ/kg, $\lambda_{W2} = 2395$ kJ/kg, $t_1 = 5$ hrs.

Putting all the values in above equation

$t_2 = 10.05$ hrs (Ans)

(7) What amount of ice at 0°C be mixed adiabatically with 1 kg water at 50°C such that the temperature of the resulting water becomes

0°C ? Take specific heat of water at 4.18 kJ/kg°C and latent heat of melting of ice at 0°C as 335 kJ/kg.

Ans:

Latent heat taken by ice = Sensible heat given by water

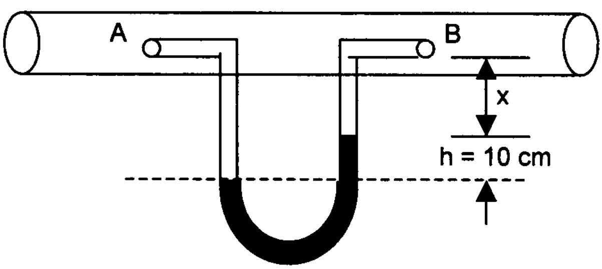
$\therefore$ mL = $MC_P \Delta T$

$\Rightarrow$ m x 335 = 1 x 4.18 x (50 – 0)

$\Rightarrow$ m = 0.62 kg (Ans)

(8) A U-tube manometer is used to determine the pressure drop between two points of a pipe. Water flows through the pipe and the manometer is placed below the pipe line. If the manometric fluid has a density 13600 kg/m^2 and the manometer reading is 10 cm, determine the pressure drop in Pascals along the two points of the pipe.

Ans:



h = 10 cm = 0.1 m

ρ_m = 13600 kg/m^3

Total pressure at 'A' = Total pressure at 'B'

$P_A + (x + h)\ 1000 = P_B + 1000\ x + 13600 \times 0.1$

$\Rightarrow P_A - P_B = 1360 - 100 = 1260$ kg/m^2 = 12348 Pa (Ans)

(9) A saturated sample of soil has a water content of 35 percent. Assuming specific gravity of the soil to be 2.70, calculate the dry density of the soil.

Ans:

$W_{sat} = 35\ \%,\ G = 2.7,\ S_r = 1$

$$e = \frac{WG}{S_r}$$

$\Rightarrow e = W_{sat}\ G$

$$\therefore \quad \gamma_d = \frac{G\gamma_w}{1+e} = \frac{G\gamma_w}{1+w_{sat}\times G} = \frac{2.7\times 9.81}{1+0.35\times 2.7} = 13.6.\text{KN/m}^3$$

$\therefore$ Dry density of soil, $\rho_d = \dfrac{\gamma_d}{g} = 1.38$ gm/cm^3 (Ans)

(10) Calculate soil loss from a plot of one hectare having slope length 122 m and slope steepness 10 percent. Rainfall erosion index of the place is 325. Assume soil erodibility factor as 0.25 Mg/ha, cropping management factor as 0.16 and conservation practice factor as 0.6.

Ans:

L = 122 m = 402.6 feet, C = 0.16, P = 0.6

S = 10 %, R = 325 K = 0.25

Soil loss from given land: A = RK LS CP

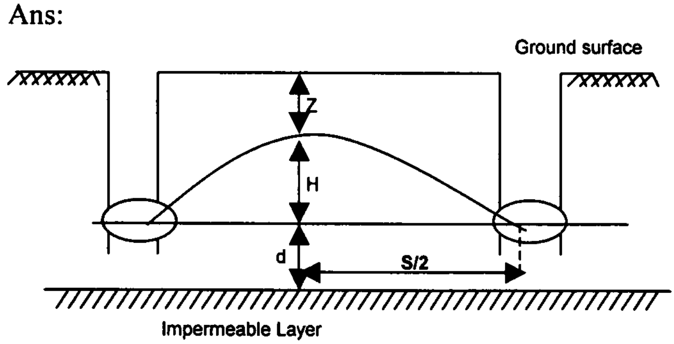
$$LS = \frac{\sqrt{L}}{10000}(76 + 53S + 7.6S^2)$$

$$= \frac{\sqrt{402.6}}{10000}(76 + 53 \times 10 + 7.6 \times 10^{2}) = 2.74$$

$\therefore$ Soil loss, A = 325 x 0.25 x 2.74 x 0.74 x 0.16 x 0.6 = 21.372 Mg/ha. (Ans)

(11) For an irrigated area, compute the approximate depth of placement of drain if the spacing of the drains are 55 m. Allowable water table height is 0.3 m above the centre of the drains. Subsurface explorations indicate a hydraulic conductivity 0.5 m/day above an impervious layer at a depth of 6.7 m. The excess irrigation rate is equivalent to a drainage coefficient of 1.2 mm/day.

Ans:



S = 55m, H = 0.3 m, K = 0.5m/day, R=1.2mm/day

Z + H + d = 6.7m = depth of impervious layer from ground surface

$$S = \sqrt{\frac{4KH(2d+H)}{R}}$$

$$\Rightarrow 55 = \sqrt{\frac{4 \times 0.5 \times 0.3(2 \times d + 0.3)}{1.2 \times 10^{-3}}}$$

$\Rightarrow d = 2.875$ m

$\therefore$ Depth of placement of drain $= Z + H$

$= (Z + H + d) - d$

$= 6.7 - 2.875 = 3.825$ m (Ans)

(12) An agricultural watershed of soil group 'C' in DVC has an average slope of 1.5 % and an area of 1000 hectares.A 2 year rainfall of 24 hours duration for the area is 76.2 mm while the runoff volume calculated by Curve number technique is 31.4 mm. The length to width ratio of the watershed is 3.5:1. Determine time to peak and peak discharge

Ans:

Time of concentration, $t_c = 0.0195L^{0.77}S^{-0.385}$

$= 0.0195(5916)^{0.77}(0.015)^{-0.385}$

$= 78.83$ min $= 1.313$ hr

Time to peak, $t_p = \frac{D}{2} + t_L = \frac{D}{2} + 0.6\, t_c = \frac{24}{2} + 0.6 + 1.313 = 12.78$ hr

Area = LxB

$\Rightarrow 1000 \times 10^4 = L \times \frac{L}{3.5}$

$\Rightarrow L = 5916\ m$

Peak discharge, $Q_p = 0.0021\frac{QA}{t_p} = 0.0021 \times \frac{31.4 \times 1000}{12.78} = 5.15\frac{m^3}{s}$ (Ans)

(13) Compute the seepage rate per unit length through a homogeneous earth dam resting on an impervious foundation if the top width is 4.3m, height of dam 12.9 m, upstream side slope 3:1 and downstream side slope 2;1, the hydraulic conductivity 0.00012 m/h, and the net free board 0.9m.

Ans:

T = 4.3m, H = 12.9 m, U/s slope = 3:1, d/S Slope = 2:1

K = 0.00012 m/h, net freeboard = 0.9 m

$\therefore$ h = H – net freeboard = 12.9 – 9 = 12m, e = h/3 = 12/3 = 4m
Mean length of seepage line or length of flow, L is given by:
L = U/S (H – 0.7h) + T + d/S (H – e/2)
= 3 (12.9 – 0.7 x 12) + 4.3 + 2 (12.9 – 4/2) = 39.6 m

$$q = \left(\frac{2h}{3}\right)^2 \times \frac{K}{L} = \left(\frac{2\times 12}{3}\right)^2 \times \frac{0.00012}{39.6} = 1.94\times 10^{-4}\,\frac{m^3}{hr-m}$$

= 0.194 lit/hr-m (Ans)

(14) Determine the minimum dimensions of a square drop inlet and pipe spillway to cause the pipe just to flow full with a 0.3 m depth of flow above the spillway crest. The pipe is 610 mm in diameter and 30m in length and the total head causing pipe flow is 4.88 m. Assume K_c = 0.15, K_c = 0.066 and the weir coefficient is 3.2.

Ans:
h = 0.3m, D = 0.61m, L = 30 m , H = 4.88 m
K_e = 0.15, K_c = 0.066, C = 0.32
For square drop inlet part of spillway
Q = 0.552 $CLh^{3/2}$ = 0.552 x 3.2 x L x $0.3^{3/2}$ = 0.29 L m^3/s
For pipe part of spillway

$$Q = AV = \left(\frac{\pi}{4}D^2\right)\sqrt{\frac{2gH}{1+K_e+K_cL}}$$

$$\Rightarrow Q = \frac{\pi}{4}\times 0.61^2 \times \sqrt{\frac{2\times 9.81\times 4.88}{1+0.15+0.066\times 40}} = 1.468\ m^3/S$$

$\therefore$ 0.29 L = 1.468
$\Rightarrow$ L = 5.06 m
$\therefore$ Length of square drop inlet and pipe spillway = L/3
= 5.06/3 = 1.69 m. (Ans)

(15) Determine the annual consumption of electrical energy by a motor-driven centrifugal pump installed in a shallow tubewell to irrigate crops by sprinkler irrigation. The pump discharge is 920 l/min against a head consisting of frictional loss due to 1000 m long pipe of 150 mm diameter (f = 0.01), static head of 75m including other losses and a dynamic head of 4.2 kg/cm^2 to run sprinklers. The pump efficiency is 70 percent and the motor efficiency 84 percent. The drive efficiency maybe assumed to be 100 percent. The pump is operated for 2500 hours per year.

Ans:
Q_p = 920 l/min, L = 1000 m, E_p = 70 %, E_m = 80 %, E_d = 100 %

$D_{Strainer} = 0.15$ m, $H_{Static} = 75$ m, $H_{Dynamic} = 4.2\ kg/cm^2 = 42$ m

Velocity of flow through pipe $= V = \dfrac{Q}{A} = \dfrac{Q}{\frac{\pi}{4}D^2} = \dfrac{0.92}{\frac{\pi}{4}(0.15)^2} = 0.86$ m/s

Frictional head loss, $H_f = \dfrac{4fLV^2}{2gD}$

$$= \frac{4\times 0.01\times 1000\times (0.86)^2}{2\times 9.81\times 0.15} = 10.25m$$

Total pumping head, H $= H_{Static} + H_{Dynamic} + H_f$

$= 75 + 42 + 10.23 = 127.23$m

$$SHP = \frac{WHP}{E_p} = \frac{YQH}{E_p}$$

$$= \frac{1000\times\left(\frac{920}{60}\right)\times 10^{-3}\times 127.23}{0.7} = 2787\frac{kg.m}{S} = 27.34 \text{ KW}$$

$$BHP = \frac{SHP}{E_d} = \frac{27.34}{1} = 27.34 \text{ kW.}$$

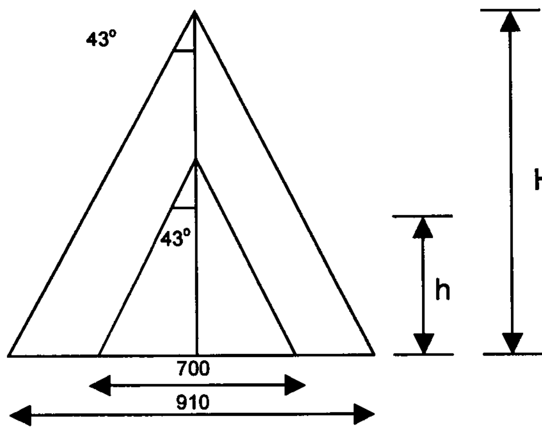
$$IHP = \frac{BHP}{E_m} = \frac{27.34}{0.8} = 34.17kW$$

$\therefore$ Consumption of electrical energy = 34.17 x 2500

= 85425 KW.hr = 85425 units (Ans)

(16) At 300 kPa, a flat fan nozzle has an 86° included angle as the spray pattern emerges from the tip of the nozzle. At such an angle, adjoining spray patterns should overlap about 30 percent of their effective width to give uniform coverage of weed spraying. If the nozzles are spaced 700 mm apart on the boom, what should be the boom height above the ground surface ? If the spraying should be done at 200 kPa, should the boom be raised or lowered to give the proper overlap ?

Ans:



With original spacing of 700 mm and original height (h) of boom, there is no overlap. But to get uniform coverage 30 % overlap is required.

$\therefore$ S = 700 x 1.3 = 910 mm

$$\tan 43^\circ = \frac{\left(\frac{910}{2}\right)}{H} = \frac{\left(\frac{700}{2}\right)}{h}$$

$\therefore$ H = 487.9 mm = 48.79 cm (Ans)

(17) Determine the time that exhaust and inlet valves of a 4-stroke cycle engine remain closed together, if the inlet valve opens 10° before TDC and closes 40° after BDC; the exhaust valve opens 35° before BDC and closes 5° after TDC. Take engine speed at 2000 rev/min.

Ans:

Theoretically both inlet and exhaust valve is to remain closed together for angle = 540 – 180 = 360°.

But according to given data they both remained close together for angle = 360 – 40 – 35° = 285°

Engine speed = 2000 rev/min.

$\therefore$ 2000 rev $\equiv$ 2000 x 360° in 1min i.e. in 60 sec.

$$\Rightarrow 285^\circ \equiv \frac{60 \times 285}{2000 \times 360} = 0.023 \text{ sec} \qquad \text{(Ans)}$$

(18) A four-cylinder tractor engine develops 50 KW at 2500 engine rpm when tested on a Prony brake dynamometer with arm length

of 95 cm. Compute the brake net scale reading in newton and the torque in newton- meter at the engine crankshaft.

Ans:

n = 4 N = 2500 rpm, P = 50 kw , r = 0.95 m

Power = 2πNT

$\Rightarrow$50 x 1000 =2π x 2500/60 x T

$\Rightarrow$T= 190. 3 N.m

F = T / r = 190.3/0.95 =200.3N (Ans)

(19) The line of pull on an implement is 15° above the horizontal and is in a vertical plane which is at an angle of 10° with the direction of travel.

(a) Calculate the draft and side draft forces for a pull of 10 kN

(b) What drawbar power would be required at 5 km/hr

Ans:

θ = 15°,ø= 10°, P = 10 kN, V = 5 km/hr

(a) L = P cos ø cos θ = P cos 10° cos 15° = 9.512 kN

S = P sinø cos θ = P sin 10. cos 15° = 1.67 kN

(b) Drawbar power, DBP = LV = 9.512 x 5/3.6 = 13.21 kW (Ans)

(20) A 4-wheel tractor is turning with its centre of gravity located 4 m from the centre of rotation. The C.G. is located 1 m in front of the rear axle and 0.75 m above the ground. The wheel base is 2.25 m and tread is 1.6 m. If the tractor weighs 30,000 N, what is the tractor speed when it begins to overturn ?

Ans:

X_1 = 1m, T = 1.6 m, X_2 = 2.55 m, Y = Z_{cg} = 0.75 m

R = 4m, W = 30,000 N

When tractor begins to overturn speed, V_m is given by

$$V_m=\sqrt{\frac{g\left(\frac{T}{2}\right)R}{Z_{cg}.Cosy}}=\sqrt{\frac{9.81\times\left(\frac{1.6}{2}\right)\times 4}{0.75\times 1}}=6.4\dot{7}\text{ m/s} \quad \text{(Ans)}$$

(21) The turning moment diagram for an engine is given by the T (Nm) = 20460 – 10000 sinθ + 2400 sin 3θ

Where, θ is the crank displacement from the inner dead centre position. Find the power developed by the engine if the mean speed is 210 rpm.

Ans:

$T_\theta = 20{,}100 - 10{,}000 \sin\theta + 2400 \sin 3\theta$ N.m.

N = 210 rpm

$$T = T_{avg} \frac{1}{\pi}\int_0^{\pi} T\theta . d\theta$$

$$= (20{,}100 - 10{,}000 \sin\theta + 2400 \sin 3\theta)\, d\theta$$

$$= \frac{1}{\pi}\left[20100\theta + 10{,}000\cos\theta - \frac{2400}{3}\cos 3\theta\right]_0^{\pi}$$

$$= \frac{1}{\pi}\left[20100\pi + 10{,}000(-2) - 800(-2)\right]$$

$$= 14243.1 \text{ N.m}$$

$$\therefore \text{HP} = 2\pi \text{NT} = 2\pi\left(\frac{210}{60}\right)\frac{14243.1}{746} = 419.8 \text{ HP} \qquad \text{(Ans)}$$

(22) A planter has a vertical-rotor metering device with no seed ejector. The unit is operated without a seed tube, the seeds being released at the lowest point of travel and falling freely by gravity to the furrow bottom 90 mm below. The peripheral speed of the motor is 20 m/min and ground speed is 5 km/hr.

(a) How far does a seed move horizontally, forward or backward, between the point of discharge and the point of impact in the furrow if the rotor turns in the direction opposite to that of the ground wheels ?

(b) At what angle from the vertical does the seed strike the bottom of the furrow ?

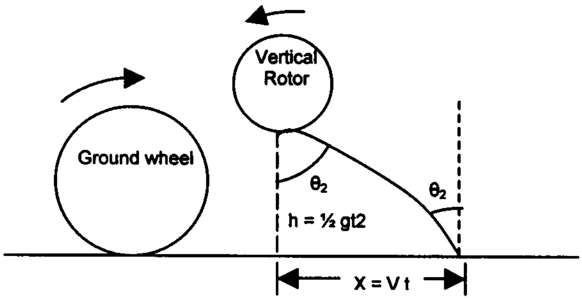
Ans:

Vertical rotor metering mechanism in planter without seed tube

h = 90 mm, V_R = 20m/min, V_G = 5 km/hr

(a) When rotor turns in opposite direction to ground wheel

$V = V_G + V_R$ = (5/3.6) + (20/60) m/s = 1.72 m/s



Again X = Vt

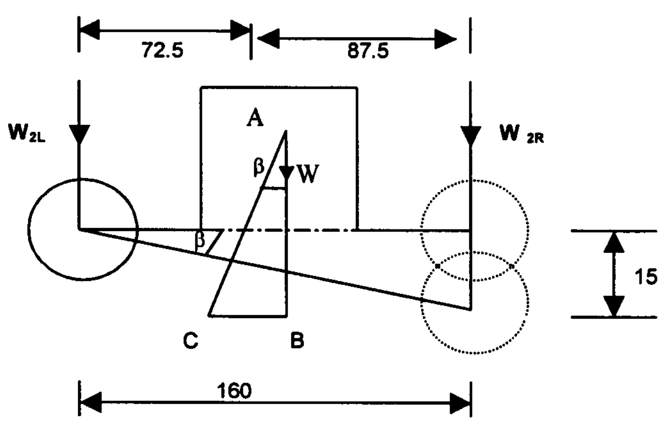
$h = \frac{1}{2} gt^2$

$$X = V\sqrt{\frac{2h}{g}} = 1.72\sqrt{\frac{2\times 0.09}{9.81}} = 0.233 \text{ m} = 23.3 \text{ cm}$$

(b) $\theta = \tan^{-1}(x/h) = \tan^{-1}(0.233/0.09) = 68.87^\circ$ (Ans)

(23) A tractor with a 160 cm rear wheel tread width has a centre of gravity 80 cm above the road way and weighs 24,000 N, while pulling a plough, 70% of the weight is supported on the rear wheels, if the right rear wheel operates in a furrow 15 cm deep and the traction is derived only from one of the wheels. Estimate the percentage increase in pull to be obtained when the differential lock is to be applied. Assume the coefficient of traction equal to 0.30 for the left rear wheel and the right rear wheel.You may neglect any change in weight transfer from the front wheels.

Ans:



(Back view)

When right wheel in furrow, initial pull =16800x0.3 = 5040N

$$\beta = \tan^{-1}\left(\frac{15}{100}\right) = 5.35^0$$

$$\tan\beta = \frac{BC}{AB}$$

$\Rightarrow$BC = AB tanθ = 80 x tan 5.35^0 = 7.5cm

W = 16800 N

If the rear wheel weights are W_{2L} and W_{2R}

Then taking moment about left wheel

W_{2R} x 160 = R_2x72.5

$$\Rightarrow W_{2R} \times 160 = 16800 \times 72.5$$

$\Rightarrow$ W_{2R} = 7612.5N

$\Rightarrow$$W_{2L}$ = 16800-7612 = 9187.5N

Second case: when the differential lock is to be applied

Pull on left rear wheel, P_L = 9187.5x0.3 = 2756.25N

Pull on right rear wheel, P_R = 7612.5x0.5 = 3806.25N

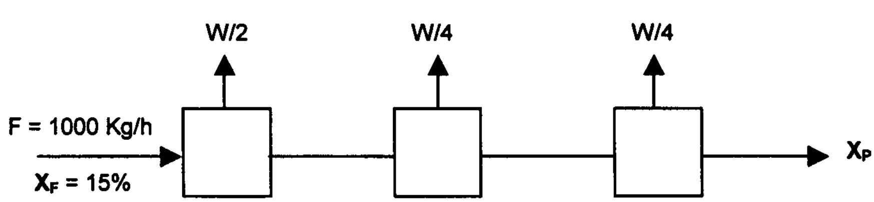
Total pull = P_L+ P_R = 2756.25+3806.25 = 6562.5N

$$\text{\% increase in Pull} = \frac{6562.5 - 5040}{5040} \times 100 = 30.2\% \qquad \text{(Ans)}$$

1990

(1) Total solid in whole milk is to be increased from 15 to 50 % in a triple effect evaporator. 50 % of evaporation is to take place on the first effect and 25 % on each of the last two effects. Milk feed rate is 1000 kg/h. Calculate the total energy used up in evaporation if three effects have temperatures of 70°C, 60°C and 50°C respectively. The latent heat of evaporation at these temperatures are 2334 kJ/kg, 2358.6 kJ/kg, and 2383 kJ/kg.

Ans:



$TS_1 = 15\ \%$ $TS_3 = 50\ \%$

$\lambda_1 = 2334$ kJ/kg, $\lambda_2 = 2358.6$ KJ/kg, $\lambda_3 = 2383$ KJ/kg

$W_1 = W/2$, $W_2 = W/4$ $W_3 = W/4$

Initially total solid present in milk = 1000 x 15/100 = 150 kg

As solid content of evaporated milk remains constant, then solid content in final product = 150 kg

Again 150 kg = 50 % of final product

$\therefore$ Weight final product = 150 x 2 = 300 kg

Other method to calculate weight of final product

$1000 \times 0.15 = X_p \times P = 0.5 \times P$

$\therefore P = 300$ Kg

$\therefore$ Total water evaporated in 3 effect, W = 1000-300 = 700 kg

Water evaporated in 1st effect = $W_1 = W/2 = 700/2 = 350$ kg

Water evaporated in 2nd effect = $W_2 = W/4 = 700/4 = 175$ kg

Water evaporated in 3rd effect = $W_3 = W/4 = 700/4 = 175$ kg

$\therefore$ Total energy used in evaporation = $W_1\,\lambda_1 + W_2\,\lambda_2 + W_3\,\lambda_3$

= 350 x 2334 +175 x 2358.6 + 175 x 2383 = 1646680 KJ (Ans)

(2) Fruit juice having a specific heat of 3.85 kJ/kg^{2}K is being preheated from 5°C to 45°C in a counter flow double pipe heat exchanger. Heating agent is hot water entering at 75°C and leaving at 65°C. The flow rate of fruit juice is 1.5 kg/sec and the area of the heat exchanger is 10m^2. Calculate the overall heat transfer coefficient.

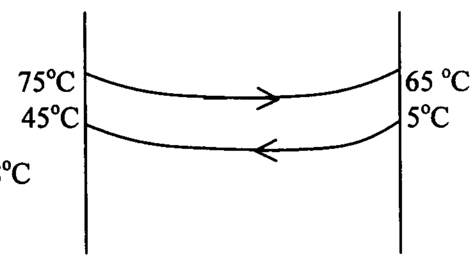
Ans:

For counterflow heat exchanger

$\theta_i = T_{hi} - T_{co} = 75 - 45 = 30°C$

$\theta_0 = T_{ho} - T_{ci} = 65 - 5 = 60°C$

$$\Delta T_m = \frac{\theta_i - \theta_0}{ln\left(\frac{\theta_i}{\theta_0}\right)} = \frac{30-60}{ln\left(\frac{30}{60}\right)} = 43.28°C$$



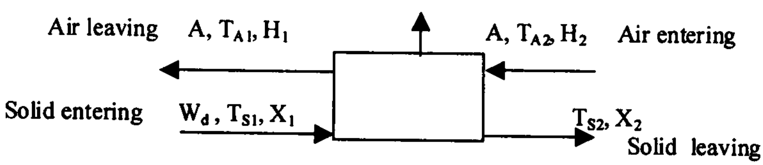
$Q = m\ C_p\ \Delta T = 1.5 \times 3.85 \times (45 - 5) = 231$ KW

But $Q = AU\Delta T = 10 \times 43.28 \times U$

Comparing both the Q values , U = 533.73 W/m^2-°C (Ans)

(3) A continuous countercurrent dryer is used to dry 400 kg of dry solid/hour containing 0.05 kg H_2O/kg dry solid to a value of 0.002 kg H_2O/kg dry solid. The granular solid enters at 30°C and is to be discharged at 60°C. The dry solid has a heat capacity of 1.5 KJ/kg°K Heating air enters at 90^0 C having an absolute humidity of 0.01 kg H_2O/kg dry air and leaves at 40°C. Calculate the air flow into and the outlet humidity, assuming no heat losses in the dryer. Heat capacity of dry air and water vapour and water are 1.005 KJ/kg°K, 1.88 KJ/kg°K. and 4.187 KJ/kg°K respectively. The latent heat of evaporation of water is 2502 KJ/kg at 0°C.

Ans:



$W_d = 400$ kg/h	$T_{A1} = 40°C$,	$T_{A2} = 90°C$
$T_{S1} = 30°C$	$T_{S2} = 60°C$	$X_1 = 0.05$ kg/kg
$X_2 = 0.002$ kg/kg,	$\lambda_0 = 2502$ kJ/kg – K,	$H_2 = 0.01$ kg/kg
$C_{PS} = 1.5$ kJ/kg-k	$C_{PW} = 4.187$ kJ/kg-k	$C_{Pa} = 1.005$ kJ/kg-k
$C_{PV} = 1.88$ kJ/kg-k		

Material balance across dryer

$A.\ H_2 + W_d X_1 = A.\ H_1 + W_d X_2$ (1)

$\Rightarrow A\,(0.01) + 400\,(0.05) = AH_1 + 400\,(0.002)$

$\Rightarrow 0.01\,A + 20 = AH_1 + 0.8$

Heat balance across dryer

$A.\ h_{A2} + W_d\, h_{s1} = A.\ h_{A1} + W_d\, h_{S2} + Q$ (2)

Where,

$h_{A2} = C_S\,(T_{A2}\text{-}0) + H_2\,\lambda_0 = (1.005 + 1.88\,H_2)\,(T_{A2} - 0) + H_2\,\lambda_0$ (3)

$= [1.005 + 1.88\,(0.1)]\,(90 - 0) + 0.01 \times 2502 = 132.39$ kJ/kg

$h_{A1} = C_S\,(T_{A1} - 0) + H_1\,\lambda_0$ (4)

$= (1.005 + 1.88\,H_1)\,(T_{A1} - 0) + H_1.\lambda_0$

$= 1.005 + 1.88\,H_1)\,(40 - 0) + H_1 \times 2502 = 40.2 + 2577.2\,H_1$

$h_{s1} = C_{PS}\,(T_{S1} - T_0) + X_1\,C_{PW}\,(T_{S1} - 0)$ (5)

$= 1.5\,(30.0) + 0.05 \times 4.187\,(30 - 0) = 51.28$ kJ/kg

$h_{S2} = C_{PS}\,(T_{S2} - T_0) + X_2\,C_{PW}(T_{S2} - 0)$ (6)

$= 1.5\,(60\text{-}0) + 0.002 \times 4.187\,(60\text{-}0) = 90.5$ kJ/kg

and $Q = 0$ (for no heat loss)

Putting value of equations 3, 4, 5, 6 in equation 2 and solving equation 1, 2 simultaneously, we get
A = 981.18 kg
H_1 = 0.029 kg H_20/kg dry air. (Ans)

(4) Find the air fuel ratio for the complete combustion of C_2H_{23} (Assume : air contains 23 percent of oxygen by weight).

Ans:
Combustion of hydrocarbon is represented by

$$C_x H_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

$\therefore C_{18} H_{18} + 12.5\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O$
$\therefore$ 114 (= 12 x 8 + 1 x 18) gm of fuel $\equiv$ 400 (= 12.5 x 32) gm of oxygen.
As air contains 23 gm oxygen per 100 gm air

$$\text{Air/fuel} = \frac{400 \times \frac{100}{23}}{114} = 15.25:1$$

Second method

Let 100 gm fuel

$$C\,\% = \frac{96}{96+18} = 84.22\%$$

$$H_2\% = \frac{18}{96+18} = 15.78\%$$

$$\text{Weight of oxygen} = \frac{32}{12} \times 84.22 + \frac{32}{4} \times 15.78 = 350.\,82$$

Weight of air = weight of oxygen x 100/23
=350. 82 x100/23 = 1525.3 gm

$$\therefore \frac{Air}{Fuel} = \frac{1525.3}{100} = 15.25:1$$ (Ans)

(5) A three cylinder 4-stroke engine develops 32 bhp, when the cylinder bore is 9 cm, stroke = 12.5 cm, compression ratio = 16.5:1, engine speed = 2000 rpm and mechanical efficiency = 80 % Calculate (i) piston displacement, (ii) displacement volume (iii) piston speed, (iv) stroke-bore ratio (v) bmep (vi) ihp and (vii) fhp.

Ans:
n = 3, D = 9 cm, L = 12.5 cm, r = 16.5

N = 2000 rpm, ME = 80 %, power = 32 BHP

(i) Piston displacement, LA = L x $\frac{\pi}{4}D^2$ = 12.5 x $\frac{\pi}{4}$ $(9)^2$ = 795.2 cm^3

(ii) Displacement volume, Q_e = LA n$\frac{N}{2}$

= 795.2 x 3 x 1000 = 2.38 m^3/min.

(iii) Piston speed = (2L) N = 2 x 12.5 x 2000 = 500 m/min.

(iv) L/D = $\frac{12.5}{9}$ = 1.38

(v) BHP = p . Q_e

$\Rightarrow$ 32 x 746 = p x $\frac{2.38}{60}$ $\Rightarrow$ p = 6.13 kg/cm^2

(vi) ME = $\frac{BHP}{IHP}$

$\Rightarrow$ 0.8 = $\frac{32}{IHP}$

$\Rightarrow$ IHP = 40 HP

(vii) FHP = IHP – BHP = 40 – 32 = 8 HP (Ans)

(6) Calculate the percentage regulation of speed, when the speed at no load of an engine is 2000 rpm and the speed at load is 1900 rpm.

Ans:

Percentage regulation of speed, R is given by

$$R = \frac{N_0 - N_1}{\left(\frac{N_0 + N_1}{2}\right)} \times 100 = \frac{(2000-1900)}{\left(\frac{2000+1900}{2}\right)} \times 100 = 5.12\% \qquad \text{(Ans)}$$

(7) A multi-disc clutch is constituted of 8 discs. The outer diameter of the contact surface is 15 cm and inner diameter is 11 cm. Determine the total load on springs with which the discs will be held together if 8 hp is to be transmitted at 1000 rpm, assuming a coefficient of friction equal to 0.08. Then what is the load carried by each effective contact surface ?

Ans:

Number of effective contact surface, Z = = n – 1 = 8 – 1 = 7

D_0 = 15 cm, D_i = 11 cm, n = 8, Power = 8 HP, N = 1000 rpm, μ = 0.08

As nothing is mentioned it is assumed to be a case of uniform wear

$\therefore$ mean radius, $r_m = \dfrac{D_0 + D_i}{4} = \dfrac{15+11}{4} = 6.5\text{cm}$

Again HP = $2\pi NT$

$\Rightarrow 8 \times 746 = 2\pi \times (1000/60) \times T$

$\Rightarrow T = 56.99$ N.m.

Also, $T = Fr_m \mu Z$

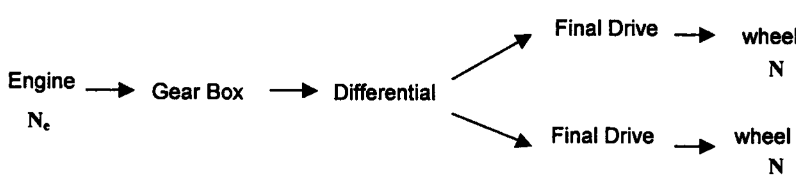
$\Rightarrow 56.99 = F \times 0.065 \times 0.8 \times 7$

$\Rightarrow F = 159.6$ kg

(b) Load on each effective contact surface = F/Z = $\dfrac{159.6}{7}$ =22.7 kg (Ans)

(8) Find the gear ratio of a tractor and of its final drive, if the tractor has 1.2 m traction wheel and travels 5 km per hour when the engine is running 1000 rpm, if the reduction of the transmission gear is 3:1 and that of the differential is 3.5:1.

Ans:



$D = 1.2\text{m}$, $V = 5$ km/hr, $N_e = 1000$ rpm

$V = \pi DN/60$

$\Rightarrow 5/3.6 = \pi \times 1.2 \times N/60$

$\Rightarrow N = 22.1$ rpm

Gear ratio of tractor = $\dfrac{N_e}{N} = \dfrac{1000}{22.1} = 45.24$

Reduction in transmission gear = 3:1

Reduction in differential = 3.5 :1

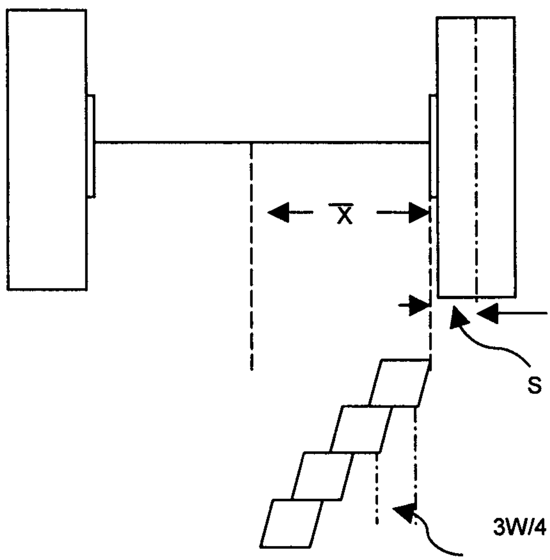
$\therefore$ Gear ratio of final drive = $\dfrac{45.24}{3 \times 3.5} = 4.3:1$ (Ans)

(9) A four-bottom 30 cm mouldboard plough (i.e. each bottom is 30 cm) is drawn by a tractor, at a speed of 5 km per hour. The soil resistance is 0.7 kg/cm^2. The working depth is 15 cm. Find

(a) the centre of resistance from the wing of the first bottom for this 4 bottom 30 cm mould load plough (b) the horse power needed to pull this plough

Ans:

$n = 4$, $W = 0.3m$, $V = 5$ km/hr, $L_u = 0.7$ kg/cm^2, $d = 0.15$ m



(a) Centre of resistance from the wing of the first bottom $\overline{X}$, is given by

$$(4R)\ \overline{X} = R\left(\frac{3W}{4}\right) + R\left(\frac{7W}{4}\right) + R\left(\frac{11W}{4}\right) + R\left(\frac{15W}{4}\right)$$

Here, R = uniform soil resistance of each bottom

$$\therefore \overline{X} = \frac{9W}{4} = \frac{9 \times 0.3}{4} = 0.675\text{m}$$

Note: Centre of resistance of each bottom lies at ¾ th of width of cut from share wing.

(b) Draft, $L = L_u$ x Area $= L_u$ x (n W d) = 0.7 x 4 x 30 x 15 = 1260 kg
HP = L x V = 1260 x (5/3.6) x (9.81/746) = 23.01 HP. (Ans)

(10) The width of a belt is 15 cm and the maximum tension per cm width is not to exceed 12 kg. The ratio of tension, on the two sides is 2.25 the diameter of the driver 1 m and it make 220 revolutions per minute. Find the horse power that can be transmitted.

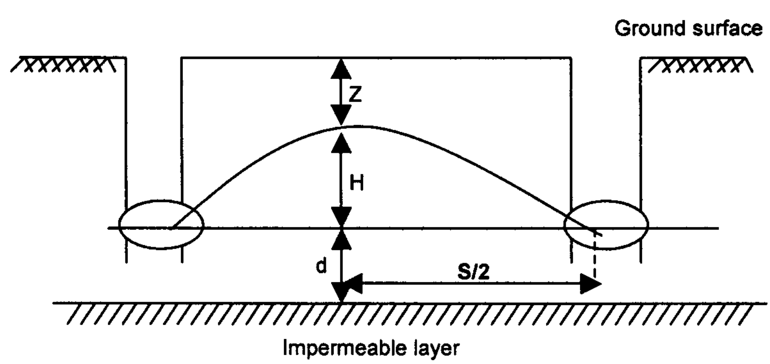
Ans:
$B = 15$ cm, $D_1 = 1$m, $T = 12$ kg/cm, $N_1 = 220$ rpm, $T_1/T_2 = 2.25$
$V = \pi DN = \pi \times 1 \times 220 = 691.15$ m/min
$T_1 = 12 \times 15 = 180$ kg
$\Rightarrow T_2 = 180/2.25 = 80$ kg
$\therefore$ Horse power needed to pull this plough, $HP = (T_1 - T_2)\,V$
$= (180 - 80) \times (691.15/60) \times (9.81/746) = 15.147$ HP (Ans)

(11) Determine the maximum practical suction lift for a centrifugal pump if the discharge is 0.05 the water temperature is 20°C and vapour pressure at this temperature is 0.25m, friction losses in suction line (pipe and pipe fittings) is 1.5 m, NPSH (net positive suction head) of the pump is 3.2 m. The pump is installed at 1500 m above sea level. The atmospheric pressure is reduced by 1.2 m for every 1000 m increased in elevation.

Ans:
$Q_p = 0.05$ m^3/s, $e_s = 0.25$ m, NPSH = 3.2m
$H_f = 1.5$m , Altitude = 1599 m = 1.56 km
$NPSH = H_a - H_f - e_S - H_s - F_s$
$\Rightarrow 3.2 = (10.33 - 1.2 \times 1.56) - 1.5 - 0.25 - H_S - 0.6$
$\therefore H_S = 2.98$ m (Ans)

(12) Determine the flow from the soil into a 2.5 m deep open drain 100 m long when the drains are spaced 50 m apart. The depth of pervious stratum is 3.5 m below the ground surface and depth of water table midway between drains is 1 m below the ground surface. The average permeability of the pervious stratum is 1.5×10^{-4} m/s. The depth of water in the drain is negligible.

Ans:



S = 50m, L = 100 m, K = 1.5 x 10^{-4} m/s
Z + H + d = 3.5 m, Z + H = 2.5m, Z = 1m
H = (Z + H) – Z = 2.5 – 1 = 1.5 m
d = (Z + H + d) – (Z + H) = 3.5 – 2.5 = 1m

∴ Flow from the soil into deep open drain, $q = \dfrac{4kH(2d+H)}{S}$

$$\Rightarrow q = \frac{4\times1.5\times10^{-4}\times1.5\times(2\times1+1.5)}{50}$$

= 6.3 x 10^{-5} m^3/s per meter length of drain

⇒ Q = q x L= 6.3 x 10^{-5} x 100 = 6.3 x 10^{-3} m^3/s (Ans)

(13) The relationship for cumulative infiltration for a soil is given as $I_c = 0.35\ t^{0.8} + 0.2$ where I_c is cumulative infiltration in cm for time t in min. Find the infiltration rate at 1 hour and average rate of infiltration for 1 hour.

Ans:

Infiltration rate, I = dI_c / dt = 0.35 x 0.8 x $t^{0.8-1}$ = 0.28 x $t^{-0.2}$

∴ infiltration rate at 1 hr, (= 60 min), I_{60} = 0.28 $(60)^{-0.2}$ = 0.123 cm

Average rate of infiltration for 1 hour, $I_{av} = \dfrac{I_c}{t}$

$$= \frac{0.35(60)^{0.8}}{60} = 0.157 \text{ cm} \quad \text{(Ans)}$$

(14) Determine the size of tile to carry the design flow from 1000 m of the spaced 36m apart, if the soil drainable porosity is 5 % and drainage requirement for optimum plant growth on an average is water table drop of 0.24 in per day. The grade for the tile is 0.25 %. Manning's roughness coefficient a for the tile may be taken equal to 0.018. Assume that the tile is flowing full.

Ans:

Drainage coefficient = Drop per day x f = 0.24 x 0.05 = 0.012 m/day

Area = L x S = 1000 x 36 = 36000 m^2

Q = DC x A = 0.012 x 36000 = 432 m^3/day

Also, $Q = \left(\dfrac{\pi}{4}D^2\right)\dfrac{1}{n}\left(\dfrac{D}{4}\right)^{2/3} S^{1/2}$

$$\Rightarrow \frac{432}{24\times 3600} = \frac{\pi}{4}\times D^{8/3}\times\frac{1}{0.018\times 4^{2/3}}\times(0.0025)^2$$

$\Rightarrow D = 0.144$ meter (Ans)

(15) Determine the hydraulic conductivity from the test conducted in an auger hole of 8 cm diameter having its bottom 1m below the water table. The depth to impervious layer from water table was 3 m. Before starting the test water level in the hole was brought to 2.2m above the impervious layer. The water level was raised in the hole to 2.80 m above the impervious layer in 3 h 30 min during the test.

Ans:

$2a = 8\text{cm}$

$d = 1\text{m}$

$d + Z = 3\text{m}$

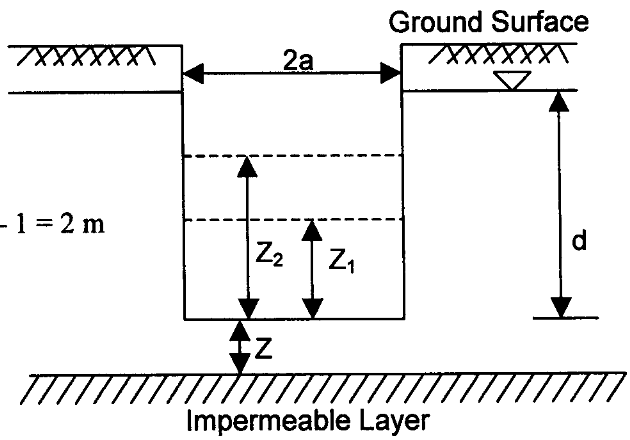
$Z + Z_1 = 2.2\text{m}$

$Z + Z_2 = 2.8\text{ m}$

$Z = (d + Z) - d = 3 - 1 = 2\text{ m}$

$Z_1 = 2.2 - 2 = 0.2\text{ m}$

$Z_2 = 2.8 - 2 = 0.8\text{ m}$



$$\therefore K = \left(\frac{d}{2d+a}\right)\left(\frac{a^2}{0.19t}\right)ln\left(\frac{d-Z_1}{d-Z_2}\right)$$

$$= \left(\frac{1}{2\times 1+0.04}\right)\left(\frac{0.04^2}{0.19\times\left(\frac{3.5}{24}\right)}\right)ln\left(\frac{1-0.2}{1-0.8}\right) = 0.039\text{ m/day} \quad \text{(Ans)}$$

(16) Compare the rainfall amount of a catchment obtained by station average method with that by Thiessen polygon method. Given below are the applicable area obtained from Thiessen polygon method and the rainfall amounts recorded at four rain gauge station :

Rain gauge station	Applicable area, ha	Rainfall amount (mm)
A	15.2	55.0
B	5.6	40.8
C	6.2	51.6
D	10.0	38.4

Ans:

Station average method

$$\overline{P} = \frac{\sum p}{N} = \frac{55 + 40.8 + 51.6 + 38.4}{4} = 46.45 \text{ MM}$$

Thiessen's polygon method

$$\overline{P} = \frac{\sum AP}{\sum A} = \frac{15.2 \times 55 + 5.6 \times 40.8 + 6.2 \times 51.6 + 10 \times 38.4}{15.2 + 5.6 + 6.2 + 10}$$

$= 47.79$ mm (Ans)

(17) Calculate crop factor for paddy at 22° 30' N latitude for September in Blaney-Criddle formula given :
Measured evapotranspiration during September = 138 mm
Mean monthly temperature for September = 30°C
Monthly percentage of daylight hours for September at 22°30 N latitude = 9.1

Ans:

ET = 138 mm, t = 30°C, P = 9.1

U = K [P (0.46t + 8.13)]

138 = K [9.1(0.46 x 30 + 8.13)]

$\Rightarrow$ K = 0.69 (Ans)

(18) A stream of 60 lps was diverted from the canal and a stream of 45 lps was delivered to the field. The root zone depth was 90 cm. The runoff averaged 18 lps for 3 hours. The depth of water penetration at the head of the field was 90 cm and 60 cm at the end of the field. Determine (i) water conveyance efficiency, (ii) water application efficiency, (iii) water storage efficiency and (iv) water distribution efficiency.

Ans:

W_r = 60 lps, W_d = 45 lps, Average runoff = 18 lps

D = 0.9m, d_1= 90 cm, d_2=60 cm

(i) $E_c = \frac{Wd}{W_r} = \frac{45}{60} = 75\%$

$$\text{(ii)}E_a = \frac{W_S}{W_d} = \frac{W_d - \text{runoff}}{W_d} = \frac{45-18}{45} = 60\ \%$$

$$\text{(iii)}\,\bar{d} = \frac{(d_1 + d_2)}{2} = \frac{(90+60)}{2} = 75cm$$

$$E_s = \frac{\bar{d}}{D} = \frac{0.75}{0.9} = 83.33\ \%$$

$$\text{(iv)}\,\bar{y} = \frac{\left(\left|d_1 - \bar{d}\right| + \left|d_2 - \bar{d}\right|\right)}{2} = 15$$

$$E_d = 1 - \frac{\bar{y}}{\bar{d}} = 1 - \frac{15}{75} = 80\ \%$$

(Ans)

(19) Calculate the rainfall kinetic energy and rainfall erosion index of a storm whose cumulative depth of rain with cumulative time is given below:

Cumulative time, min	0	6	12	22	30	35
Cumulative depth, mm	0	6.0	10.0	14.0	14.8	15.6

Ans:

Δt(min)	0	6	6	10	8	5
ΔP (mm)	0	6	4	4	0.8	0.8
I (mm/hr)	-	60	40	24	6	9.6

Here, I< 76 mm/hr

$\Rightarrow E_i = 0.119 + 0.0873 \log (I)$ MJ/ha mm

$\therefore E_1 = 0.119 + 0.0873 \log 60 = 0.274$ MJ/ha mm

$E_2 = 0.119 + 0.0873 \log 40 = 0.259$ MJ/ha mm

$E_3 = 0.119 + 0.0873 \log 24 = 0.24$ MJ/ha mm

$E_4 = 0.119 + 0.0873 \log 6 = 0.19$ MJ/ha mm

$E_5 = 0.119 + 0.0873 \log 9.6 = 0.2$ MJ/ha. mm

$\therefore$ Kinetic energy of total rainfall = $E = \sum E_i\,(\Delta P)_i$

$\Rightarrow E = 0.274 \times 6 + 0.25q \times 4 + 0.24 \times 4 + 0.19 \times 0.8 + 0.2 \times 0.8$

$= 3.95$ MJ/ha

$\therefore$ 30 minute maximum rainfall (= 6+6+10+8) = 6 + 4 + 4 +0.8
= 14.8 mm

$\Rightarrow I_{30}$ = 14.8/30 x 60 = 29.6 mm/hr

$\therefore$ Rainfall erosion index = E I_{30}

$$= 3.95 \times 29.6 = 116.74 \frac{MJ.mm}{ha.hr} \quad \text{(Ans)}$$

1991

(1) The diesel engine of a tractor is required to start cold at – 20°C . The fuel has an auto ignition temperature of 350°C. What minimum compression ratio must the engine have to facilitate starting ? It is found by test that this engine consumes 0.25 kg of diesel fuel per kilowatt-hour. What is the thermal efficiency ? Take n = 1.3 and fuel calorific value = 42,000 kJ/kg

Ans:

Cold starting temperature, T_1 = -20°C = - 20 + 273 = 253°K

Auto ignition temperature, T_2 = 350°C = 350 + 273 = 623°K

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1} = r^{n-1}$$

$$\Rightarrow \frac{623}{253} = r^{1.3-1} = r^{0.3} \quad \Rightarrow r = 20$$

$$\text{Thermal efficiency} = \frac{641\dfrac{Kcal}{hr}}{\dfrac{Kg}{BHP-hr} \times \dfrac{Kcal}{Kg}} = \frac{641}{(\dfrac{0.25}{1.34}) \times \dfrac{42000}{4.2}}$$

= 0.3429 = 34.29 % (Ans)

(2) A traction wheel having 600 mm diameter was tested in a soil bin and the following data were recorded : angular speed of wheel = 10 rev/min: input torque to wheel axle = 60 Nm: drawbar pull = 150 N; Normal load on wheel axle = 500 N: wheel forward speed = 0.25 m/sec. Compute (a) coefficient of traction (b) wheel slippage (c) tractive efficiency

Ans:

(a) Coefficient of traction, $\mu = \dfrac{\text{drawbar pull}}{\text{dynamic weight on rear axle}}$

$$= \frac{150}{500} = 0.3$$

(b) wheel theoretical speed, $V_t = \pi DN = \pi \times 0.6 \times (10/60) = 0.314$ m/s
wheel forward speed, $V_a = V_t\,(1\text{-}S)$
$\Rightarrow 0.25 = 0.314\,(1\text{-}S)$
$\Rightarrow S = 0.2038 = 20.38\ \%$

(c)Tractive efficiency $= \dfrac{\text{drawbar power}}{\text{axle power}} = \dfrac{P.Va}{T\omega} = \dfrac{P.Va}{(2\pi N)T}$

$$= \frac{150 \times 0.25}{2\pi \times \left(\frac{10}{60}\right) \times 60} = 0.5968 = 59.68\ \% \quad \text{(Ans)}$$

3(a) While turning a 4-wheel tractor equipped with the Ackermann steering mechanism, the axis of the inner front wheel makes an angle of 45^0 whereas the angle made by the axis of the outer front wheel is 30^0 with horizontal and parallel to the front axle. The kingpins of the axle are 1300 mm apart . The spindle lengths are essentially zero. What should be the wheel base of the tractor if there is no slippage of any of the wheels?

(b) An airblast sprayer is to be operated at 3 km/hr and the desired application rate is 18 liter per tree. The tree spacing is 9 x 9 m and each nozzle delivers 50 liter/min at the operating pressure of 40 x 10^5 N/m^2. If one half row is sprayed from each side of the machine, how many nozzles will be needed ?

Ans:

(a) $\text{Cot}\,\theta - \cot\phi = \dfrac{W}{L}$

$\Rightarrow \text{Cot}\,30 - \cot 45 = \dfrac{1300\text{mm}}{L}$

$\Rightarrow L = 1776$ mm $= 1.776$ m

(b) Discharge per plant, Q' = 18 lit

Velocity of operator, V = 3km/h
Plant to plant spacing in row L = 9m

Time required to cover 1 plant, t' = L/V = $\frac{9m}{(3/3.6)} = 10.8$ sec

If one half row is sprayed from each side of machine, then discharge on one side = Q/2 = 18/2 = 9 lit

$\therefore$ Rate of spraying on one side, Q = 9/10.8 = 0.83 lit/s

But Q = nq, where n = number of nozzles on each side

Q = spraying rate from each nozzle = 5 lit/min. = 0.083 lit/s

$\therefore$ n = Q/q =0.83/ 0.083 =10

$\therefore$ Total number of nozzles on 2 sides = 2n = 2 x 10 = 20 (Ans)

(4) A single plate friction clutch with both sides effective is to transmit 15 kW at 2,000 rev/min. The axial pressure is limited to 0.1 N/mm^2. If the outer diameter, of the friction lining is 1.5 times the inner diameter find the required outer and inner diameters of the friction lining. Assumes uniform wear conditions . The coefficient of friction may be taken as 0.3

Ans:

Power = 2πNT

$$\Rightarrow 15 \times 1000 = 2\pi \frac{2000}{60} T$$

$\Rightarrow$ T = 71.619 N.m.

But torque acting on plate clutch, $T = F\, r_m\, \mu Z = PA\, r_m\, \mu\, Z$ (1)

For uniform wear

$$A = D_i \frac{(D_0 - D_i)}{2} \quad (2)$$

$$r_m = \frac{(D_0 + D_i)}{4} \quad (3)$$

Given $D_0/D_i = 1.5$

$P = 0.1 \times 10^6$ Pascal, $\mu = 0.3$, $Z = 2$

$\therefore$ Using equation (1) and (2) and putting all the known values,

$D_0 = 0.2$m = 20 cm

$\therefore D_i = D_0/1.5 = 0.2/1.5 = 13.4$ cm (Ans)

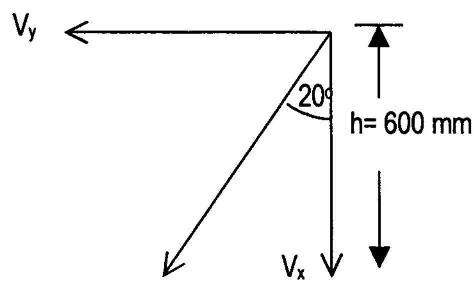
5(a) The seed tube on a plate-type maize planter is angled 20° rearward from the vertical and the seed plate is 600 mm above the furrow bottom. If the planter speed is 7 km/hr, what would be the horizontal velocity of the seed with respect to the ground when the seed reaches the furrow ? Assume the initial velocity of the seed entering the tube is zero. Neglect the effects of friction and seed bouncing in the tube .

(b) A 2-bottom 350 mm mould board plough is operated at 5 km/hr and maintained at 150 mm depth in a sandy soil. The specific draft of the plough is 4×10^{-2} N/mm^2. Calculate
(i) the draw bar power requirement in kW
(ii) the area covered in hectares per hour if the field efficiency is 75 %

Ans:

(a) Velocity of strike of seed to ground = V $= \sqrt{2gh}$

$$= \sqrt{2 \times 9.81 \times 0.6} = 3.43 \text{ m/s}$$



Horizontal velocity of seed with respect to Planter, $V_y = V \sin 20^O$
$= 3.43 \times \sin 20^\circ = 1.17$ m/s $= 4.22$ km/h V_x
Planter speed, $V_p = 7$ km/h
$\therefore$ Horizontal velocity of seed with respect to ground $= V_y + V_p$
$= 4.22 + 7 = 11.22$ km/h

(b) Draft , L = unit draft x area covered = $4 \times 10^{-2} \times (2 \times 350 \times 150)$
$= 4.2$ kN

(i) Drawbar power = LV= 4.2 x (5/3.6) = 5.83 kW
Theoretical field capacity = nWV = 2 x 0.35 x (5/10) = 0.35 ha/hr
(ii) Actual field capacity = Theoretical field capacity x field efficiency
= 0.35 x 0.75 = 0.2625 ha/hr (Ans)

(6) Calculate the design peak discharge expected to occur once in 25 years at a site for construction of a drop-structure to handle the run-off from a watershed comprising 20 ha of cultivated terraced land (C = 0.50), 15 ha of hilly forest land (C = 0.30) and 8 ha of

rolling grass land (C = 0.35). The maximum length of flow is 2 km and the total fall along the path is 200 m. The maximum rainfall recorded for various durations in 25 years are given below.

Duration in minutes	5	10	15	20	40	60
Maximum rainfall in cm	2.0	3.0	4.0	5.0	9.0	12.0

Use $T_c = 0.0195\ L^{0.77}\ S^{-0.345}$

Ans:

Time of concentration (T_c) of watershed is given by,

$T_c = 0.\ 0195\ L^{0.77}\ S^{-0.385}$

$\Rightarrow T_c = 0.0195\ (2000)^{0.77}\ (200/2000)^{-0.385} = 16.475$ min

Runoff coefficient (C) of watershed is given by

$$C = \frac{a_1C_1 + a_2C_2 + a_3C_3}{a_1 + a_2 + a_3} = \frac{20 \times 0.5 + 15 \times 0.3 + 8 \times 0.35}{20 + 15 + 8} = 0.402$$

From Duration Vs maximum rainfall table, rainfall (P) corresponding to duration equal to time of concentration 16.475 min is given by,

P = 4 + (1.475/5) = 4.295 cm

$$\therefore \text{ Rainfall intensity, } I = \frac{P}{T_c} = \frac{4.295}{16.475} = 156.4 \text{ mm/h}$$

$$\therefore \text{ Peak discharge, } Q_p = \frac{CIA}{360} = \frac{0.402 \times 156.4 \times 43}{360} = 7.5 \text{ m}^3/\text{s} \qquad \text{(Ans)}$$

(7) In a falling head permeameter test, the initial head is 43 cm. The head drops by 6 cm in 12 minutes. Calculate the time required to run the test if a final head of 21 cm is to be attained. Also, if the sample is 8 cm in height and 50 cm^2 in cross-sectional area calculate the coefficient of permeability taking the area of stand pipe as 0.5 cm^2.

Ans:

For falling head permeameter test, permeability (k) is given by

$$K = \frac{aL}{At} ln\frac{h_1}{h_2} = \frac{0.5 \times 8}{50 \times 720} ln\left(\frac{43}{37}\right) = 1.002 \times 10^{-3} \text{ cm/min}$$

From previous equation we get

$$t_1 = \frac{aL}{AK} ln\frac{h_1}{h_2}$$

$$t_2 = \frac{aL}{Ak} ln\frac{h_1}{h_3}$$

$$\therefore \frac{t_1}{t_2} = \frac{ln\left(\frac{h_1}{h_2}\right)}{ln\left(\frac{h_1}{h_3}\right)} \Rightarrow \frac{12}{t_2} = \frac{ln\left(\frac{43}{47}\right)}{ln\left(\frac{43}{21}\right)} \Rightarrow t_2 = 57.22 \text{ min} \qquad \text{(Ans)}$$

8 (a) Find the discharge carrying capacity of a grassed water way on 4 percent bed slope with 1.0 m bottom width and 0.4m flow depth at 4:1 side slopes. The roughness coefficient can be taken as 0.04.

(b) Keeping 100 cans uniformly spaced in an area covered by four sprinklers, the average depth caught in a given time was 27 mm with an average deviation of 2.4 mm from the mean. What is the uniformity coefficient ? Assuming that the infiltration rate was not exceeded and the percolation loss was 5 percent, find the application efficiency.

Ans:

(a) S = 4 %, b = 1m, d = 0.4m, Z = 4:1, n = 0.04

Discharge carrying capacity of grassed water way, Q = AV

Where $A = bd + Zd^2 = 1 \times 0.4 + 4 + 0.4^2 = 1.04 \text{ m}^2$

$V = 1/n\ R^{2/3}\ S^{1/2} = 1/n\ (A/P)^{2/3}\ S^{1/2}$

$$\therefore P = b + 2d\sqrt{z^2+1} = 1 + 2\times 0.4\sqrt{4^2+1} = 4.298\text{m}.$$

$$\therefore V = \frac{1}{0.04}\left(\frac{1.04}{4.298}\right)^{2/3}(0.04)^{1/2} = 1.93\text{m/s}$$

$\therefore Q = 1.04 \times 1.93 = 2.01 \text{ m}^3/\text{s}$

(b) Uniformity coefficient of sprinkler application is given by,

$$C_u = 1 - \frac{\bar{y}}{\bar{d}}$$

where $\bar{y} = 2.4$ mm, $\bar{d} = 27$mm

$$\therefore C_u = 1 - \frac{2.4}{27} = 91.11\%$$

Assuming that infiltration rate was not exceeded and percolation loss = 5 %, application efficiency, $E_a = 100 - 5 = 95$ % (Ans)

(9) Find out the diameter of the pipe of a drop-inet spillway for the following conditions.
Length of pipe = 10 m, Total drop = 3 m, Design discharge = $2m^3$/sec., Entrance loss coefficient,K = 0.1, Head loss coefficient, K = 0.01, If the total drop is reduced to 1.5m what is the percentage change in discharge carrying capacity ?

Ans:

For drop inlet spillway discharge capacity, Q is given by

$$Q = AV = \left(\frac{\pi}{4}d^2\right)\sqrt{\frac{2gH}{1+K_e+K_cL}}$$

$$\Rightarrow 2 = \left(\frac{\pi}{4}d^2\right)\sqrt{\frac{2\times 9.81\times 3}{1+0.1+0.01\times 10}} \Rightarrow d = 0.6m$$

When H = 1.5m

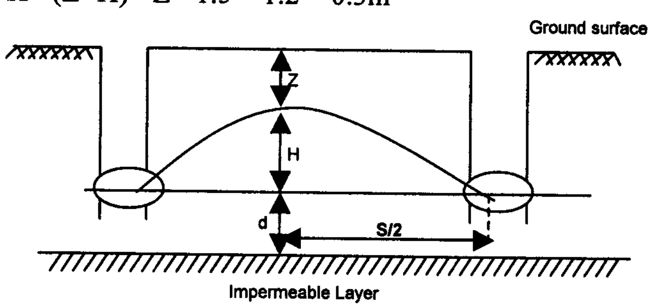
$$\therefore Q = \left(\frac{\pi}{4}0.6^2\right)\sqrt{\frac{2\times 9.81\times 1.5}{1+0.1+0.01\times 10}} = 1.414\ m^3/S$$

$\therefore$ Percentage change in discharge capacity = $\dfrac{2-1.414}{2} = 29.28\%$ (Ans)

(10) Neglecting resistance due to convergence of flow near the drain, compute the spacing of open drains in a field of clay loam soil with hydraulic conductivity of 0.6m per day when the impervious layer is at 2.4m below the drains. Bottom of the drain and minimum water table level below the ground surface are 1.5 m and 1.2m respectively. The excess irrigation rate is equivalent to the drainage coefficient of 1.5 mm per day.

Ans:

K = 0.6 m/day, R = 1.5 mm/day , d = 2.4 m, Z+H=1.5 m, Z=1.2m
H =(Z+H) - Z= 1.5 – 1.2 = 0.3m



Spacing of open drain, S is given by,

$$S = \sqrt{\frac{4kH(2d+H)}{R}} = \sqrt{\frac{4\times0.6\times0.3(2\times2.4+0.3)}{1.5\times10^{-3}}} = 49.47 \text{ m}$$

(11) A liquid food is being pumped through a 3.5 cm diameter 50 m long pipe at a flow rate of 200 liters/min. What pressure would be generated at the discharge of the pump. If the end of the pipe is at atmospheric pressure ? Viscosity of the food = 0.1 Pa. S and its density = 1020 kg/m^3.

Ans:

Cross sectional area of pipe, $A = \frac{\pi}{4}D^2 = \frac{\pi}{4} \text{ x } (0.035)^2 = 9.62 \text{ x } 10^{-4} \text{ m}^2$

Velocity of flow through pipe, $V = Q/A = \frac{(0.2/60)}{9.62\times10^{-4}} = 3.46$ m/s

Reynolds number of flow, $Re = \frac{\rho DV}{\mu} = \frac{1020\times0.035\times3.46}{0.1} = 1237$

Reynolds number is less than 2100. So flow nature is laminar

For laminar flow pressure drop (ΔP) across 2 ends of pipe is given by,

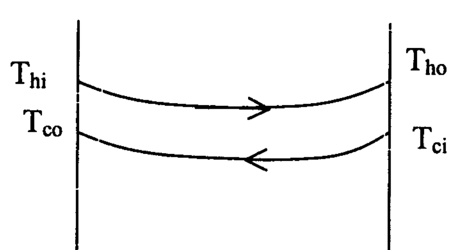
$$\Delta P = \frac{32\mu VL}{D^2} = \frac{32\times0.1\times3.46\times50}{(0.035)^2} = 452.44 \text{ kPa}$$

Pressure generated at the discharge of pump $= P_{atm} + \Delta P$

$= 101.325 + 452.44 = 553.765$ kPa (Ans)

(12) A pasteurized milk stream flowing at the rate of 50 kg/h is to be cooled from 73°C to 15°C in a heat exchanger by flowing cooling water in counter-current flow. Calculate the quantity of cooling water required and the required heat transfer area for the heat exchanger. Overall heat transfer coefficient based on inside surface is 600 W/m^{2}K. Specific heat of milk = 3.9 kJ/kg K and specific heat of water = 4.2 kJ/kg K. Cooling water enters at 10°C and leaves at 17°C.

Ans:



$T_{hi} = 73^0C$, $T_{h0} = 15^0C$, $T_{ci} = 10^0C$, $T_{co} = 17^0C$
Heat lost by hot fluid (milk) = Heat gained by cold fluid (water)
$\therefore m_h C_{ph} (T_{hi} - T_{h0}) = m_c C_{pc} (T_{c0} - T_{ci})$
$\Rightarrow 50 \times 3.9 \times (73 - 15) = m_c \times 4.2 \times (17 - 10)$
$\Rightarrow m_c = 384.7$ kg/h
$\therefore$ Quantity of cooling water required is equal to 384.7 kg/h.

$$\Delta T_m = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\left(\frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}\right)} = \frac{56 - 5}{\ln\left(\frac{56}{5}\right)} = 21.11^\circ C$$

Again heat gained by cold fluid = Heat transferred from inside (milk side) to outside (water side) of pipe
$\Rightarrow m_c C_{pc} (T_{c0} - T_{ci}) = A\, U_i\, \Delta T_m$
$\Rightarrow 384.7 \times 4.2 \times 7 = (A \times 600 \times 21.11) \times 3.6$
$\Rightarrow A = 0.248\ m^2$
$\therefore$ Required heat transfer area = $0.248\ m^2$ (Ans)

(13) Freshly harvested paddy containing 33 % moisture content (dry basis) is to be dried to 15 % moisture content (dry basis). Calculate the energy requirement per kg of water removed. If the initial temperature of paddy is 25°C and temperature of drying is 40°C. Latent heat of vaporization in paddy at 40°C = 2700 kJ/kg. Specific heat of paddy = 1.7 kJ/kg°C.

Ans:

Amount of water removed = $W_d \left(\frac{33 - 15}{100}\right) = 0.18\ W_d$ kg

Where W_d = weight of dry matter present in paddy
Heat used in heating grain (i.e. dry part of paddy)
$= W_d C_{PG}\, \Delta T_G = W_d \times 1.7 \times (40 - 25) = 25.5\ W_d$ kJ
Heat used in heating water (i.e. liquid part of paddy)
$= M_i\, C_{PW}\, \Delta T_W = \left(W_d \times \frac{33}{100}\right) \times 4.18 \times (40 - 25) = 20.69\ W_d$

Heat used in evaporating water = $0.18\ W_d \times 2700$ kJ = $486\ W_d$ kg
$\therefore$ Total energy required = $486\ W_d + 25.5\ W_d + 20.69\ W_d = 532.19\ W_d$ kJ

$\therefore$ Energy required per kg of water evaporated $= \frac{532.19 W_d}{0.18 W_d}$
$= 2956.6$ kJ/kg

Other method

Energy required per kg of water evaporated

$$= 2700 + \frac{20.69W_d}{0.18W_d} + \frac{25.5W_d}{0.18W_d} = 2956.6\frac{kJ}{kg} \qquad \text{(Ans)}$$

14(a) Calculate the settling velocity of a fat globule of diameter 2mm in milk at 30°C . Density of fat at 30°C is equal to 918 kg/m^4 and density of milk = 1024 kg/m^3. Kinematic viscosity of fat = 1.85 x 10^{-6} m^2/s.

(b) If the fat globules of the above dimension are to be separated by a centrifuge at a rotational speed of 1500 rev/min and at effective radius of separation of 3.8 cm what would be the velocity of the fat globule through milk ?

Ans:

(a) Dynamic viscosity of fat globule, $\mu = \upsilon \times \rho$

$$= 1.85 \times 10^{-6} \times 918 = 12.698 \times 10^{-3} \text{ kg/m.s}$$

Settling velocity of fat globule, $V_T = \dfrac{D^2(\rho_s - \rho_f)g}{18\mu}$

$$\therefore V_T = \frac{(2\times10^{-6})^2(1024-918)9.81}{18\times1.698\times10^{-3}} = 0.489 \text{ mm/hr}$$

(b) In the given centrifuge velocity,V of fat globule through milk is given by

$$V = \frac{D^2(\rho_s - \rho_f)\omega^2 R}{18\mu}$$

where $\omega = 2\pi N = 2\pi \times (1500/60 = 157.01$ rad/S

$$\therefore V = \frac{(2\times10^{-6})^2(1024-918)(157.01)^2(3.8\times10^{-2})}{18\times1.698\times10^{-3}} = 47.08 \text{ mm/hr (Ans)}$$

1992

(1) A single plate clutch, with both sides effective, has an outer diameter of 30 cm and inner diameter of 20 cm. The maximum intensity of pressure at any point in the contact surface is not to exceed 1 kg/cm^2. If the coefficient of friction is 0.3 determine the horse-power transmitted-based clutch at a speed of 2000 rev/min.

Ans:

As nothing is mentioned it is customary to assume to be a case of uniform wear.

$\therefore$ Torque acting on clutch plate, $T = F\, r_m\, \mu\, Z = PA\, r_m\, \mu\, Z$

Where $A = \pi D_i (D_o - D_i)/2 = \pi \times 0.2\,(0.3 - 0.2)/2 = 0.0314\ m^2$

$r_m = (D_o + D_i)/4 = (0.3 + 0.2)/4 = 0.125\ m$

$\therefore\ T = (9.81 \times 10^4) \times 0.0314 \times 0.125 \times 0.3 \times 2 = 231$ N.m.

$\therefore$ Horse power transmitted by clutch, $P = 2\pi NT$

$= 2\pi\ (2000/60) \times 231/746 = 64.85$ HP (Ans.)

(2) A 2-wheel drive 35 hp tractor has 1.5 m near wheel diameter . The engine runs at 1200 rev/min. The reduction of speed is 50:1. Find the travelling speed of the tractor in km/hr and the tractive force at each driving wheel.

Ans:

RPM of rear wheel, N = 1200/50 = 24 rpm.

(i) Velocity of travel, $V = \pi DN$

$= \pi \times 1.5 \times (24/60)$

$= 1.88$ m/s $= 1.88 \times 3.6 = 6.78$ km/h

(ii) Power at each wheel = 35/2 = 17.5 HP

$\therefore$ Power $= 2\pi\, NT$

$\Rightarrow 17.5 \times 746 = 2\pi\,(24/60)\,T$

$\Rightarrow T = 5194$ N.m.

Again Torque on each wheel , $T = F.r$

$\Rightarrow 5194 = F\,(1.5/2)$

$\Rightarrow F = 6925$ N

$\therefore$ Tractive force at each driving wheel = 6925 N (Ans)

(3) Calculate the brake horse power of a 2-stroke single-cylinder engine from the following data : Cylinder diameter = 7.5 cm, Length of stroke = 10.0 cm, rev/min = 1000, mean effective pressure = 6 kg/cm^2, frictional horse power = 3 hp

Ans:
Indicated horse power of engine, IHP = P x LAnN

$\therefore$ IHP $= (6 \times 9.81 \times 10^4) \times 0.1 \times (\frac{\pi}{4} \times 0.075^2) \times 1 \times (1000/60) \times (1/746)$

$= 5.81$ HP

$\therefore$ Brake horse power of engine, BHP = IHP – FHP
= 5.81 – 3 = 2.81 HP (Ans)

(4) Calculate the time required to sow 1 hectare of land with a bullock drawn seeder of size 5 x 20 cm. The operating speed is 3 km/hr and the loss due to turning is 20 %.

Ans:
Width of coverage = 5 x 20 = 100 cm = 1 m
Theoretical field capacity,TFC = width x velocity
= (1 x 3)/10 = 0.3 ha/hr
Theoretically time (T_T) required to cover = 1/0.3 = 10/3 hr/ha
Time loss due to turning = 20 %

$$\therefore \text{Field efficiency} = \frac{100}{100+20} = 0.8333$$

$$\text{Field efficiency} = \frac{\text{Theoretical time } (T_T)}{\text{Actual time } (T_A)}$$

$$\therefore \text{Actual time } (T_A) \text{ required} = \frac{T_T}{FE} = \frac{10/3}{0.8333} = 4.01 \text{ hr/ha}$$

Other Method
Actual field capacity, AFC = FE x TFC = 0.8333 x 0.3 = 0.249ha/hr
$\therefore$ Actual time (T_A) required hr/ha = 1/0.249 = 4.01 hr/ha (Ans)

5(a) The pair of bullocks weigh 600 kg and can pull about 1/10th of their body weight. Find out the power required and the power available to operate this seeder when each of the 5 furrow openers makes a rectangular furrow cross-section of 5 cm wide x 5 cm deep. The soil resistance on the seeder is 0.4 kg/cm^2.

Ans:
Width of coverage = 5 x 5 = 25 cm
Area of coverage = width x depth = 25 x 5 = 125 cm^2
Draft (L) of seeder = 0.4 x 125 = 50 kg
Power required to pull = LV = (50 x 3)/3.6 = 41.67 kg.m/S = 0.548 HP

Weight of bullocks = 600 kg
Pull that bullocks can exert = 600/10 = 60 kg

$\therefore$ Power available = $\dfrac{60 \times 3}{3.6} = 50 \dfrac{\text{kgm}}{\text{S}}$ = 0.657 HP (Ans)

(b) The seed drill is calibrated to sow 60 kg of seeds/ha. What will be the seed rate, if the speed of operation is increased to 5 km/hr ?
Ans:
Seed rate is independent of velocity of operation. So if speed of operation is increased to 4.5 km/hr then same seed rate of 60 kg/ha will be maintained.

(6) Calculate the coefficient of permeability of a soil sample 6 cm in height and 60 m^2 in cross sectional area. If a quantity of water equal to 450ml passed down in 10 numbers under an effective constant head of 40cm

Ans:
Flow rate of water through permeable soil is given by

$$\frac{Q}{t} = kiA = K\left(\frac{\Delta h}{\Delta L}\right)A$$

$$\Rightarrow \frac{450 \times 10^{-3} \times 10^{-3}}{600} = k\left(\frac{0.4}{0.06}\right) \times 50 \times 10^{-4}$$

$\Rightarrow$ K = 2.25 x 10^{-5} m/s = 0.135 cm/min (Ans)

(7) Determine the capacity of a sprinkler system which has 12 sprinklers spaced at 10 m interval on each of the two laterals spaced at 15 m apart . Application rate of water is 150 cm/hr.

Ans:
Capacity of sprinkler system (Q) is given by
Q = nq = n x S_L x S_m x I
Where n = total number of sprinklers = 2 x 12 = 24
$\therefore$ Q = 24 x 10 x 15 x 1.5 x 10^{-2} m^3/hr = 54 m^3/hr = 15 lit/s (Ans)

(8) A 20 cm well completely penetrates an artisian aquifer .The length of the strainer is 15 cm. What is the yield for a drawdown of 5 meter. Assume K=36 m/day. Radius of influence, R=500 meter.If the diameter of the well is doubled, find the percentage increase in the yield, if other conditions remain same.

Ans:

Yield of the well , $Q = \dfrac{2\pi kbS}{ln(R/r_w)} = \dfrac{2\pi \times 36 \times 15 \times 5}{ln(500/0.2)}$ = 1992 m^3/day

When the diameter is doubled,

$$Q = \frac{2\pi kbS}{ln\left(\dfrac{R}{r_w}\right)} = \frac{2\pi \times 36 \times 15 \times 5}{ln\left(\dfrac{500}{0.2}\right)} = 2168.3 \text{ m}^3\text{/day}$$

$\therefore$ Percentage increase in yield = $\dfrac{2168.3 - 1992}{1992}$ = 8.88 % (Ans)

Other method

Percentage increase in yield $= \dfrac{Q_2 - Q_1}{Q_1} \times 100 = (\dfrac{Q_2}{Q_1} - 1) \times 100$

$$= \left(\frac{\ln \dfrac{R}{r_{w1}}}{\ln \dfrac{R}{r_{w2}}} - 1 \right) \times 100 = \left(\frac{\ln \dfrac{500}{0.1}}{\ln \dfrac{500}{0.2}} - 1 \right) \times 100 = 8.88\%$$

(9) An area of 1 hectare was irrigated in 15 hours with a stream of 20 litres/acre. Depth of root zone was 80 cm and available moisture-holding capacity 20 cm/m. Irrigation was applied when 50 % of available moisture was depleted. Water application efficiency was 60 %. Determine the water storage efficiency.

Ans:

Depth of water stored, d_s is calculated as follows

$$Q = \frac{Ad_s}{tE_a}$$

$$\Rightarrow 20x10^{-3} = \frac{10^4 \times d_s}{0.6x15 \times 3600}$$

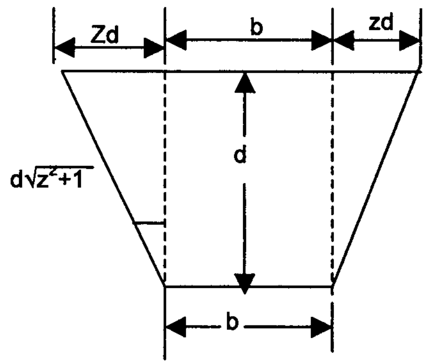
$\Rightarrow d_s$= 6.48 cm

Depth of water needed, d_n = D x AMHC x 0.5 = 0.8 x 20 x 0.5 = 8 cm

$\therefore$ Water storage efficiency, E_s= d_s/d_n = 6.48/8 = 81 % (Ans)

(10) Calculate the bottom width of a trapezoidal channel having best hydraulic section to carry a design discharge at a flow depth of 2 m . Slide slope for the channel may be taken as 1:1

Ans:



Method 1

For best trapezoidal cross section, bottom width , b = 2d tan θ/2
where θ = $\tan^{-1}$ (1/z) = $\tan^{-1}$ (1/1) = 45°
∴ b = 2 x 2 x tan (45/2) = 1.66 m

Method 2

For best trapezoidal cross section, $R=\frac{A}{P}=\frac{bd+zd^2}{b+2d\sqrt{z^2+1}}=\frac{d}{2}$

$$\Rightarrow 2bd+2zd^2 = bd+2d^2\sqrt{z^2+1}$$

$$\Rightarrow bd = 0.414\times 2d^2$$

$$\Rightarrow b = 0.828\times d = 1.66m$$

Method 3

half of top width = one of the sloping sides, (for best trapezoidal cross section)

$$\Rightarrow \frac{b+2zd}{2} = d\sqrt{z^2+1}$$

$$\Rightarrow b = d(2\sqrt{2}-2) = (1.414-1)\times 2\times 2 = 1.66$$ (Ans)

(11) A roller crusher required 10 kW power to crush spherical grains of 25 mm diameter into 5 mm diameter particles at a feeding rate of 5 kg/s.

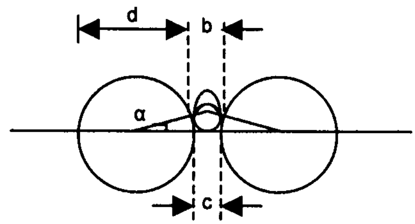
(a) If the coefficient of friction is 0.268, what should be the diameter of the rolls ?

(b) If the capacity is reduced to 2.5 kg/s and the particles diameter to 2.5 mm, what should be the power consumption ?

Ans:

(a) Coefficient of friction between grain and roll, $\mu = \tan\alpha$

$\Rightarrow \alpha = \tan^{-1}(\mu) = \tan^{-1}(0.268) = 15^\circ$



$$\cos\alpha = \frac{d+c}{d+b}$$

$$\Rightarrow \cos 15^\circ = \frac{d+5}{d+25}$$

$\Rightarrow d = 56.2$ cm

(b) In first case power required (P_1) to crush grain is given by

$$\frac{P_1}{f_1} = K_b\left(\frac{1}{\sqrt{D_{P1}}} - \frac{1}{\sqrt{D_f}}\right)$$

$$\Rightarrow \frac{10}{5} = K_b\left(\frac{1}{\sqrt{5}} - \frac{1}{\sqrt{25}}\right) \Rightarrow K_b = 8.09kW$$

In second case power required (P_2) to crush grain is given by

$$\frac{P_2}{f_2} = K_b\left(\frac{1}{\sqrt{D_{P2}}} - \frac{1}{\sqrt{D_f}}\right)$$

$$\Rightarrow \frac{P_2}{2.5} = 8.09\left(\frac{1}{\sqrt{2.5}} - \frac{1}{\sqrt{25}}\right)$$

$\Rightarrow P_2 = 8.75kW$ (Ans)

(12) How much water should be evaporated from 1 kg of 5 % sugar solution at 30°C to concentrate it upto a level of 50 % ? Calculate the specific energy required if the efficiency of evaporator is 85 percent.

Given: Specific heat of solution 3.95 kJ/kg °C: Boiling point of solution 105°C; and Latent heat of vaporization 2502.3 kJ/kg

Ans:

(i) Total solid in = Total solid out

$\therefore F.X_f = P.X_p$

$\Rightarrow 1 \times 0.05 = P \times 0.5$
$\Rightarrow P = 0.1$ kg
Total material in = Total material out
$F = P + W$
$\Rightarrow 1 = 0.1 + W$
$\Rightarrow W = 0.9$ kg
Amount of water to be evaporated is 0.9 kg
(ii) Specific energy required $= m\, C_p\, \Delta T + W\lambda$
$= 1 \times 3.95 \times (105 - 30) + 0.9 \times 2502.3$
$= 2548.32$ kJ
If evaporator efficiency = 85 %, then

specific energy required $= \dfrac{2548.32}{0.85} = 2998$ kJ (Ans)

(13) A particle in free fall will reach a steady-state velocity is constant terminal velocity
(a) What are the different forces that will act on the particle in free fail.
(b) Derive a general expression for the terminal velocity.

Ans:
(a) When a particle in free fall will reach a steady state velocity, different forces acting on the particle in that condition are
(1) Drag force (F_d)
(2) Gravity force (F_g)
(3) Buoyancy force (F_b)
(b) For terminal velocity condition
Drag force = Gravity force – Buoyancy force i.e. $F_d = F_g - F_b$
$\Rightarrow C_d\, \rho_m\, A(V^2/2) = mg - V_p \times \rho_m \times g$

$$\Rightarrow C_d\, \rho_m\, A\, (V^2/2) = \rho_p \left(\frac{\pi}{6} D^3\right) g - \left(\frac{\pi}{6} D^3\right) \rho_m g \quad (1)$$

Here $V = V_T$ (terminal velocity) and $A = \pi/4\, (D^2)$
Thus solving equation (1) for terminal velocity

$$V_T = \sqrt{\frac{4}{3} \frac{gD(\rho_p - \rho_m)}{C_d \rho_m}} \quad (2)$$

For laminar flow (Re < 1), $C_d = 24/\text{Re} = \dfrac{24}{(\rho D V_T / \mu)}$

Putting this value of C_d in equation (2) and solving

$$V_T = \frac{gD^2(\rho_p - \rho_m)}{18\mu}$$

where

ρ_m = density of the medium through which particle falls

ρ_p = density of the particle

D = diameter of the particle

μ = coefficient of viscous drag acting on the particle

(14) Atmospheric air at 30°C room temperature is heated to 160°C for drying 100 kg milk containing 80 % water at the room temperature in a spray drier to a moisture content of 4 %. The temperatures of milk powder and outlet air were noted as 55°C and 95°C respectively.

Calculate :

(a) the amount of air required in kg to dry the milk

(b) the thermal efficiency of air drying

Given :

Specific heat of milk 0.95 kcal/kg°C

Specific heat of air 0.24 kcal/kg°C

Latent heat of vaporization 545 kcal/kg.

Ans:

Amount of solid entering dryer = Amount of solid leaving dryer

i.e. $F\,X_p = P.X_p$

$\Rightarrow 100\,(20/100) = P\left(\frac{100-4}{100}\right)$

$\Rightarrow P = 20.83$ kg

Total matter entering dryer = total matter leaving dryer

i.e. $F = P + W$

$\Rightarrow 100 = 20.83 + W$

$\Rightarrow W = 79.17$ kg

$\therefore$ Amount of water evaporated = 79.17 kg

$\therefore$ Heat used in evaporating water = $W\lambda$ = 79.17 x 545 = 43148 kcal

Heat used in heating milk = $m_m\,C_{p\,m}\,\Delta T_m$

= 100 x 0.93 x (55 – 30) = 2325 kcal

Total heat used = 43148 + 2325 = 45473 kcal

Heat supplied by air = $m_a\,C_{pa}\,\Delta T_a$ = m_a x 0.24 x (160 – 95)

Heat supplied by air = Total heat used

$\therefore$ m_a x 0.24 x (160 – 95) = 45473

$\Rightarrow m_a = 2914.9$ kg
$\therefore$ 2914.9 kg dry air is required to dry milk
Thermal efficiency of air drying
= heat actually used by heated air/ maximum amount of heat that can be given by hot air
$= m_a C_{pa} (160 - 95) / m_a C_{pa} (160 - 55)$
$= (160 - 95)/(160 - 55) = 61.9$ % (Ans)

1994

(1) A 25 kW engine runs at 1500 rev/min. It is fitted with a cone clutch built inside the flywheel. The cone has a face angle of 12° and a maximum mean diameter of 300 mm. The coefficient of friction is 0.15. The normal pressure on the clutch face should not exceed 0.1 N/mm^2. Determine the axial spring force necessary to engage the clutch and the face width required.

Ans:
Power = 2π NT
$\Rightarrow 25000 = 2\pi\ (1500/60)T$
$\Rightarrow T = 159.16$ N.m
$r_m = D_m/2 = 300/2 = 150$ mm $= 0.15$ m
For cone clutch torque transmitted, $T = T\, r_m\, \mu \operatorname{cosec} \alpha$
$\therefore 159.16 = F \times 0.15 \times 0.15 \times \operatorname{cosec} 12°$
$\Rightarrow F = 1470.67$ N

Again the normal pressure on cone clutch face, $P = \dfrac{F}{2\pi r_m b \sin\alpha}$

$\therefore 0.1 \times 10^6 = 1470.67/2\pi \times 0.15 \times b \times \sin 12°$
$\Rightarrow b = 75$ mm (Ans)

(2) A soil with available moisture-holding capacity of 25 cm per metre depth of soil was irrigated after depletion of 60 percent of the available moisture. A stream of 0.04 m^3/s was diverted from a tubewell and 0.032 m^3/s was delivered to the field. An area of 1 ha was irrigated in 14 hours. The root zone depth was 1 m. Moisture penetration varied linearly from 1.2 m at the head to 0.8 m at the tail of the field. Determine the water conveyance efficiency, application efficiency, storage efficiency and distribution efficiency.

Ans:

Water conveyance efficiency, $E_c = \dfrac{W_d}{W_r} = \dfrac{0.032}{0.04} = 80\ \%$

Depth of available moisture = available moisture-holding capacity x depth of root zone = 25 x 1 = 25 cm.

Depth of water needed to compensate depletion = 25 x 0.6 = 15 cm

$\therefore$ Volume of water stored in root zone, W_s = 15 cm x 1 ha = 1500 m^3

Volume of water diverted to root zone, W_d = 0.032 x 14 x 3600

= 1612.8 m^3

Water application efficiency, $E_a = W_s/W_d = 1500/1612.8 = 93\ \%$

Water storage efficiency, $E_S = \dfrac{W_s}{W_n} = \dfrac{15cm}{15cm} = 100\ \%$

Water distribution efficiency, $E_d = 1 - \dfrac{\overline{y}}{\overline{d}}$

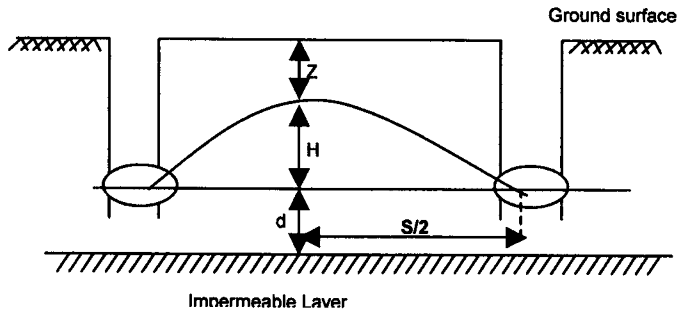
Where $\overline{d} = \dfrac{d_1 + d_2}{2} = \dfrac{1.2 + 0.8}{2} = 1\text{m}$

And $\overline{y} = \dfrac{(\overline{d} - d_1) + (\overline{d} - d_2)}{2} = \dfrac{0.2 + 0.2}{2} = 0.2\text{m}$

$\therefore E_d = 1 - \dfrac{\overline{y}}{\overline{d}} = 1 - \dfrac{0.2}{1} = 0.8 = 80\ \%$ (Ans)

(3) For an irrigated land, compute the approximate depth of placement of drain if the spacing of drains are 55m. Allowable water table height is 0.3 m above the centre of the drains. Subsurface explorations indicate a hydraulic conductivity of 0.5 m/day above an impervious layer located at a depth of 6.7 m. Excess irrigation rate is equivalent to a drainage coefficient of 1.2 mm per day.

Ans:



Where excess irrigation rate, R = 1.2 mm/day
S = 55m, H = 0.3m, K = 0.5m/day

Spacing of drain, $S = \sqrt{\dfrac{4KH(2d + H)}{R}}$

$\Rightarrow 55 = \sqrt{\dfrac{4 \times 0.5 \times 0.3(2 \times d + 0.3)}{1.2 \times 10^{-3}}}$

$\Rightarrow$ d = 2.875 m

It is given that depth of impervious layer = 6.7 m i.e. Z + H + d = 6.7 m

$\therefore$ Depth of placement of drain (i.e. Z + h) = (Z + H + d) – d

= 6.7 – 2.875 = 3.825m (Ans)

4(a) Find the peripheral force on the lever of a prony brake dynamometer and the brake power of the prime mover running at 750 rev/min. The length of the lever of dynamometer is 1.4 m . The weights in the pan of balance measure 37 kg and the tare is 7 kg.

(b) Determine the length of the cross-belt to connect two pulleys 4 m apart. The diameter of driving and driven pulleys are 1.25 and 0.75 m respectively.

Ans:

(a) Peripheral force on the lever, F = gross weight – tare
= 37 – 7 =30 kg = 294.3 N

Brake power of the prime mover = 2πNT= 2πN(F.r)
= 2π (750/60) (294.3/1000) x 1.4
= 32.36 KW

(b) Length of cross-belt drive, L= 2C + $\dfrac{(D_2 + D_1)^2}{4c} + (D_2 + D_1)\dfrac{\pi}{2}$

$\therefore$ L = 2 x 4 + $\dfrac{(1.25+0.75)^2}{4\times 4} + (1.25+0.75)\dfrac{\pi}{2}$ =11.39 m (Ans)

(5) A single-cylinder four-stroke diesel engine runs at 750 rev/min. The diameter of the cylinder is 15 cm. The stroke-bore ratio is 1.2. The clearance volume is 600 cm^3 and the mean effective pressure is 5 kg/cm^2. The mechanical efficiency is 75 %. Calculate :
(i) ihp (ii) bhp (iii) fhp (iv) Compression ratio (v) Swept volume

Ans:

(i) Indicated horse power, IHP = P.LAn N/2

$\therefore$ IHP = (5 x 9.81 x 10^4) x (1.2 x 0.15) x $\dfrac{\pi}{4}(0.15)^2 \times \left(\dfrac{750}{60\times 2}\right)$

= 13.07 HP

(ii) Mechanical efficiency, ME = $\dfrac{BHP}{IHP}$

$\Rightarrow 0.75 = \dfrac{BHP}{13.07}$ $\Rightarrow$BHP = 9.8 HP

(iii) Frictional horse power, FHP = IHP – BHP = 13.07 – 9.8 = 3.27 HP

(iv) Compression ratio, r =1+$\dfrac{V_s}{V_c}$ =1+ $\dfrac{\frac{\pi}{4}(0.15)^2 \times (1.2\times 0.15)}{600\times 10^{-6}} = 6.3$

(v) Swept volume, V_s = π/4 (15)^2 x 15 x 1.2 = 3180 cm^3 (Ans)

6 (a) Find the air-fuel ratio for the complete combustion of C_3H_{15} fuel

(b) A single-cylinder high speed diesel engine operates at 2000 rev/min. During compression stroke the fuel injection starts 20^o before top dead centre and ends at top dead centre. Calculate the duration of fuel injection in seconds that takes place in the cylinder.

Ans:

(a) The general formula for combustion of hydrocarbons given by

$C_x H_y + (x + y/4)\, O_2 \rightarrow x\, CO_2 + y/2\, H_2O$

$\therefore C_8 H_{18} + \left(8+\dfrac{18}{4}\right) \rightarrow 8CO_2 + \dfrac{18}{2}H_2O$

$\therefore$ $C_8H_{18} + 12.5\,O_2 \rightarrow 8CO_2 + 9\,H_2O$
$\therefore$ (12 x 8 + 1 x 18) = 114 gm fuel requires 12.5 x 32 = 400 gm O_2
400 gm oxygen is present in 400 x 100/23 = 1739.13 gm of air
$\therefore$ Air to fuel ratio = 1739.13/114 = 15.25:1
(b) 2000 revolution is equal to 2000 x 360 = 720000°
720000° is equivalent to 1 minute (= 60 sec)

$$20^\circ \text{ is equivalent to} = \left(\frac{60}{720000}\right)\times 20 = 1.667 \times 10^{-3} \text{ sec}$$

$\therefore$ Duration of fuel injection = 1.667×10^{-3} sec. (Ans)

(7) Evaluate the maximum traction thrust of a track type tractor with two tracks each 360 mm wide by 1680 mm long. The weight of the tractor is 31.75 kN. Assume that the lugs on the track are such that the soil is sheared off in a plane area at the ends of the lugs. Soil parameters are C = 14 kPa and ø = 30°.

Ans:
For track type tractor
Traction thrust per track = AC + (W_t/2) tanø = (bl) C + (W_t/2) tanø
= (0.36 x 1.68) x 14 x 10^{-3} + (31750/2) tan 30° = 17632.6 N
Traction thrust per 2 track = 2 x 17632.6 = 35.265 kN (Ans)

(8) A two bottom 30 cm mould board plough was operated in a field of size 40 m long by 25 m wide. The speed of operation was 5 km per hour. During operation, there was an average overlap of 4 cm. The turning loss was found to be 5 seconds per turn. The time lost in adjustment and repair was 50 min/ha. Calculate the field efficiency.

Ans:

$$\text{Area of field} = \frac{400\times 25}{10{,}000} = 1 \text{ hectare}$$

Theoretical field capacity = nWV = 2 x 0.3 x (5/10) = 0.3 ha/hr

$$\text{Percentage width utilized, K} = \frac{\textit{width} - \textit{overlap}}{\textit{width}}$$

$$= \frac{2\times 0.3 - 0.4}{2\times 0.3} = 0.993$$

$$\text{Field efficiency} = \frac{T_T}{T_e + T_a + T_h}$$

where theoretical time needed, $T_T = \dfrac{1}{\textit{Theoretical field efficiency}}$

$= 1/0.3 = 3.33$ hr/ha

$\therefore$ $T_e = T_T/K = 3.33/0.933 = 3.571$ hr/ha

$\therefore$ Field efficiency $= \dfrac{3.33}{3.571+0.471+0.83} = 0.6914 = 69.14\ \%$ (Ans)

9(a) Calculate the suction capacity of a power sprayer, if the diameter of the plunger is 20 mm, speed is 1000 rev/min length of stroke is 21 mm and the number of plunger is 3.

(b) Calculate the shaft power in kW when the pressure is 30 kg/cm^2, suction volume is 26.4 l/min and the pump efficiency is 65 %.

(c) What length of boom is needed on a sprayer, operating at 8 km/hr to permit spraying a 32 ha field in 8 working hours. The time lost in filling the tank and in turning is 30 %.

Ans:

(a) Suction capacity of power sprayer, Q = AV $= \dfrac{\pi}{4} D^2 NLn$

$\therefore$ Q $= \dfrac{\pi}{4}\ 0.02^2$ x (1000/60) x (21/1000) x 3

= 19.79 lit/min

= 19.79 x 10^{-3} m^3/min

(b) Pump efficiency $= \dfrac{\textit{Power}\text{ output}}{\text{Power input}} = \dfrac{P.Q}{\textit{Shaft}\text{ power}}$

$$\Rightarrow\ 0.65 = \frac{\left(\dfrac{26.4 \times 10^{-3}}{60}\right) \times 30 \times 9.81 \times 10^{4}}{\text{Shaft power}}$$

$\Rightarrow$ Shaft Power = 1.99 KW

(c) Time lost in filling and turning = 30 %

$\therefore$Field efficiency $= \dfrac{100}{100+30}$ =76.92 %

Theoretical field capacity = S x (8/10) = 0.8S ha/hr

$$\text{Field efficiency} = \frac{\text{Actual field capacity}}{\text{Theoretical field capacity}}$$

$$\Rightarrow 0.7692 = \frac{\text{Actual field capacity}}{0.8S}$$

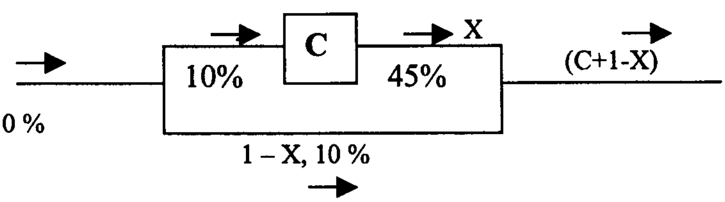
$\Rightarrow$Actual field capacity = 0.7692 x 0.8S = 0.615S ha/hr

$\therefore$ 0.615 S = 32/8 = 4 ha/hr

$\Rightarrow$ S = 6.5 m (Ans)

(10) In order to overcome flavor loss in concentrated orange juice, a portion of fresh juice is mixed with the concentrated juice. If the fresh juice is initially concentrated to 45 wt % solids and the desired final concentration of the product is 40 wt %, find the weight fraction of the fresh juice which is required to be concentrated. The fresh juice contains 10 wt % solids.

Ans.



Take basis as 1 kg of feed

Taking solid balance across concentrator

X (0.1) = C(0.45) (1)

Again taking solid balance at initial and final point of process

1 (0.1) = (C + 1 – X) (0.4) (2)

Solving equation (1) and (2)

X = 0.964

$\therefore$ Weight fraction of fresh juice which is required to be concentrated = X/1 = X = 0.964 (Ans)

(11) 1000 kg milk at 80°C having specific heat 3900 J/kg°C is required to be heated to 140°C by injecting saturated steam at 150°C. If the latent heat of steam at 150°C is 2115 kJ/kg and the specific heat of liquid water is 4184 J/kg°C, find the amount of steam required to be injected into the milk.

Ans:
Direct steam injection means, final temperature of steam = Required final temperature of milk
In this condition required final temperature of milk = 140°
Heat gained by milk = $M_m C_{pm} \Delta T_m$ = 1000 x 3.9 x (140-80) = 234000 kJ
Heat lost by steam by coming to 140°C = $mL + mC_p \Delta T$
= m x 2115 + m x 4.184 x (150 – 140) = 2156.84 m KJ
2156.84 m =234000
∴ m = 108.49 kg
∴ 108.49 kg of steam required to be injected. (Ans)

(12) Centre temperature of steam containing a semisolid food could be raised from 80°C to 90°C in 5 min and from 80°C to 100°C in 7 min. The initial temperature of the food was uniform at 80°C and it was heated inside a retort maintained at 125°C by saturated steam. Neglecting the heat transfer resistances on the surface of the food, estimate the time required for the centre of the can to be heated from 80°C to 120°C .

Ans:
The general process equation of unsteady heating is given by
$T_\infty - T_t = a\, e^{-b\, t}$
where
T_∞ = Inside temperature of retort
T_t = Temperature of food offer time 't' inside retort
∴ $125 - 90 = a\, e^{-b \times 5}$ (1)
$125 - 100 = a\, e^{-b \times 7}$ (2)
$125 - 120 = a\, e^{-b \times t}$ (3)
Dividing equation (1) by equation (2) and solving
b = 0.168 and a = 81
Putting this value of 'a' and 'b' in equation (3)
$5 = 81 \times e^{-0.168 \times t}$
⇒ t = 16.58 min (Ans)

(13) Grinding of Bengal gram in a hammer mill required 8.3 kWh of energy per ton of material for reducing its size from 6.25 mm to 0.75 mm. Assuming that Bond's law holds good for the material, estimate the amount of energy required for reducing the size down to 0.1mm.

Ans: Energy required for size reduction is given by,

$$E = P/f = K_b\left(\frac{1}{\sqrt{D_p}} - \frac{1}{\sqrt{D_f}}\right)$$

For Case 1:

$$8.3 = K_b\left(\frac{1}{\sqrt{0.75}} - \frac{1}{\sqrt{6.25}}\right) \qquad \Rightarrow K_b = 10.99$$

For Case 2:

$$E_2 = K_b\left(\frac{1}{\sqrt{0.1}} - \frac{1}{\sqrt{6.25}}\right)$$

$$\therefore E_2 = 10.99\left(\frac{1}{\sqrt{0.1}} - \frac{1}{\sqrt{6.25}}\right) = 30.378 \text{ KWh/tonne} \qquad \text{(Ans)}$$

(14) A wet material is dried inside a tray dryer by using air at 65°C dry bulb and 50°C wet bulb temperature. If the heat transfer coefficient on the surface of the material is 10 w/m^2 °C and the latent heats of vaporization of water at 65°C and 50°C are 2346 kJ/kg and 2406 kJ kg respectively, find the rate of drying in kg water removed per square metre of the exposed surface per hour.

Ans:

Rate of drying inside tray dryer,

$$R = \frac{\dot{W}}{A} = \frac{hA(T - T_W)}{A\lambda_w} = \frac{h(T - T_w)}{\lambda w}$$

$$= \frac{10(65-50)}{2406 \times 1000} \times 3600 = 0.22 \text{ kg/hr-m}^2 \qquad \text{(Ans)}$$

(15) An ideal gas is adiabatically compressed from a pressure P_1 to a pressure P_2 when its temperature rises from T_1 to T_2 degrees Kelvin. If the ratio of specific heat of the gas at constant pressure and at constant volume is K, express the value of T_2 as a function of the other variables.

Ans:
The equation of state of adiabatic process is given by

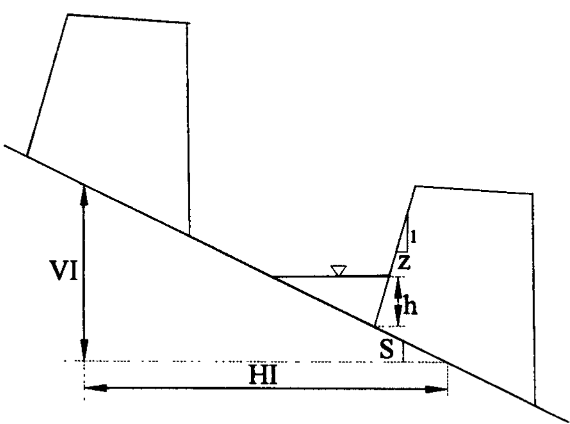
$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1-k} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$\therefore T_2 = T_1\left(\frac{V_2}{V_1}\right)^{1-k} \quad \text{and} \quad T_1 = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

Where T_2, T_1, P_2, P_1, V_2 V_1 and K carries the conventional meaning as in question.

(16) Design the dimensions of a rectangular weir used to discharge excess runoff through a contour bund for the following conditions: Volume of water stored being the bund during rainfall = 700 m^2. Horizontal spacing of bund = 50 m. Length of bund = 300 m, Intensity of rainfall for the time of concentration for a 10-year return period = 10 cm/h. Constant infiltration rate = 3 cm/h. Assume a notch height of 20 cm. There is no stored water behind the bund before the peak rainfall.

Ans:



I = 10 cm/h, F = 3 cm/h, HI = 50 m, L_B = 300

The runoff volume, R = (I – f) x A = (I – f) (HI x L_B)
= (0.1 – 0.3) x (50 x 300) = 1050 m^3/hr

Note: Calculation for excess runoff is not required because flow rate will remain same both for runoff and excess runoff

$\therefore$ Discharge through weir, Q = 1050 m^3/hr

But $Q = 1.77\ LH^{3/2}$

$\Rightarrow 1050/3600 = 1.77 \times L \times (0.2)^{3/2}$

$\Rightarrow L = 1.84$ m

$\therefore$ length of weir = 1.84 m

Again adding a free board of 5 cm to notch height, total depth of weir = 20 + 5 = 25 cm (Ans)

(17) The pressure and vacuum readings at the outlet and inlet of a centrifugal pump are 2 kg/cm^2 gauge and 0.8 kg/cm^2 vacuum respectively. Vertical distance between the tappings is 50 cm. The pump is to deliver 78 l/s of fresh water. Velocity of water in the delivery and suction pipes are 3 and 2 m/s respectively. Calculate the manometric head, gross head and power output of the pump.

Ans:

$P_d = 2$ kg /cm^2, $P_s = -0.8$ kg/cm^2, $H_e = 0.5$ m

Manometric head, $H_m = \dfrac{P_d - P_s}{\rho g} + H_e$

$$= \frac{2-(-0.8)\times 9.81\times 10^4}{1000\times 9.81} + 0.5 = 28.5 \text{ m}$$

Other method

$P_{abs} = P_{atm} - P_{vacum} = 1 - 0.8 = 0.2$ kg / cm^2

$P_d - P_s = 3 - 0.2 = 2.8$ kg/cm^2 = 28 metre

Manometric head, $H_m = 28 + 0.5 = 28.5$ metre

Gross head, $H = H_m + H_v$

$$= H_m + \left(\frac{V_d^2 - V_s^2}{2g}\right) = 28/5 + \left(\frac{3^2 - 2^2}{2\times 9.81}\right) = 28.755 \text{ m}$$

Power output of the pump = γ QH

= 1000 x (78 x 10^{-3}) x 28.755 = 2.243 KW (Ans)

(18) Calculate the discharge from a fully penetrating confined well of 300 mm diameter if the thickness of aquifer is 20 m, drawdown is 5 m, hydraulic conductivity of aquifer is 0.4 mm/s and radius of influence is 500 m.

Ans:

Discharge from a fully penetrating confined well

$$= Q = \frac{2\pi kbS}{\ln(R/r_w)} = \frac{2\pi \times 0.4 \times 10^{-3} \times 20 \times 5}{\ln(500/0.25)} = 0.03 \text{ m}^3/\text{s} \qquad \text{(Ans)}$$

(19) Design the most economical trapezoidal section of a channel to carry a discharge of 10 m^2/s in a bed slope of 1 in 3000. For stability, the side slope is 1.5:1 and the value of Manning's is 0.025.

Ans:

For most economical trapezoidal cross section, $b = 2d \tan(\theta/2)$

Where $\theta = \tan^{-1}(1/z) = \tan^{-1}(1/1.5) = 33.69^{\circ}$

$\therefore b = 2 \text{ x } d \text{ x } \tan(33.69/2)$

$\Rightarrow b = 0.605\ d$

$\therefore$ Cross sectional area of channel, $A = bd + zd^2$

$= 0.605\ dxd + 1.5\ d^2 = 2.105\ d^2$

Velocity of flow through channel, $V = 1/n\ R^{2/3}\ S^{1/2} = 1/n\ (d/2)^{2/3}\ (S)^{1/2}$

$\therefore V = 1/0.025\ (d/2)^{0.67}\ (1/3000)^{1/2} = 2.18\ d^{2/3}$

$\therefore$ Rate of flow through channel, $Q = AV$

$= 2.105\ d^2 \text{ x } 2.18\ d^{2/3} = 4.586\ d^{8/3}$

But $Q = 10\ m^3/s$

$\therefore 4.58\ d^{8/3} = 10$

$\Rightarrow d = 1.339$ m

$\therefore b = 0.605 \text{ x } 1.339 = 0.81$m

$\therefore$ Bottom width of channel = 0.81m and depth of channel

= 1.339 m (Ans)

(20) It is desired to design a combination of flood control reservoir and farm pond for a site with a drainage area of 50 ha. The total runoff for a 50 year return period is 100 mm and the peak rate of runoff is 6 m^3/s. A box inlet spillway and circular concrete outlet pipe are to be used in the outlet structure. The storage corresponding to maximum allowable stage in the reservoir is 2 ha-m. Calculate the rate of outflow when the pipe first flows full.

Ans:

Rate of outflow (q_o) through the given structure when pipe flows full is given by

$$\frac{q_o}{q_p} = 1.25 - \sqrt{\frac{1500V}{RA} + 0.0625}$$

$$\Rightarrow \frac{q_o}{6} = 1.25 - \sqrt{\frac{1500 \times 2}{100 \times 50} + 0.0625}$$

$\Rightarrow q_o = 2.616\ m^3/s$ (Ans)

1995

1. Complete the following statements by filling appropriate numerical value in the blanks

1(a) If the turning angles subtended by axes of inner and outer front wheels of a 4- wheel tractor are 46° and 28° respectively, and kingpins of the axle are 150 cm apart, the wheel base of the tractor to avoid skidding of front wheels should be_______

Ans:

$\cot\theta - \cot ø = W/L$

$\cot 28 - \cot 46 = 150/L$

$\Rightarrow L = 163.927$ cm (Ans)

1(b) If a 4-cylinder, 4-stroke cycle diesel engine operates at 2000 rev/min and uses 7.5 litres of fuel per hour the average volume in millilitres of the individual injections will be___________

Ans:

For 4 stroke cycle, $Q_e = m^3/min = (AL)\ (N/2)\ n$ (1)

Where Q_e = fuel consumption on volumetric basis

AL= average volume of individual injection

Putting the values in equation (1)

7.5 lit/hr = AL x (2000/2) x 4

$$\Rightarrow \frac{7.5}{1000 \times 60}\frac{m^3}{min} = (AL) \times 4000$$

$$\therefore AL = \frac{7.5}{60000 \times 4000}\ m^3 = \frac{7.5 \times 10^9\ mm^3}{60000 \times 4000} = 31.25\ mm^3$$

$= 31.25 \times 10^{-3}\ cm^3 = 0.031\ cm^3 = 0.031$ ml (Ans)

1(c) Two triangular channels A and B have the same bed slope(s), roughness coefficient(n) and depth of flow. The side slope of channel A is 1 horizontal: 1 vertical while that of B is 2 horizontal:1 vertical. The ratio of discharges in channels A and B is _______

Ans:

$z_1=1, z_2=2$

$$Q = AV = (bd + zd^2)\frac{1}{n}\left(\frac{bd + zd^2}{b + 2d\sqrt{z^2+1}}\right)^{\frac{2}{3}} s^{\frac{1}{2}}$$

For triangular channel, b = 0

$$\frac{Q_1}{Q_2} = \frac{z_1}{z_2}\left(\frac{z_1}{\sqrt{z_1^2+1}} \times \frac{\sqrt{z_2+1}}{z_2}\right)^{\frac{2}{3}} = \frac{1}{2}\left(\frac{1}{\sqrt{2}} \times \frac{\sqrt{5}}{2}\right)^{\frac{2}{3}} = 0.427 \qquad \text{(Ans)}$$

1(d) A pitot tube indicated a differential head of 0.75 m of water between its two openings when inserted in a grassed waterway flowing half full. If coefficient of the tube is 0.99, the velocity of flow, m/s at the location of the tube is_______

Ans:

Coefficient of pivot tube, C_v=0.99

$V_{ac} = C_v x V_H = C_v x \sqrt{2gh} = 0.99\sqrt{2 \times 9.81 \times 0.75} = 3.79$ m/s (Ans)

1(e) 500 kg vegetable is dried from 70 % moisture content (wet basis) to 8 % moisture content (wet basis). The weight of dried vegetable will be _______

Ans:

Initial moisture content, IMC = 500 x 70/100 = 350 kg

Weight of dry matter, W_d = 500-350 = 150 kg

8 % moisture content (wet basis) ≡ 8/(100-8)

= 8.69 % moisture content (dry basis)

Final moisture content, FMC = 150 x (8.69/100) = 13kg

Thus dried weight of vegetables = 150 + 13 = 163 kg (Ans)

1(f) 100 kg milk is cooled from 335 K to 273 K. If the specific heat of milk is 0.93, the amount removed will be ________

Ans:

$Q = mC_p\,\Delta T = 100 \times 0.93 \times (335 - 273) \doteq 5766$ Kcal (Ans)

(2) A 4-wheel tractor weighing 25 kN has a wheel base of 1.2 m. The CG is located on a vertical plane 0.4 m ahead of rear axle. Determine the maximum drawbar pull that a tractor can exert on a level road where coefficient of rolling resistance is 0.04 and

coefficient of traction between the road surface and tyres is 0.5. The hitch height may be taken as 0.4 m. Also calculate the rim pull if there is no slip.

Ans:

$W = 25$ KN, $\rho = 0.04$, $\mu = 0.5$

$X_2 = 1.2$ m, $X_1 = 0.4$m, $Y_1 = 0.4$ m

$R_1 + R_2 = W$ (1)

$R_1X_2 + P_{max} Y_1 = W.X_1$ (2)

$\mu_g = \mu + \rho$

$\mu = P/W = P_{max}/R_2$ (3)

$R_1 \times 1.2 + P_{max} \times 0.4 = 25 \times 0.4$

$0.5 = P_{max}/R_2$

$1.2 R_1 + 0.5 R_2 \times 0.4 = 10$

$1.2 R_1 + 1.2 R_2 = 10$

$R_1 + R_2 = 25$

$\Rightarrow R_2 = 20$ KN

$R_1 = 5$ kN

(i) $P_{max} = \mu R_2 = 0.5 \times 20 = 10$ kN

(ii) Rim pull, $f = P_{max} + R = 10 + 0.04 \times 20 = 10.8$ kN (Ans)

(3) A multiple-disc clutch is composed of 5 steel and 4 bronze discs. The clutch is required to transmit 16 Nm of torque. If the inner diameter is restricted to 50 mm, determine the necessary outer diameter of the discs and the necessary axle force. The coefficient of friction may be taken as 0.1 and the average pressure is not to exceed 350 kN/m^2. Assume uniform pressure.

Ans:

$T = 16$ N.m, $D_i = 50$ mm $= 0.05$ m, $\mu = 0.1$, $P_{ave} = 350$ kN/m^2,

$Z = 5 + 4 - 1 = 8$

(i) For uniform pressure, $r_m = \dfrac{1}{3}\dfrac{(D_0^3 - D_i^3)}{(D_0^2 - D_i^2)}$

$$F = P.A. = P \times \frac{\pi}{4}(D_0^2 - D_i^2) = 35 \times 10^4 \times \frac{\pi}{4}(D_0^2 - D_i^2)\ N$$

$T = \mu F r_m Z$

$$\Rightarrow 16 \text{ N.m} = 0.1 \times 35 \times 10^4 \times \frac{\pi}{4}(D_0^2 - D_i^2) \times \frac{1}{3}\frac{(D_0^3 - D_i^3)}{(D_0^2 - D_i^2)} \times 8$$

$\Rightarrow 16 \text{ N.m} = 73303.8\ (D_0^3 - D_i^3)$ N.m.

$\Rightarrow 16 = 73303.8\ (D_0^3 - 0.05^3)$

$\Rightarrow D_0 = 0.07$ m = 70 mm

(ii) Axle force (F) $= P \times \frac{\pi}{4}\ (D_0^2 - D_i^2)$

$= 35 \times 10^4 \times \frac{\pi}{4}\ (0.07^2 - 0.05^2) = 659.73$ N (Ans)

(4) A successive three-hourly ordinates of a 6 hour storm for a particular watershed are 5, 47, 122, 107, 95, 65, 47, 35, 23, 14 and 5 cumecs. The depth of storm rainfall is 60 mm. Assuming a constant base flow of 5 cumecs and an average storm loss of 5 mm/h, determine the successive 3-hourly ordinates of a unit graph.

Ans:

$\sum P = 60$mm, Base flow = $5m^3/s$

$$W_{index} = 5\text{mm/hr} = \frac{\sum P - ER}{\sum t} = \frac{60 - ER}{6}$$

$\Rightarrow$ ER = 30mm = 3cm

DRH Ordinates (cumecs)	0	42	117	102	90	60	42	30	18	90
UH Ordinates (cumecs)	0	14	39	34	30	20	14	10	6	30

Note:
DRH Ordinates = FH ordinates - Base flow
UH ordinates = DRH ordinates / ER

(5) An irrigation main channel of a trapezoidal cross-section is designed to carry a discharge of 45 cumecs. The allowable maximum depth of water is 1.8 m. The bottom width of the channel is 6 m while side slope. Z to be 2. Assuming roughness

coefficient to be 0.025, find the bed slope on which the channel needs to be constructed.

Ans:

$Q = 45 m^3/s, d$ = depth of water = 1.8m,

b = width of channel = 6m, z = 2, n = 0.025

Trapezoidal Channel

$$Q = AV = (bd+zd^2)1/n\left(\frac{bd+zd^2}{b+2d\sqrt{(z^2+1)}}\right)^{\frac{2}{3}} s^{\frac{1}{2}}$$

Putting the above values, S = 0.003216 i.e. 0.32% (Ans)

(6) If a grain is at 303 K and 10 % RH, the values of 'C and 'n' taken as 3.11 x 10^{-7} per K and 3.03 respectively in Henderson's equation, determine the value of EMC.

Ans:

Henderson equation: $1 - RH = e^{-CTMe^n}$

$\Rightarrow 1 - 0.1 = e^{-3.11\times10^{-7}\times303\times Me^n}$

$\Rightarrow \ln(0.9) = -3.11 \times 10^{-7} \times 303 \times M_e^{3.03}$

$\Rightarrow M_e^{3.03} = 111.08$

$\Rightarrow \ln Me = \dfrac{\ln(1118.08)}{3.03} = 2.316$

$\Rightarrow Me = e^{2.316} = 10.135$ % (Ans)

(7) A tractor with a wheel base of 195 cm has a tread width (both front and rear wheels) of 165 cm. If the tractor is negotiating a 5 m (measured from centre of turning along rear axle centre line to point midway between rear wheels) turn at 6 km/h and the rolling radius of the rear wheels is 60 cm.

(a) Calculate the speed (in rpm) of the inside and the outside wheels

(b) During the turn, what percentage of engine power and torque is transmitted through each of the two rear wheels ?

Ans:

$$\text{(a) } N_R = \frac{V_R}{\pi D} = \frac{\frac{4.175}{3.6}\left(\frac{m}{s}\right)}{\pi\times(2\times0.6)}\times[60] = 18.4 \text{ rpm}$$

$$R_R = 5 - \frac{1.65}{2} = 4.175 \text{ m}$$

$T_L = 5 + \frac{1.65}{2} = 5.825$ m

$R = 5 \Rightarrow V = 5$ km/h

$\Rightarrow R_R = 4.175$ m $\Rightarrow V_R = 4.175$ km/h

& $R_L = 5.825$ m $\Rightarrow V_L = 5.825$ km/ha

$$N_L = \frac{V_L}{\pi D} = \frac{\frac{5.825}{3.6}\times[60]}{\pi\times(2\times0.6)} = 25.75 \text{ rpm}$$

(b) Percent power distribution at rear wheels during turning :

Percentage power at right rear wheel

$$= \frac{2\pi N_R T}{2\pi N_R T + 2\pi N_L T} = \frac{N_R}{N_R + N_L} = \frac{18.4}{18.4+25.75} = 0.4167 = 41.67\ \%$$

$\therefore$ percentage power at rear (left) wheel = 100 – 41.67 = 58.33 %

Torque distribution :

Engine torque = torque at each wheel

$\Rightarrow$ 100 % torque at each rear wheel (Ans)

(8) A four-cylinder, four-stroke compression ignition engine has a stroke-bore ratio of 0.96. The total swept volume of the engine is 4000 cm^3 and the clearance volume per cylinder is 62.5 cm^3. At a mean piston speed of 7.5 m/s 40 kW power is produced. Determine

(a) the engine compression ratio

(b) the brake mean effective pressure

Ans:

n = 4, L/D = 0.96, Power = 40 KW

V_s x n = 4000 cm^3 = total swept volume of engine

V_c (per cylinder) = 62.5 cm^3, Piston speed = 7.5 m/s

$$CR = \frac{V_c + V_s}{V_c} = 1 + \frac{V_s}{V_c} = 1 + \frac{\left(\frac{4000}{4}\right)}{62.5} = 17:1$$

$$\text{Power} = P.Q_e = P\ (LAN\ \frac{N}{2}) = P(Vs)\frac{N}{2}$$

Piston speed = 2 LN = 7.5 m/s

$\Rightarrow$2 x 10.54/100 x N = 7.5

$\Rightarrow$N = 2135 rpm

Again V_s x n = 4000 cm^3
$\Rightarrow \pi/4\ D^2$ x L x n = 4000
$\Rightarrow \pi/4\ D^2$ x .96D x 4 = 4000
$\Rightarrow$ D = 10.98cm
$\Rightarrow$ L = 0.96 x D = 0.96 x 10.98 = 10.54 cm
$\therefore$ 4000 = P x (4000 x 10^{-6}) x 35.58/2
$\Rightarrow$ P = 0.56 Mpa (Ans)

(9) A field chopper with a flywheel type cutter head has 6 knives and a diameter of 450 mm. The peripheral speed in 25 m/s. The throat size is 45 x 15 cm. For a 10 mm length of cut, with corn sillage, calculate

(a) the linear speed of feed mechanism

(b) the rated feeding capacity in tones/h

Assume rated capacity = 80 % of theoretical maximum and chop density = 300 Kg/m^3

Ans:

n = 6, D = 0.45 m, ρ= 300 kg/m^3, L = 0.01 m
$V_p = \pi DN$ = 25 m/s (of cutter head)
W x H = 0.45 x 0.15
(a) Linear velocity of flywheel (V) = velocity of feed roll (V')
$\Rightarrow$ N Ln = πD'N'
π D(N) = V_p = peripheral velocity of flywheel
V = Linear speed of feed mechanism = Linear speed of flywheel

$$V = \frac{V_p}{\pi D} LN = \frac{25}{\pi \times 0.45} \text{ x } 0.01 \text{ x } 6 = 1.06 \text{ m/s}$$

Theoretical maximum capacity = $\dot{m}$ = ρQ
= ρAV =ρ(WH) (NLn)
= 300 x 0.45 x 0.15 x 1.06

Actual maximum capacity = $\dot{m}_R$ = 0.8 x m = 0.8 x 77.27
= 61.816 ton/hr (Ans)

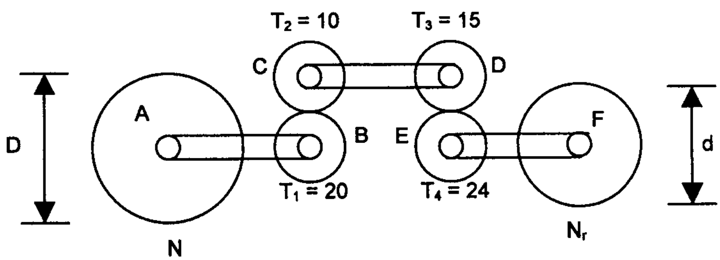
(10) A horizontal plate planter has 54 cells on 160 mm diameter circle. The effective radius of the ground drive wheel is 0.45 m. A 20-tooth sprocket on the drive wheel drives a 10-teeth sprocket on the feed shaft. A 15-teeth bevel gear on the feed shaft drives a 24-tooth gear on the plate shaft. Calculate

(a) the seed spacing in the row for 100 % cell fill and

(b) the desired forward speed in km/h for 100 % cell fill if the late speed is 15 m/min

Ans:

Horizontal plate planter



AB = main shaft

CD = feed shaft

EF = plate drive shaft

(a) n = 54 = number of cells

D = Diameter of rotor = 160 mm = 0.16 m

R = 0.45 m ⇒ D = 0.9 m = Diameter of ground wheel

$$V_R = \frac{N_r}{N} = \frac{N_4}{N_1} = \frac{T_1 \times T_3}{T_2 \times T_4} = \frac{20 \times 15}{10 \times 24} = \frac{15}{12} = 1.25$$

$$L = \frac{V}{nN_r} = \frac{\pi DN}{nN_r} = \frac{\pi \times 0.9 \times 1}{54 \times 1.25} = 0.042\text{m} = 4.2 \text{ cm}$$

(b) $V = \pi$ DN, $V_p = \pi\, dN_r$

$$\Rightarrow \frac{V}{V_p} = \frac{D}{d}\left(\frac{N}{N_r}\right) \Rightarrow \frac{V}{15} = \frac{0.9}{1.16}\left(\frac{1}{1.25}\right)$$

⇒ V = 67.5 m/min = 4.05 km/hr (Ans)

(11) The line of pull on an implement is 20° above the horizontal and in a vertical plane which is at an angle of 10° with the direction of travel.

(a) Calculate the draft and side draft forces for a pull of 9 kN.

(b) What drawbar power in kW would be required at 5 kg/h ?

Ans:

$\theta = 20^\circ$, $ø = 10^\circ$, P = 9 kN

(a) Draft, L = (Pcos θ) cosø = 9 cos 20° cos 10° = 8.328 kN

(b) Side draft, S = (P sin ø) cos θ = 9 x sin 10 x cos 20° = 1.468 kN (Ans)

(12) A flat belt, 8 mm thick and 100 mm wide, transmits power between two pulleys. Running at 1600 m/min. The mass of the belt is 0.9 kg/m in length. The angle of lap in the smaller pulley is 165° and the coefficient of friction between the belt and pulleys is 0.3. If the maximum permissible stress in the belt is 2 MN/m^2 find the maximum power that can be transmitted at the above speed.

Ans:

Belt Thickness = 8 mm = t, μ=0.3

Width = 100 mm = b, V = 1600 m/min

θ =165° = angle of lap in the smaller pulley = 2.879 (rad)

$Stress_{max} = 2 \times 10^6\ N/m^2 = \tau_{max}$

Power = 2π NT = 2 πN (F.r) = (2πr.N) F = F.V.

$\therefore$ P = F.V. = $(T_1 - T_2)$ V

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3 \times 2.879} = 2.363$$

$$T_C = mV^2 = 0.9 \times \left(\frac{1600}{60}\right)^2 = 640\ N$$

$T = \tau_{max}(A) = (2 \times 10^6\ N/m^2) \times (0.1) \times (0.008) = 1600\ N$

$T = \tau_{max} \times (A) = \tau_{max}(bt) = T_1 + T_C$

$\Rightarrow T_1 = T - T_C = 1600 - 640 = 960\ N$

$$\Rightarrow T_2 = \frac{T_1}{e^{\mu\theta}} = \frac{960}{2.363} = 406.26\ N$$

$$\therefore P = (T_1 - T_2)V = (960 - 406.26) \times \frac{1600}{60}$$

$$= 493.74N \times \frac{1600}{60}\left(\frac{m}{s}\right) = 13.166\ kW \qquad \text{(Ans)}$$

(13) A saturated sample of soil mass has a water content of 33.33 %. Assuming specific gravity of the soil to be 2.679, Calculate the porosity of the soil sample.

Ans:

$S_r = 1$, $W_{sat} = 33.3\%$, G = 2.679

$$e = \frac{wG}{s} = w_{sat}G = 0.3333 \times 2.679 = 0.8929$$

$$n = e / (1+ e) = \frac{0.8929}{1+0.8929} = 0.4717 = 47.17\%$$ (Ans)

(14) A cylinder of soil mass when laterally unconfined failed under axial vertical stress of 175 kN/m^2. If the value of soil cohesion is 63.752 kN/m^2, calculate the angle of internal friction of the soil.

Ans:
$C = 63.572 kN/m^2$
Laterally unconfined $\Rightarrow \sigma_3 = 0$
Axial vertical stress = $\delta_1 = 175 kN/m^2$ σ
$$\sigma_1 = \sigma_3 + 2C\tan\alpha = 2C\tan\alpha$$
$\Rightarrow$ 175=2 X 63.572 X tanα
$\Rightarrow \alpha = 54^0$
$$\alpha = 45 + \frac{\phi}{2} \Rightarrow \phi = 18^0$$ (Ans)

(15) A mass concrete rectangular surplus weir (life span of 50 years) is to be designed for a farm pond having 5 km^2 of watershed area. Find the length of the weir if maximum depth of water over the weir still should not exceed 1 m. Maximum intensity of rainfall for the time of concentration of the watershed is 50 mm/h for a return period of 10 years. Assume run off coefficient value for the watershed to be 0.6 and coefficient of discharge for the weir is 0.623.

Ans:.
$C_d = 0.623$, $A = 5km^2$, $I_{max} = 50mm/h$, $C = 0.6$,
$$Q = \frac{CIA}{360} = \frac{0.6 \times 50 \times 500}{360} = 41.66 m^3/s$$
But $Q = 1.77 L h^{3/2}$
$\Rightarrow$ 41.66 = 1.77 x L x 1
$\Rightarrow$ L = 23.548 m (Ans)

(16) Find the size of square check basin if a stream of 0.03 cumecs is diverted for 15 min to irrigate wheat crop. The field capacity of the soil is 20 %. Irrigation is to be given regularly when the moisture content of the soil depletes to 50 % of field capacity.

Assume maximum average root depth of the crop as 1 m and apparent specific gravity of the root zone soil as 1.6.

Ans:.

Q = 0.03 m^3/s, D = 1m , ρ=1.6, t = 15min

Yield capacity of soil=20%= field capacity of moisture content

After depletion of 50% moisture of field capacity

$$d = \frac{(m_{fc} - m_{bi}) \times \rho \times D}{100} = (\frac{20-10}{100}) \times 1.6 \times 100cm = 16\text{cm}$$

$$Qt=Ad \Rightarrow A=Qt/d=\frac{0.03 \times 15 \times 60}{0.16} = 168.75m^2$$

Side of square check basin = $\sqrt{168.75} = 12.99$

∴ Size is 12.99 × 12.99 (Ans)

(17) Suggest type of flow of oil in a heat exchanger if the internal diameter of pipe is 50 mm with a discharge value of 15 l/s. Take kinematic viscosity of oil as 21.4 stokes at operating temperature

Ans:

$$D = D_i = 0.05m, \; Q = \frac{15 \times 10^{-3}}{60}\frac{m^3}{s}, \quad \nu = 21.4 \text{ strokes} = 21.4\text{x}10^{-4}\text{m}^3/\text{s}$$

$$R_e = \frac{\rho D v}{\mu} = \frac{Dv}{\upsilon} = \frac{DQ}{\frac{\pi}{4}D^2\upsilon} = \frac{4Q}{\pi D\upsilon} = \frac{4 \times 15 \times 10^{-3}}{\pi \times 60 \times 0.05 \times 21.4 \times 10^{-4}} = 2.97$$

∴ Laminar flow takes place. (Ans)

(18) Calculate the amount of steam at 120°C (enthalpy, h = 2700 KJ/kg) that must be added to 100 kg of food material with a specific heat of 3.5 kJ/kg K to heat the product from 4°C to 80°C by direct steam injection. Enthalpy of condensate (water) is 344 KJ/kg. Heat loss to the atmosphere from the system may be neglected.

Ans:

Heat lost by steam by going into condensate form= X (2700 – 344) kJ

Head gained by food = $mC_p \, \Delta$ T= 100 x 3.5 x (80-4) = 26600 kJ

∴ X = 26600/(2700 – 344) = 11.29 kg

(19) An evaporator has a rated evaporation capacity of 200 kg/h of water. What will be the rate of production of concentrated juice containing 40 % of total solids from a raw juice containing 10 % solids ?

Ans:

$V = 200$ kg/h, $X_F = 0.1$, $X_P = 0.4$

$F.X_F = P.\,X_P$ (1)

$F = P + V$ (2)

$\therefore (P + V)\,X_F = P\,X_P$

$(P + 200)\,0.1 = P\,(0.4)$

$\Rightarrow P/10 + 20 = 4P/10$

$\Rightarrow P = 66.67$ kg/h (Ans)

(20) Thin walled tube of stainless steel (18 % Cr, 8 % Ni, $k_p = 19$ W/m-K) with 2 cm ID add 4 cm outer diameter is covered with a 3 cm layer of asbestos insulation (k_a = 0.2 W/m-K). If inside wall temperature of the pipe is maintained at 120°C and the outside insulation at 40°C, calculate the heat loss per meter.

Ans:

$D_1 = 2$ cm $\Rightarrow r_1 = 0.01$ m

$D_0 = 4$cm $\Rightarrow r_2 = 0.02$m

$R_3 = r_2 + 0.03 = 0.05$ m

$T_i = 120°C$ $k_1 = 19$ W/m-k

$T_0 = 40°C$ $k_2 = 0.2$ W/m-k

$$Q = \frac{2\pi LK(T_i - T_0)}{ln\left(\frac{r_1}{r_2}\right)}$$

$$\Rightarrow \frac{Q}{L} = \frac{2\pi(T_i - T_0)}{\frac{1}{k_1}ln\left(\frac{r_1}{r_2}\right) + \frac{1}{k_2}ln\left(\frac{r_3}{r_2}\right)}$$

$$= \frac{2\pi(T_i - T_0)}{\frac{1}{19}\ln\left(\frac{0.02}{0.01}\right) + \frac{1}{0.2}\ln\left(\frac{0.05}{0.02}\right)} = 108.84 \text{ W/m} \quad \text{(Ans)}$$

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(1) Calculate the BHP of a 2-cylinder 4-stroke cycle internal combustion engine 12.5 x 15 cm. The mean effective pressure is 7 kg/cm^2 and speed of crank shaft is 1200 revolutions per minute. The mechanical efficiency is 75 %.

Ans:

n = 2, P = 7 kg/cm^2, ME = 75 %, N = 1200 rpm, L/D = 15/12 = 1.25

When only MEP given it means IMEP

IHP = $P.Q_e$ = P [(N/2) L nA]

$\Rightarrow$ IHP= $7 \times 9.81 \times 10^4 (1200/60\text{x}2) \times 0.15 \times 2 \times \frac{\pi}{4}\left(\frac{12.5}{100}\right)^2 = 33.88$ HP

ME = BHP/IHP

$\Rightarrow$ BHP = 25. 416 HP (Ans)

2(a) Total draft of a four-bottom 40 cm trailed mould board plough is 2000 kg when it is moving at a speed of 5 kilometres per hour. Calculate

(i) the unit draft in kg/cm^2 if the depth of cut is 20 cm

(ii) drawbar horsepower required to operate the implement

(b) A centrifugal pump delivers 1200 litres per minute of water against a head of 10 metre and requires 5 h.p when running at 1000 rpm. Find the discharge and the horsepower if the pump has to run at 1500 rpm

Ans:

(a) d = 20 cm, L = 2000 kg, V = 5 km/hr

A = 4 x 0.4 x 5/10 = 0.8 ha/hr

Area of depth of cut = 0.2 x 4 x 0.4 = 0.32 m^2

(i)L_u = L/A = 2000/3200 = 0.625 kg/cm^2

(ii) DBHP = FV = LV = $\frac{2000 \times 9.81 \times 5}{3.6 \times 746}$ =36.528 HP

(b) Centrifugal pump

Q_1 = 1200 lit/min, H = 10 m, $HP_1 = HP_{in}$ = 5 HP

N_2 = 1500 rpmm, N_1 = 1000 rpm

(i) $\frac{HP_2}{HP_1} = \left(\frac{N_2}{N_1}\right)^3 \Rightarrow HP_2 = 5 \times (1.5)^3 = 16.875$ HP

(ii) $\frac{Q_2}{Q_1} = \left(\frac{N_2}{N_1}\right) \Rightarrow Q_2 = 1200 \times 1.5 = 1800$ l/min (Ans)

(3) A watershed has 50 hectare of row crop cultivated good terraced land and 10 hectare of good pasture land with hydrologic soil group C. The weighted curve number for the watershed for antecedent moisture condition II is 90. The 6-hour, 50-year frequency rainfall for the area is 120 mm. Determine the estimated maximum volume of runoff for 50 years recurrence interval for antecedent moisture condition II.

Ans:

$a_1 = 50ha$, $a_2 = 10ha$, 6hr rainfall = 120mm = P, $CN_w = 90$

$$CN = \frac{25400}{254+s} \Rightarrow s = 28.22mm$$

$$Q = \frac{(p-0.28)^2}{p+0.8s} = \frac{(120-0.2\times 28.22)^2}{(120+0.8\times 28.22)} = 91.72mm$$

In terms of ha-m: $Q = (a_1+a_2)\,Q = (50+10)(91.72/1000) = 5.5$ha.m (Ans)

4 (a) Determine the system capacity for a sprinkler irrigation system to irrigate 10 hectares of maize crop. Design moisture use rate is 5 mm per day. The moisture-holding capacity of soil is 18 cm per metre depth and the depth of root zone is 1 metre. The moisture content at the root zone at the time of irrigation is 12 cm. Irrigation efficiency is 70 percent and the irrigation period is 10 days in 12 days interval. The system is to be operated for 20 hours per day.

(b) A 1 cm thick steel pipe with an internal diameter of 5 cm is used to convey steam. The inside pipe surface temperature is 120°C. The pipe is covered with 3 cm thick insulation. Under steady state condition the outer insulation surface temperature is 30°C. Calculate the heat loss per metre from the pipe (with insulation). The thermal conductivity of steel is 16.3 W/m-k and of the insulation is 0.038 W/m-k.

Ans:

(a) Moisture use rate = 5mm/day, MHC = 18cm/m, A=10ha,

D = 1m, M_{bi}=12cm, Ea=70%, F = 10days = irrigation period

I = 12days = irrigation interval, H = 20hrs/day

$$Q = \frac{Ad}{FHE}$$

$$d = \left(\frac{M_{fc} - M_{bi}}{100}\right)\rho D = 18cm\text{-}12cm = 6cm = 0.06m$$

$$Q = \frac{10 \times 10^4 \times 0.06}{10 \times 20 \times 3600 \times 0.7} = 0.012 m^3/s$$

(b)Thickness of steel pipe = 1 cm

D_i = 5 cm $\Rightarrow r_1$=0.025 m

T_1 = 120°C $\Rightarrow r_2 = r_1$ + thickness = 0.025 + 0.01 = 0.035 m

$r_3 = r_2$ + insulation = 0.035 + 0.03 = 0.065 m

T_0 = 30°C, K_s = 16.3 W/K = K_1, K_2 = 0.038 W/K

$$q = \frac{Q}{L} = \frac{2\pi(T_1 - T_0)}{\frac{1}{k_1} ln\left(\frac{r_2}{r_1}\right) + \frac{1}{k_2} ln\left(\frac{r_3}{r_2}\right)} = \frac{2T(120^o - 30^0)}{\frac{1}{16.3} ln\left(\frac{0.035}{0.025}\right) + \frac{1}{0.038} ln\left(\frac{0.065}{0.035}\right)}$$

= 34.668 KW/m (Ans)

5(a) Find the amount of moisture to be removed in drying one tonne of grain, initially at 24 % moisture (wet basis) to 12 % moisture (wet basis). Also, calculate the weight of dried grain.

(b) Orange juice with 11 % total solids is being concentrated to 50 % total solids in a single effect evaporator with a feed rate of 5,000 kg per hour at 20°C. The evaporator is being operated at sufficient vacuum to allow the product moisture to evaporate at 70°C while steam is being supplied at 198.5 KPa. Calculate the final product rate in kg per hour.

Ans:

(a) Initial moisture content , IMC =1000 x 24/100 = 240 kg

Weight of dry matter, $W_d = 1000 - 240 = 760$ kg
Moisture content (db) = 12/(100-12) = 0.136 %
Final moisture content, FMC = 13.6/100 x 760 = 103.36 kg
Amount of moisture removed = 240-103.36 = 136.64 kg
Weight of dried grain = FMC + W_d = 103.36 + 760 = 863.36 kg

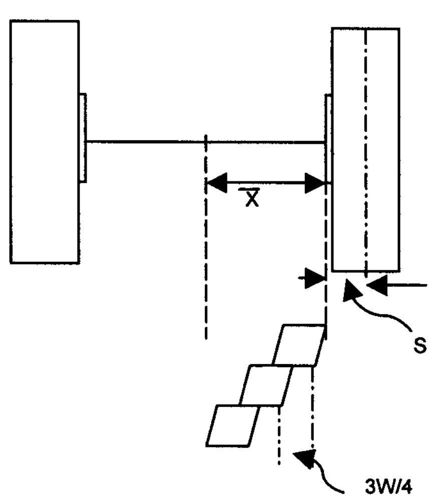
(b)$X_F = 0.11$, $X_P = 0.5$, $T_P = 70°C$
F = 15000 kg/h, P_S = 198 kPa
$F\,X_F = P\,X_p$
$\Rightarrow 15000 \times 0.11 = P \times 0.5$
$\Rightarrow P = 3300$ kg/h (Ans)

1997

(1) A tractor is attached with a 3 x 35 cm trailed type mouldboard plow and was operated at a depth of 15 cm at 3.0 km/ha. The tractor was fitted with 6.0 x 16.0 and 12.4 x 28.0 size tyres respectively in front and rear wheels. Assuming a clearance of 5 cm between the furrow wall and inner surface of wheel, calculate the wheel tread.

Ans:

D = 15 cm,	V = 3 km/hr	
Front tyres = 6" x 16" size,	6"= rim width,	16" = rim diameter
Rear tyres = 12.4 x 28" size	12.4"= rim width,	28" = rim diameter



Taking momentum about furrow wall,

$$\frac{3W}{4}R + \frac{7W}{4}R + \frac{11W}{4}R = 3R\bar{X}$$

where

W = width of each bottom

R = uniform soil reaction

$\bar{X}$ = Distance of resultant soil reaction from furrow wall

$$\Rightarrow \bar{X} = \frac{21W}{4\times 3} = \frac{7W}{4} = \frac{7\times 35}{4} = 61.25 \text{ cm}$$

Wheel tread = centre to centre distance between rear wheels

$$= (61.25 + 5 + \frac{\text{width of rear wheel}}{2}) \times 2$$

$= (61.25 + 5 + 12.4 \times 2.54/2) \times 2 = 163.996$ cm (Ans)

(2) A two-cylinder, four-stroke compression ignition engine with volumetric efficiency 88 per cent has stroke to bore ratio as 1.12:1 and stroke length as 100 mm. The clearance volume of each cylinder is 100 cc and mean effective pressure is 6 x 10^5 Pa. If the piston makes 3000 strokes per minute, calculate.

(a) the bhp of the engine

(b) air flow required in cubic metre per minute

(c) compression ratio

Ans:

$n = 2$, $V_n = 88\ \%$, $L/D = 1.2$, $L = 100$ mm

$V_c = 100$ cc/cycle, $P_{mean} = 6 \times 10^5$,

$P_a = P$, $N = 3000$ Strokes/min = 1500 rpm

(a) IHP of engine = PQ_e = PLA (N/2) n

$$= 6 \times 10^5 \frac{N}{m^2} \times 0.1 \times \frac{\pi}{4}\left(\frac{0.1}{1.12}\right)^2 \times \frac{1500}{2} \times 2$$

= 563503 N.m/min = 12.589 HP

$\therefore$ BHP = IHP-FHP = 12.589 HP – 0 = 12.589 HP

$$\text{(b) } V_s = \frac{\pi}{4}D^2 \times L = 0.1 \times \frac{\pi}{4}\left(\frac{0.1}{1.12}\right)^2 = 6.26 \times 10^{-4} \text{ m}^3$$

$$CR = \frac{V_c + V_s}{V_c} = 1 + \frac{V_s}{V_c} = 1 + \frac{6.26\times 10^{-4} m^3}{100 \times 10^{-6} m^3} = 7.26$$

(c) Engine displacement (m^3/min) = Q_e= (AL) (N/2) N

$\therefore Q_e = 6.26 \times 10^{-4} \times 750 \times 2 = 0.939\ m^3/min$

$$\text{Volumetric efficiency} = \frac{\text{air taken in}}{\text{engine displacement}} = 0.88$$

Air taken in = air flow required in cubic meter per minute
= $0.939 \times 0.88 = 0.82\ m^3/min$

(3) One kilogram of an air-stream (A) at 30°C and 90 % relative humidity is mixed with 2 kg of air-stream (B) at 30°C having absolute humidity of 0.0103 kg/kg of dry air. The mixture is then heated to 60°C. Find out the relative humidity of the resultant mixture. The vapour pressure of water at 30 and 60°C are 4.11 and 19.93 kPa, respectively. Total pressure of the system is 101.325 kPa. Average molecular weight of air is 29 kg/kmol. Use of psychrometric chart is not permitted in this problem.

Ans:

A (air)	B (air)
30°C	30°C
RH = 90 %	H = 0.0103 kg/kg
1 kg	2 kg
$P_s = 4.11$ kPa	$P_s = 4.11$ kPa

$\Rightarrow$ Mixture of air stream A and B is heated to 60°C
Total pressure of the system = 101.325 kPa
Molecular mass of air = 29 kg/k-mol
Vapour pressure of water = P_s = 19.93 kPa
Atmospheric Pressure, P = 101.325 kPa

Taking moisture balance

$m_1 H_1 + m_2 H_2 = m_3 H_3 = (m_1 + m_2) H_3$ (1)

$1 \times 0.023 + 2 \times 0.0103 = 3 \times H_3$

$\Rightarrow H_3 = 0.0147$

Air stream A:

$RH = \phi = 0.9 = P_v/P_s$ (2)

$\Rightarrow P_v = 0.9 \times P_s = 9.9 \times 4.11\ kPa = 3.699\ kPa$

$\therefore\ H = 0.622\ P_v/P_a = 0.622\ P_v/P-P_v$
$= 0.622\ (3.699/101.325 - 3.699) = 0.023 = H_1$

In a system by heating a mixture its relative humidity decreases but absolute humidity, H does not change.

$$\text{Thus } H_3 = H_4 = 0.622\ \frac{P_v}{P - P_v} = 0.0147$$

$\Rightarrow P_v = 2.342$ kPa

$\therefore\ \phi = P_v/P_s = 2.342/19.93 = 0.11755 = 11.75\ \%$ (Ans)

(4) Estimate the peak runoff rate for 25-year recurrence interval, for a watershed comprising 22 ha of cultivated land (runoff coefficient = 0.05), 13 ha of hilly forest land (runoff coefficient = 0.3) and 15 ha of rolling grassland (runoff coefficient = 0.35). The maximum length of the flow is 2 km and the fall along the flow path is 400 m. 1-h rainfall for the watershed with 25-year recurrence interval is 6.8 cm. The straight line relationship between I_f (i.e. 1-h rainfall intensity in cm/h) and I (i.e. rainfall intensity for the duration equal to the time of concentration in cm/h) is as follows :
$I = 1.50\ I_f$, for time of concentration = 30 min.
$I = 1.75\ I_f$ for time of concentration = 20 min
$I = 2.00\ I_f$, for time of concentration = 10 min.

Ans:
Recurrence interval = 25 years, I_f=6.8cm/hr
$a_1 = 22$ha, $c_1 = 0.5$, $a_2 = 13$ha, $c_2 = 0.3$, $a_3 = 15$ha, $c_3 = 0.35$
L = 2km = 2000 m, H = 100m, Slope, S = H/L = 400/2000 = 0.2

$$c=\frac{\sum c_1 a_1}{\sum a_1}=\frac{22\times0.5+13\times0.3+15\times0.35}{(22+13+15)}=0.403$$

$T_c = 0.0195 \text{x } L^{0.77} \text{x } S^{-0.385} = 12.62$ min

So for this T_c, factor of multiplication for $I_f = 2-\frac{0.25}{10}\times 2.62 = 1.94$

$\Rightarrow I = 1.94 \text{x} I_f = 1.94 \text{ x } 6.8 = 12.62$ cm/hr = 126.2 mm/hr

$$Q_{peak}=\frac{CIA}{360}=\frac{0.403x126.2x50}{360}=7.06m^3/\sec \qquad \text{(Ans)}$$

(5) Using Lacey's regime theory, design an irrigation channel section for the following data :
Discharge, Q = 50 m^3/s ,side slope, Z = ½: 1(H:V),Silt factor, f = 1.0
Also determine the longitudinal slope.

Ans:
Lacey's theory

$$V=(\frac{Qf^2}{140})^{\frac{1}{6}} \qquad (1)$$

$$\Rightarrow V=(\frac{50\times1^2}{140})^{\frac{1}{6}}=0.842\frac{m}{s}$$

A = Q/V = 50/0.842 = 59.38m^2

$P = 4.75\sqrt{Q}$ (2)

$\Rightarrow P = 4.75\sqrt{50} = 33.487m$

$A = bd+zd^2 = bd+1/2d^2 = 59.38m^2$ (3)

$P = b+2d\sqrt{(z^2+1)} = b+2.236d = 33.587m$ (4)

Solving (3) and (4) simultaneously

d = 17.37m or 1.968m

so d = 1.968m

b = 33.587-2.236x1.968 = 29.18m

T = b+2zd = 29.18+2x0.5x1.968 = 31.15m

Longitudinal slope, $S = \dfrac{f^{5/3}}{3340 \times Q^{1/6}}$

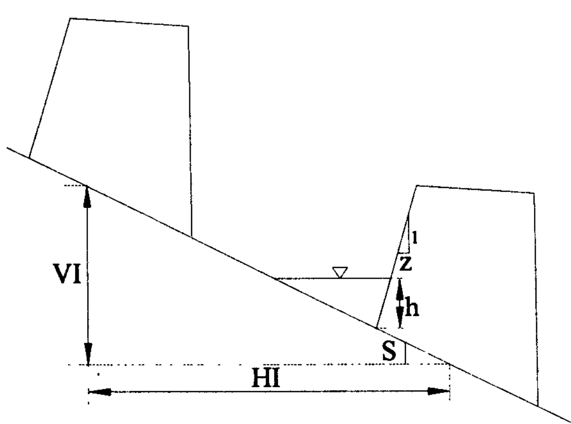
$$= \frac{1}{3340 \times 50^{1/6}} = 1.559 \times 10^{-4} = 0.016\,\% \text{ (Ans)}$$

(6) A contour bund is to be constructed for an area having an average slope of 2.5 %. The maximum expected rainfall in the area with 10-year-recurrence interval is 15 cm.The infiltration capacity of the soil is such that 40 % of the rainfall is absorbed in the field. Calculate the storage area required if the horizontal distance between the bunds is 60 m. Also find the dimensions of the contour bund. Use bund side slope = 1.5 :1 (H:V); Seepage line slope = 5:1 (H:V); and free board = 20 % of the water depth.

Ans:

S = 2.5%, P = 15cm = rain fall, Z = 1.5:1(H:V)

f = 0.4 x 15 = 6cm = infiltration



(i) When all the run off is to be stored
Storage volume = Runoff volume

$\Rightarrow \frac{h^2}{2}(z+\frac{100}{5})$ x L_B= HI x L_B(I-f)

$\Rightarrow$ h = $\sqrt{\frac{2HI(P-f)}{(z+\frac{100}{s})}} = \sqrt{\frac{2\times 60\times 0.09}{(1.5+\frac{100}{2.5})}} = 0.51\text{m}$

Cross-sectional area of water behind bund =$A_w = \frac{h^2}{2}(z+\frac{100}{s})$

$\Rightarrow A_w = \frac{h^2}{2}(z+\frac{100}{s}) = \frac{0.51^2}{2}(1.5+\frac{100}{2.5}) = 5.4m^2$

(ii) Dimension of contour bond:
b = h (z+i)=0.51(1.5+5)=3.315
H = h (height of flow over weir) + free board
= 0.51+(20/100 X 0.51)= 0.612 m
where, H = Height of the bund
h = Depth of water

(7) The mass specific gravity of a fully saturated specimen of clay, having a water content of 38 %, is 1.92. On oven drying, the mass specific gravity drops to 1.79. Calculate the specific gravity of the specimen.

Ans:
Mass specific gravity of fully saturated clay is given by:

G_m(Sat)=$\frac{M_{sat}}{V} = \frac{y_{sat}}{y_w} = \frac{(G+e)y_w}{(1+e)y_w} = \frac{G+e}{1+e} = 1.92$

W_{sat} = 3.8% = 0.38
For saturated specimen ;

$\frac{G+e}{1+e} = 1.92$

$\Rightarrow \frac{G+w_{sat}G}{1+w_{sat}G} = \frac{G+0.38G}{1+0.38G} = 1.92$

$\Rightarrow$ G = 2.95 (Ans)

(8) The peak of a flood hydrograph due to a 4-h effective storm is 400 m^3/s. The mean depth of the rainfall is 5.9 cm. Assuming an average infiltration loss of 0.35 cm/h and a constant base flow of 25 m^3/s, estimate the peak of a 4-h unit hydrograph.

Ans:

Peak of storm hydrograph (Flood Hydrograph) = $400 m^3/s$

Base flow = $25 m^3/s$, $P_m = 5.9$ cm

Average infiltration loss, $W_{index} = 0.35$cm/hr

$$W = \frac{P - ER}{t} = \frac{5.9 - ER}{4} = 0.35$$

$\Rightarrow$ ER = 4.5cm

Peak of DRH = 400-25 = $375 m^3/s$

Peak of UH = 375/4.5 = 83.33 m^3/s (Ans)

(9) In a falling head permeameter test, the initial head is 40 cm. The head drops by 6 cm in 12 min. Calculate the time required to run the test for the final head to be at 20 cm. If the sample is 10 cm in height and 50 cm^2 in cross-sectional area. Calculate the coefficient of permeability. Take area of the stand pipe as 0.5 cm^2.

Ans:

(a) Initial head, $h_1 = 40$cm, $\Delta h = 6$cm, a = 0.5 cm^2

t = 12min = 720sec, A = 50 cm^2, L= 10cm = 0.1m

$h_2 = h_1 - \Delta h = 40-6 = 34$cm

Falling head permeameter test: $k = \frac{al}{At}\ln(\frac{h_1}{h_2})$

$$\Rightarrow \frac{kA}{aL} = \frac{1}{t}\ln\left(\frac{h_1}{h_2}\right) = \frac{1}{720}\ln\left(\frac{40}{34}\right) = 2.25\text{x}10^{-4} \text{ (a constant value)}$$

$$\text{Again } h_2 = 20\text{cm, } t = \frac{aL}{kA}\ln\left(\frac{h_1}{h_2}\right) = \frac{1}{2.25\times10^{-4}}\ln\left(\frac{40}{20}\right) = 51.34\,\text{min}$$

$$\text{(b) } K = \frac{0.5\times10^{-4}\text{m}^2\times0.1}{50\times10^{-4}\text{m}^2\times(12\times60)}\ln\left(\frac{40}{34}\right) = 2.257\times10^{-7}\,\text{m/s} \qquad \text{(Ans)}$$

(10) A 10 ha field is to be irrigated at a maximum rate of 1 cm/h with a sprinkler system. The root zone depth is 90 cm. The available moisture-holding capacity of the soil is 16.5 cm/m depth. The water application efficiency is 70 %. The field is to be irrigated when 40 % of the available moisture is depleted. The peak rate of

moisture use is 5 mm/day. Determine the net depth of application per irrigation, depth of the water to be pumped, days to cover the field and the area irrigated per day, if the sprinkler is operated for 8 h/day.

Ans:

A = 10ha, I = 1cm/hr, h = 8hr/days, D = 0.9m,

AMHC = 16.5cm/m, E_a = 70%

d_{fc} = AMHC x D = 16.5x 0.9 = 14.85cm

Depth before irrigation, $d_{bi} = 0.6d_{fc}$

$\Rightarrow$ Net depth of application per irrigation ,$d = 0.4d_{fc} = 0.4 \times 14.85 =$ 5.94cm

$IR = d/E_a = 5.94/0.7 = 8.48$cm

Days to cover field = irrigation period

$$F = \frac{Loss}{Rate\ of\ loss} = \frac{5.94 \times 10}{5} = 11.88\,days$$

$$\text{Area irrigated per day} = \frac{Total\ area}{Total\ days} = \frac{10 \times 10^4}{11.88} = 0.84 ha/day \qquad \text{(Ans)}$$

(11) In a maize planter, the ground wheel of 50 cm diameter drives the seed metering shaft by open belt. The largest pulley on the ground wheel shaft is 25 cm in diameter. It is desired that the seed metering shaft be rotated at 35 and 40 rpm at a time for better control of seeds. The distance between the ground wheel shaft and the seed metering shaft is 70 cm. Determine the remaining diameters of stepped pulleys for planter speed of 2.1 km/h. Belt thickness and slip may be neglected.

Ans:

$N_1 = 35$, $N_2 = 40$, $D_1 = 25$ cm = 0.25 m

Velocity of travel ,V = π DN= 2.1 km/hr

$$\Rightarrow \frac{2.1}{3.6} = \pi \times D \times N = \pi \times 0.5 \times N$$

$\Rightarrow$ N = 0.37 r/s = 22.28 rpm

Again, $\pi D_1 N = \pi dN_1$

$\Rightarrow 0.25 \times 22.28 = d \times 35$

$\Rightarrow d = 0.159$ m

Again, $\pi D_2 N = \pi dN_2$

$\Rightarrow D_2 \times 22.28 = d \times 40$

$\Rightarrow D_2 = 0.28$

Thus d = 0.159 m, D_2 = 0.28 and D_1 = 0.25 m
But according to question D_1 is larger pulley. So let's reverse the rpm of metering shaft.
$\therefore \pi D_1 N = \pi d N_2 \Rightarrow 0.25 \times 22.28 = d \times 40 \Rightarrow d = 0.139$ m
$\pi D_2 N = \pi d N_1 \Rightarrow D_2 \times 22.28 = 0.139 \times 35 \Rightarrow D_2 = 0.218$ m
Thus d = 0.139 m, D_2 = 0.218 m, D_1 = 0.25 m (Ans)

(12) The carburettor of a 4-cylinder engine was adjusted to evaporate 70 percent of fuel at the manifold at full throttle when engine speed was 1200 rpm. The rope brake dynamometer attached to this engine showed spring balance reading as 150 N at a dead load on the brake as 780 N. The drum diameter was 70 cm. The dead weights as 578, 570, 563 and 561 N and spring tensions as 121, 116, 120 and 113 N were recorded to maintain the same speed when the spark plug of each cylinder was short circuited in turn respectively. Determine :
(a) mechanical efficiency of the engine and
(b) air-fuel ratio for air-vapour ratio of 17.14:1
Assume rope diameter as 2.0 cm.

Ans:
n = 4, N = 1200, A/V = 17.14:1, rope dia = 2m, drum dia = 0.7 m
spring balance reading, F = 150N; dead load on brake = 780 N
BHP of engine = $2\pi NT = 2\pi(1200/60) \times 226.8 = 28.5$ kW
T = F.r = 630 x 0.36 = 226.8 N.m
F = (780 – 150) = 630 N
r = effective radius = (70+2)/2 = 36 cm = 0.36 m

$$BHP_1 = 2\pi\left(\frac{1200}{60}\right)(578-121)\times 0.36\times\left(\frac{1}{1000}\right) = 20.67 \text{ kW}$$

$$BHP_2 = 2\pi\left(\frac{1200}{60}\right)(570-116)\times 0.36\times\left(\frac{1}{1000}\right) = 20.53 \text{ kW}$$

$$BHP_3 = 2\pi\left(\frac{1200}{60}\right)(563-120)\times 0.36\times\left(\frac{1}{1000}\right) = 20.04 \text{ kW}$$

$$BHP_4 = 2\pi\left(\frac{1200}{60}\right)(561-113)\times 0.36\times\left(\frac{1}{1000}\right) = 20.26 \text{ kW}$$

BHP_1 = BHP of engine when 1st cylinder is short-circuited
IHP_1 = IHP of first cylinder = BHP – BHP_1= 28.5 – 20.67 = 7.83
IHP_2 = 28.5 – 20.53 = 7.97

$IHP_3 = 28.5 - 20.04 = 8.46$
$IHP_4 = 28.5 - 20.26 = 8.24$
$IHP = \Sigma\, IHP = 7.83 + 7.97 + 9.46 + 8.24 = 32.5$ kW

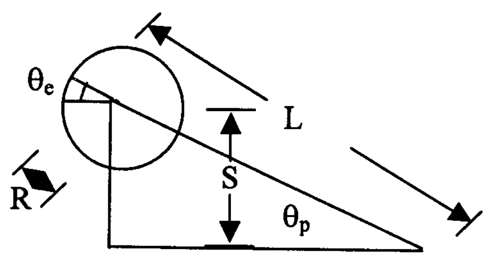
(a) $ME = BHP/IHP = \dfrac{28.5}{32.5} = 87.69\ \%$

(b) $\dfrac{A}{F} = \dfrac{A}{V} \times \dfrac{F_E(\%)}{100} = 17.14 \times \dfrac{70}{100} = 11.998 = 12$ (Ans)

(13) The crank of radius 4 cm is rotated at 900 rpm by the PTO of a tractor and is connected to a 2.0 m cutter bar through a pitman of length 70 cm. If the vertical height of crank centre is 30 cm above the cutter bar level, determine the acceleration of the knife when the pitman is in line with the crank pin and crank centre.

Ans:

Crank radius, R = 4cm, S = 30 cm,
Crank rpm, N = 900 rpm



L = 70 cm, Length of cutter bar = 2m

$$K = \frac{R}{\sqrt{L^2 - S^2}} = \frac{4}{\sqrt{70^2 - 30^2}} = 0.063$$

$\omega = 2\pi N = 2\ \pi$ x $(900/60) = 94.24$ rad/sec

Pitman is in line with the crankpin and crank centre

$\Rightarrow \theta_C = \theta_p = Sin^{-1}(S/L\text{-}R) = Sin^{-1}(30/30\text{-}4) = 27.03°$

$\therefore$ Acceleration of the knife, $a = R\omega^2 [\cos\theta_c - K \cos 2\theta_c + KS/R \sin\theta_c]$

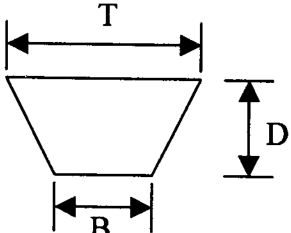
$\therefore a = 0.04 \text{ x } (94.24)^2 [\text{Cos } 27.03 - 0.063 \cos(2 \text{ x } 27.03) +$

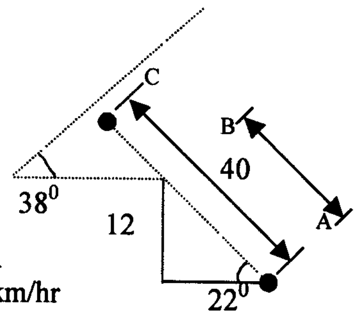
$$\frac{0.063 \times .3}{0.04}\sin(27.03)] = 379.6\frac{m}{s^2}$$ (Ans)

(14) A desi plow has a trapezoidal shape share of dimension 6 cm as bottom width, 34 cm as top width and 40 cm long. The plow was operated at a depth of 12 cm and at a speed of 1.8 km/h. During

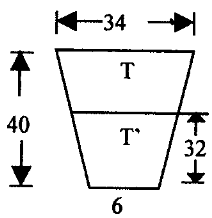
operation, the share and the line of pull made an angle of 22 and 38 degree respectively with horizontal. For 20 percent reserve power and 5 cm overlap between successive runs Calculate the unit draft in third pass. Assume that a pair of bullock generates 1 horse power.

Ans:





T = 34 cm
d = 12 cm
B = 6 cm
V = 1.8 km/hr
Length of plough = 40 cm
Pull with horizontal = 38°
Share with horizontal = 22°
1 pair of bullock = 1 HP



(Top view)

Useful draft power $= 1 - \frac{20}{100} \times 1 = 0.8$ HP

Draft $= \frac{0.8 \times 746}{1.8/3.6} = 1193.6\text{N}$

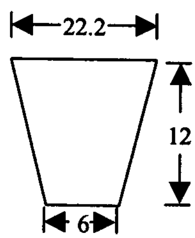
$\text{Sin } 22° = \frac{12}{AB}$

AB = 12/sin 22 = 32 cm

$\frac{T}{40} = \frac{T'}{32} \Rightarrow \frac{34}{40} = \frac{T'}{32}$

$\Rightarrow$ T' = 27.2 cm

T'' = 27.2 – 5 = 22.2 cm



A = ½ (b + T'')d = ½ (6 + 22.2) x 12 = 169.2 cm² (Side view)

Unit draft $= \frac{1193.6}{169.2} = 7\frac{\text{N}}{\text{cm}^2}$ (Ans)

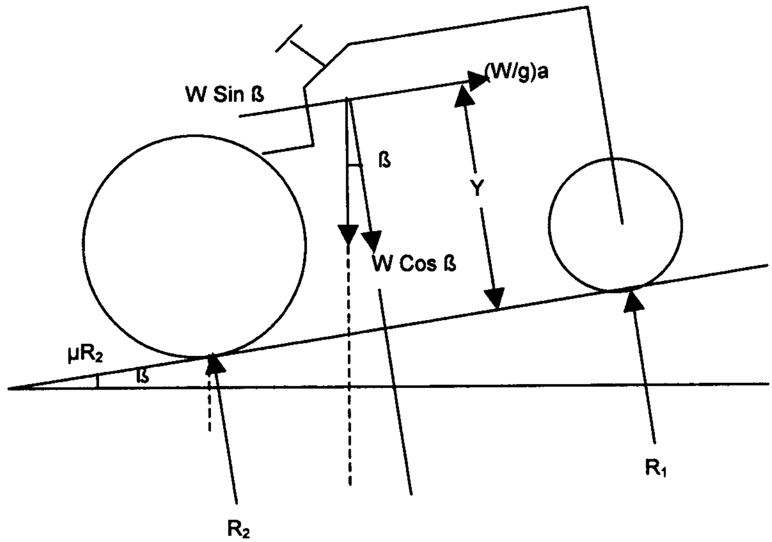
(15) A tractor weighing 14.5 kN and wheel base as 140 cm is moving up the slope 1 in 20 (vertical : horizontal) without load at a speed of 30 km/h. The CG is located 20 cm ahead of rear axle and 75 cm above the ground level. If the coefficient of friction between the

ground and the tyre is 0.40, find the distance traveled after the application of brake in the rear wheel.

Ans:

W = 14.5 KN, X_1 = 20 cm, X_2 = 140 cm

V = 30 km/h, μ= 0.4, Y = 75 cm



Slope = 1:20 (V : H) $\Rightarrow$ tan β = 1/20 $\Rightarrow$ β = 2.862^0

$R_1 X_2 + W \sin\beta\, Y = W \cos\beta . X_1$ (1)

$\Rightarrow R_1 (1.4) + 14.5 (\sin 2.862)\, 0.75 = 14.5 (\cos 2.862) (0.2)$

$\Rightarrow R_1 = 1.68$ kN

$R_1 + R_2 = W \cos\beta$ (2)

$R_2 = 14.5 \times \cos 2.862 - 1.68 = 12.799$ kN

Again F = μR_2 and F = (W/g) a

$\Rightarrow \mu R_2 = (W/g)\, a$

$$\Rightarrow 0.4 \times 12.799 = \frac{14.5 \times a}{g}$$

$\Rightarrow a = 3.46\ m/s^2$

$$V^2 = U^2 + 2as \quad \Rightarrow S = \frac{V^2}{2a}$$

Other method to calculate stopping distance (s):

$$\tfrac{1}{2} MV^2 = F.S = ma\,S \Rightarrow S = \frac{V^2}{2a}$$

$$V = \frac{30}{3.6} = 8.33 \text{ m/s}$$

$$\Rightarrow S = \frac{V^2}{2a} = \frac{(8.83)^2}{2\times 3.46} = 10.03 \text{ m} \qquad \text{(Ans)}$$

(16) The power consumed by an ensilage cutter having 3 knives to cut napier fodder at load was found to be 0.860 kW and 0.140 kW at no load for a flywheel speed of 650 rpm. The diameter of feed roller is 15 cm while the distance of the inner edge of throat is 12 cm from the flywheel centre. The mean throat dimension is 18 cm x 6 cm. The speed ratio between the flywheel and feed roller is 11:1. If the effective cut area of fodder is 65 per cent of throat area, calculate.

(a) length of cut for two knives, and
(b) dynamic shear stress of fodder.

Ans:

First method to calculate dynamic shear stress of fodder:

$n = 3$, $N = 650$ rpm

$P = 0.86$ KW (at load) and $P = 0.14$ KW (at no load)

Diameter of feedroll, $D' = 0.15$ m

r_i = distance of inner edge of throat from flywheel centre

$= 12$ cm $= 0.12$ m

$A = W \times H = 18 \times 6$ cm

$$\frac{N}{N'} = \frac{N_{\text{Flywheel}}}{N_{\text{feedroll}}} = 11 = \text{speed ratio between flywheel and feedroll.}$$

Effective area of fodder, $A_0 = 65\ \% \times$ throat area

(a) $NLn = \pi D'N'$

$$L = \frac{\pi D'N'}{Nn} = \frac{\pi\times 0.15\times 1}{3\times 11} = 0.014 \text{ m}$$

When n = 2, it will produce 2 lengths of different cut

One $\rightarrow$ 0.014 m = 1.427 cm

and another $\rightarrow$ 0.014 x 2 = 0.028 m = 2.855 cm

(b) Power used in cutting = 0.86 – 0.14 = 0.72 kW

Assuming all the energy is available for cut,

$$0.72 \text{ kW} = 0.72 \text{ KJ/S} = 0.72 \frac{KJ}{(650/50)rev} = 0.066 \text{ kJ/rev}$$

$$= 0.066 \frac{\text{KJ}}{3\text{cut}} = 0.022 \frac{\text{KJ}}{\text{Cut}} = \text{Work done/cut}$$

Work done/cut = F.r θ = ($A_0 \tau$)r θ = ($A_0 \tau$) r ($2\pi/3$)

θ = Angle of rotation of flywheel/cut (= 2π per revolution)

$\therefore$ 0.022 = (65/100 x 18 x 6 x 10^{-4} x τ) x 0.12 x $2\pi/3$

$\Rightarrow \tau = 12469 \text{ N/m}^2$

Second method to calculate dynamic shear stress of fodder

$$\text{Work done/rev} = \frac{0.066\text{KJ}}{\text{rev}}$$

Work done/rev = F.r. θ = ($A_0 \tau$) r (2π)

0.066 x 1000 = (0.65 x 18 x 6 x 10^{-4} x τ) x 0.12 x (2π)

$\Rightarrow \tau = 12469 \text{ N/m}^2$

Third method to calculate dynamic shear stress of fodder

P = 2 π NT

$$\Rightarrow 0.72 \text{ kW} = 720 \text{ N.m/S} = 2\,\pi \text{ x } \frac{650}{60}\frac{r}{S} \times T$$

$\Rightarrow$ T = 10.577 N.m

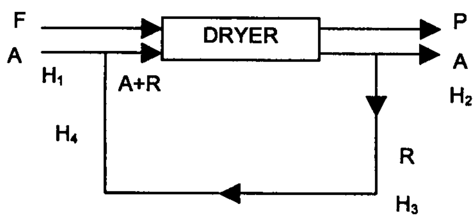
T = F.R = ($A_0 \tau$) r

$$10.877 = \left(\frac{65}{100} \times 18 \times 6 \times 10^{-4} \times \tau\right) \times 0.12$$

$\Rightarrow \tau = 12556 \text{ N/m}^2$ (Ans)

(17) A food with an initial moisture content of 15 % (wet basis) is dried in a continuous dryer to attain a final moisture content of 7 % (wet basis). This drying is accomplished by blowing fresh warm air after it was mixed with some part of the exhaust air (recycled stream) from the dryer. The absolute humidity of fresh, recycled and mixed air-streams are 0.01, 0.1 and 0.03 kg/kg of dry air, respectively. For a feed rate of 100 kg/h, calculate the required flow rates of fresh and recycled air-streams (in terms of kg of dry air/h) and the amount of dried product obtained per hour.

Ans:
$F = 100$kg/hr, X_F=0.85,
X_P=0.93
$H_1 = 0.01$ kg/kg, $H_2 = 0.1$kg/kg
$H_3 = 0.1$ kg/kg, H_4=0.03 kg/kg



A = flow rate of fresh air
R = flow rate of recycled air
A + R = mixed air
W = moisture removed out with heated air
At exhaust amount of air = A

For food product part

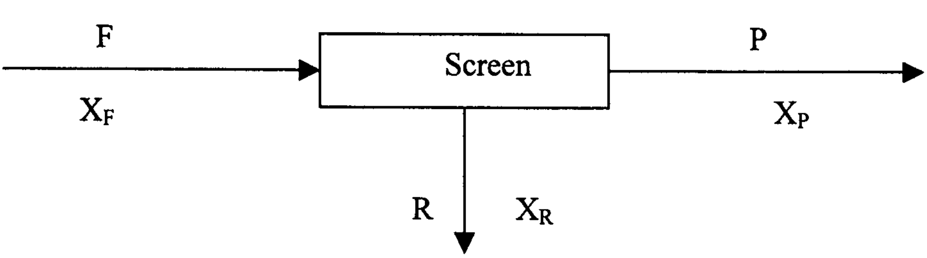
$F X_F = P X_P$ (1)
$100 \times 0.85 = P \times 0.93$
$\Rightarrow P = 91.4$ kg/h
$F = W + P$ (2)
$\Rightarrow W = F - P = 100 - 91.4 = 8.6$ kg/hr = moisture removed with air

For Air movement part:

Moisture balance in fresh air:
$A \times 0.01 + 8.6 = 0.1 \times A$
$\Rightarrow A = 95.55$ kg/hr = Flow rate of fresh air
Moisture balance of recycled and mixed air at inlet:
$(A + R)\,0.03 = A \times 0.01 + R \times 0.1$
$(95.55 + R)\,0.03 = 95.55 \times 0.01 + R \times 0.1$
$\Rightarrow R = 27.3$ kg/hr (Ans)

(18) A screen is used to separate two components (A and B) from a feed where F, O and U are taken as mass flow rates of feed, overflow and underflow streams, respectively. The corresponding mass fraction of the oversize component A in these streams are x_F, x_O and x_u. Derive an expression for overall effectiveness of this screen.

Ans:
Using notations F, O, U for F, P, R respectively



$F = P + R$ (1)

$F X_F = P X_P + R X_R$ (2)

Efficiency of overflow, $E_P = P X_P / F X_F$ (3)

Efficiency of underflow, $E_R = \dfrac{R(1-X_R)}{F(1-X_F)}$ (4)

Overall effectiveness of this screen, $E = E_P E_R = \dfrac{PR}{F^2}\dfrac{X_P}{X_F}\left(\dfrac{1-X_R}{1-X_F}\right)$ (5)

$$\Rightarrow E = \frac{(X_P - X_F)(X_F - X_R)}{(X_P - X_R)^2}\frac{X_P(1-X_R)}{X_F(1-X_F)} \quad (6)$$

(19) The proximate composition of cow milk shows that it contains 3.85 % fat, 3.48 % protein, 5.08 % lactose (milk sugar) and 0.72 % minerals; thus comprising 13.13 % total soluble solid (TSS). To obtain skim milk, the cow milk is centrifuged to separate 80 % of the fat initially present. The skim milk is then evaporated to such an extent that its TSS is increased to 30 %. Find out the final composition of the evaporated milk.

Ans:

	Cow milk	Skim milk
Fat	3.85 %	0.77 %
Protein	3.48 %	3.48 %
% Lactose (milk sugar)	5.08 %	5.08 %
Mineral	0.72 %	0.72 %
Total soluble solid (TSS)	Σ =13.13 %	Σ = 10.05 %

Skim milk

% Fat, $F_0 = 3.85 - 3.85 \times \dfrac{80}{100} = 0.77$ %

$$\frac{F_0}{F_C} = \frac{100 - X_0}{100 - X_C}$$

$$\Rightarrow \frac{0.77}{F_C} = \frac{100 - 89.95}{100 - 70} \qquad \Rightarrow F_C = 2.29\%$$

Other method to calculate F_C

$\frac{F_0}{F_C} = 0.335$ $\Rightarrow F_C = \frac{F_0}{0.35} = \frac{0.77}{0.335} = 2.29\ \%$

$\frac{P_0}{P_C} = \frac{100 - X_0}{100 - X_C} = 0.335$ $\Rightarrow P_C = \frac{P_0}{0.335} = \frac{3.48}{0.335} = 10.388\ \%$

$\frac{L_0}{L_C} = \frac{100 - X_0}{100 - X_C} = 0.335$ $\Rightarrow L_C = L_0/\ 0.335 = 15.164\ \%$

$\frac{M_0}{M_C} = \frac{100 - X_0}{100 - X_C} = 0.335$ $\Rightarrow M_C = M_0/0.335 = 2.15\ \%$

Note: $F_C + P_C + L_C + M_C = 2.29 + 10.388 + 15.164 + 2.15 = 30\ \%$ (Ans)

(20) Corn grits, a raw material for making cornflakes, is prepared by crushing corn using a pair of rolls. The rolls rotate towards each other at equal speed. The corn, having an equivalent diameter of 8 mm, is crushed into grits (equivalent diameter of 3 mm). If the coefficient of friction between the corn and the material of the roll surface is 0.25, calculate the diameter of each roll.

Ans:

Equivalent diameter of corn, b = 8 mm

Equivalent diameter of crushed product, c = 3 mm

$\mu = 0.25 = \tan\alpha$

$\Rightarrow \alpha = 14.036^{\circ}$

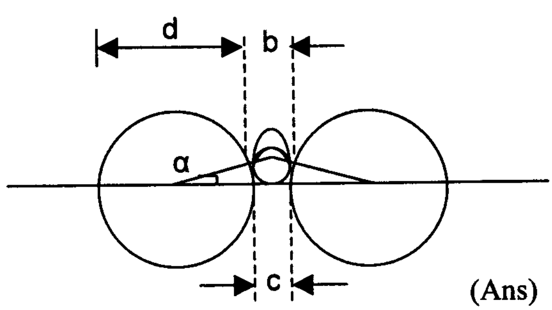
$\text{Cos}\ \alpha = \frac{d+c}{d+b}$

$\Rightarrow \cos(14.036) = \frac{d+3}{d+8}$

$\Rightarrow 0.97 = \frac{d+3}{d+8}$

$\Rightarrow 0.97\ d + 0.97 \times 8 = d + 3$

$\Rightarrow d = 158\ \text{mm} = 15.8\ \text{cm}$



(Ans)

(21) A silo of 1.82 m in diameter and 20 m high is made of mild steel sheet. Corn is stored into it upto a height of 15.24 m. Compute the vertical and lateral pressures at the base of the silo. Given, bulk density of corn 700 kg/m^3, angle of inter grain friction 30° and

coefficient of friction between grain and mild steel is 0.42. The ratio of lateral to vertical pressure is 0.33.

Ans:

D = 1.82 m, H = 20 m, h = 15.24 m

$P_L/P_V = K = 0.33$, $\omega = 700$ kg/m^3

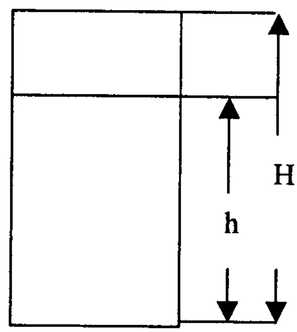
$\theta = 30^\circ$ (grain to grain)

$\mu = 0.42$ (grain to wall)

Testing

(i) h > D $\Rightarrow$ Deep bin

(ii) h/D = 15.24/1.82 = 8.37



$$0.75/\mu K = \frac{0.75}{0.42 x 0.33} = 5.41$$

8.37 > 5.41

$\Rightarrow$ Deep bin

$\Rightarrow$ Janssen equation can be applied.

(a) R = D/4 = 1.82/4 = 0.455

$$P_L = \frac{WR}{\mu'}\left(1 - e^{\frac{-\mu kh}{R}}\right)$$

$$\Rightarrow P_L = \frac{700 \; x\, 0.455}{0.42}\left(1 - e^{-\frac{0.42 \; x\, 0.33 \; x\, 15.24}{0.455}}\right) = 751 \text{ kg/m}^2$$

(b) $\quad P_V = P_L/K = \dfrac{7.51}{0.33} = 2275.8 \text{ kg/m}^2$ (Ans)

(22) Experimental results on equilibrium moisture contents (M_e) of wheat at corresponding relative humidity values have been plotted in the linearised from (Y = mX + C) to obtain constant of the Henderson equation as mentioned below:

log [-1n(1-RH)] = n log (M_e) + log (CT)

The intercept is estimated to be – 4.025 at T = 303 K. The moisture content of wheat found to be 18.9 % (dry basis) under an equilibrium condition of 50 % relative humidity and 30°C. What would be the value of M_e for wheat stored at 70 % relative humidity and 40°C ?

Ans:

log [-ln (1-RH)] = n log (M_e) + log (CT)

This equation represents a form of Henderson's equation

At T = 303°K, intercept = – 4.025
When RH = 50 %, T = 30°C ⇒M_e = 18.9 % (db)
It is important to note that the magnitude of the intercept, "C" = 4.025 (at 303° K or 30° C)
we know $1 - RH = e^{-CT M_e^n}$

1st condition

$\Rightarrow 1 - 0.5 = e^{-4.025 \times 305 \times 18.9^n}$

Taking ln of both sides

⇒ $0.693 = 4.025 \times 303 \times 18.9^n$

⇒ $18.9^n = 5.683 \times 10^{-4}$

⇒ n = -2.54

2nd condition

$1 - 0.7 = e^{-4.025 \times 313 \times M_e^{-2.54}}$

Taking ln of both the sides

⇒ $M_e^{-2.54} = 9.55 \times 10^{-4}$

⇒ M_e = 15.45 % (Ans)

Note: Increasing temperature equilibrium moisture content decreases

(23) Saturated stream at 205 kPa (absolute) is used as heating medium for a milk pasteurizer. A tube, 50 mm OD and 30 mm ID is carrying steam at a flow rate of 2 kg/s. In order reduce heat loss from this tube surface, it has been insulated with 60 mm thick silica foam having a thermal conductivity of 0.055 W/m-K. If the ambient temperature is 30°C, calculate the heat loss per metre length of this insulated tube. Neglect the resistance of tube wall for heat transfer.

Ans:

OD = 50 mm, ID = 30 mm, m = 2kg/s, $K_i = K_2$ = 0.055 W/m-k
r_1 = 0.015 m, T_3 = 30°C, r_2 = 0.025 m, r_3 = 0.025 + 0.06 = 0.085 m
P = 205 kPa (abs) ⇒ T_1 = 121°C (from steam table)

$$\frac{Q}{2\pi L} = \frac{T_1 - T_2}{\frac{1}{K_1} ln\left(\frac{r_2}{r_1}\right)}$$

$$\Rightarrow Q = \frac{2\pi L(T_1 - T_3)}{\frac{1}{K_1} ln\left(\frac{r_2}{r_1}\right) + \frac{1}{K_2} ln\left(\frac{r_3}{r_2}\right)}$$

Heat resistance of tube wall is neglected⇒ First term of denominator = 0

$$\Rightarrow \frac{Q}{L} = \frac{2\pi(121-30)}{\frac{1}{0.055} ln\left(\frac{0.085}{0.025}\right)} = 25.41 \text{ W/m} \qquad \text{(Ans)}$$

1998

(1) In a nozzle testing experiment, hydraulic nozzles are fixed at a height of 400 mm above the ground level and a pressure of 275 kPa is maintained. The pressure is then decreased by one-fourth. Compute the percentage change in the flow rate of the nozzle at a spray angle of 60°

Ans:

P_1 = 275 KPa,

P_2 = decreasing pressure (P_1) by ¼ = ¾ P_1= ¾ x 275 = 206.25 kPa

$$\frac{V_1}{V_2} = \frac{Q_1}{Q_2} = \sqrt{\frac{P_1}{P_2}}$$

$$\Rightarrow Q_2 = Q_1 \text{ x } \sqrt{\frac{P_2}{P_1}} = Q_1 \times \sqrt{\frac{206.25}{275}} = 0.86\, Q_1$$

$$\Rightarrow \text{Percent change} = \frac{Q_2 - Q_1}{Q_1} = \frac{0.86Q_1 - Q_1}{Q_1} = 14\ \%\ \text{(Ans)}$$

(2) In a tractor the noise measured at the operator's ear level and the bystander's position are found to be 84 dBA and 76 dBA, respectively. What would be the corresponding RMS values in N/m^2 at these positions? If the sound pressure is increased four times, determine the resulting sound pressure in decibels.

Ans:

$$\text{(i) BPL} = 20 \log \frac{P}{0.00002}$$

$$\Rightarrow 84 = 20 \log \frac{P}{0.00002}$$

$\Rightarrow P = 0.3169\ N/m^2$

Again, $76 = 20 \log \dfrac{P}{0.00002}$

$\Rightarrow P = 0.126\ N/m^2$

(ii) If the sound pressure is increased 4 times

$dB_1 = 20 \log (P/P_0)$ and $dB_2 = 20 \log (4P/P_0)$

$dB_1 - dB_2 = 20 [\log (P/P_0) - \log (4P/P_0]$

$$= 20 \log \left(\frac{P/P_0}{4P/P_0} \right) = 20 \log \left(\frac{1}{4} \right) = -12\ dB$$

$\Rightarrow dB_2 - dB_1 = 12\ dB$

Thus resulting SPL is increased by 12 decibel (Ans)

(3) A centrifugal pump works against static suction and delivery heads of 5 m and 10 m, respectively, and yields a discharge of 25 l/s. The lengths of suction and delivery pipes are 10m and 50m; respectively and the corresponding diameters are 125 mm and 100 mm . The suction pipe is fitted with a foot valve and delivery pipe is fitted with a 90° long radius elbow. Friction factor for head-loss in pipes equals 0.028 and coefficient k for 90° long radius elbow equals 1.5. Calculate the horsepower of the pump if overall efficiency is 45 %.

Ans:

$H_{ss} = 5m$, $H_{sd} = 10m, Q = 25l/s,$

$L_s = 10m, L_d = 50m, D_s = 0.125m, D_d = 0.1m$

Suction side pipe

$H_{vs} = V_s^2/2g = (2.03)^2/2\times 9.81 = 0.21m$

$$V_s = \frac{Q}{A_s} = \frac{25 \times 10^{-3}}{\frac{\pi}{4}(0.125)^2} = 2.03 \frac{m}{\sec}$$

$$H_{fs} = \frac{4f\,L_s\,V_s^2}{D_s\ 2g} = \frac{0.028 \times 10 \times (2.03)^2}{0.125 \times 2 \times 9.81} = 0.47m$$

Discharge side pipe

$V_d = Q/A_d = 25\times10^{-3}/(\pi/4)(0.1)^2 = 3.18m/s$

$$H_{fd} = \frac{4f\,L_d\,V_d^2}{D_d 2g} = \frac{0.028 \times 50 \times (3.18)^2}{0.1 \times 2 \times 9.81} = 7.23m$$

$$H_{Ld} = k.\frac{v_d^{\,2}}{2g} = 1.5 \times \frac{(3.18)^2}{2 \times 9.81} = 0.77m$$

$$H_{Vd} = \frac{v_d^{\,2}}{2g} = 0.515m$$

$H_s = H_{ss} + H_{fs} + H_{Ls} + H_v = 6.68m$
$H_d = H_{sd} + H_{fd} + H_{ld} + H_v = 18.515m$
$H = H_s + H_d = 25.195m$

Second Method to calculate H

$H_{static} = H_{ss} + H_{sd} = 5+10 = 15m$
H_L = all head losses including H_f and excluding H_v
$= (0.47+1) + (7.23+0.77) = 9.47$
$H_m = H_{static} + H_L = 15+9.47 = 24.47m$
$H = H_m + H_v = H_m + (H_{vd} - H_{vs}) = 22.47 + (0.515-0.21) = 24.77$ m

$$HP = \frac{QH\gamma}{E} = \frac{25 \times 10^{-3} \times 25.195 \times 9.81 \times 1000}{746 \times 0.45} = 18.4hp \qquad \text{(Ans)}$$

(4) A thick-walled tube of stainless steel (A) having k = 16 w/m-K with dimensions of 0.0254 m ID and 0.0508 m OD is covered with a 0.0254 m layer of asbestos (B) insulation, k = 0.25 w/m-K. The inside wall temperature of the pipe is 150° C and the outside surface of the insulation is at 30° C. For 1 m length of the pipe calculate the heat loss.

Ans:

$K_1 = 16$ w/m-k, $K_2 = 0.25$ w/m-k, $T_1 = 150°C$, $T_3 = 30°C$
$D_1 = 0.0254$ m $\Rightarrow r_i = r_1 = 0.0127$ m
$D_0 = 0.0508$ m $\Rightarrow r_0 = r_2 = 0.0254$ m
Insulation = 0.0254m $\Rightarrow r_3 = 0.0254 + 0.0254 = 0.0508$ m

$$Q = \frac{2\pi L(T_1 - T_3)}{\frac{1}{K_1} ln\frac{r_2}{r_2} + \frac{1}{k_2} ln\frac{r_3}{r_2}}$$

$$= \frac{2\pi \times 1 \times 120}{\frac{1}{16} ln\left(\frac{0.0254}{0.0127}\right) + \frac{1}{0.25} ln\left(\frac{0.0508}{0.0254}\right)} = \frac{753.98}{2.792} = 270 \text{ w/m} \qquad \text{(Ans)}$$

(5) Goryachkin in his drum theory assumed that the stroke of the rasp-bar against the grain layer is inelastic. Using this theory show that the critical angular speed (ω_c) of a rasp-bar type threshing drum of radius R is given by

$\omega_c = 8.65\sqrt{\dfrac{P(1-f)}{m' R^2}}$, where

P represents the rated horsepower output, f is the coefficient of materials rubbing in the working slit and m is mass of material delivered through the concave of the drum in one second.

Ans:

$$F = \frac{\Delta m}{\Delta t} \times V + f F \qquad (1)$$

where

F = Total force

$\dfrac{\Delta m}{\Delta t}$ = m'= mass of material delivered through the concave of the drum/second

f = coefficient of materials rubbing in the working slit

V = speed of drum

$\therefore$ F = m' V + f F

$\Rightarrow$ F- f F = m' V

$$\Rightarrow F = m' \frac{V}{1-f} \qquad (2)$$

$$V = \omega R \qquad (3)$$

$$\text{Rated HP output, } P = \frac{FV}{75} \qquad (4)$$

Substituting equations (2) and (3) in (4)

$$\therefore P = \frac{m' V^2}{(1-f)\times 75} = \frac{m' (\omega_c R)^2}{(1-f)x75}$$

$\therefore$ Critical angular speed, ω_c of rasp-bar type threshing drum of radius 'R' is given by

$$\omega_c = \sqrt{\frac{P(1-f)\times 75}{m' R^2}} = 8.65\sqrt{\frac{P(1-f)}{m' R^2}} \qquad \text{(proved)}$$

(6) In hydraulic power transmission systems, motors convert fluid power to a rotary mechanical output. In such a system, the output torque from the motor is 90 N-m at 255 rpm. The required flow rate is 30 l/min, the motor displacement is 0.105 per revolution and the motor overall efficiency is 75 %. The total pressure loss in lines, fittings, valves etc., are negligible. Calculate the volumetric efficiency of the motor and the required pressure drop across the motor.

Ans:

The governing equation of motor is represented by

$$\frac{DN}{Q_{in}} \times \eta_T = \eta_V \times \eta_T = \eta_{0a} = \frac{2\pi NT}{\Delta p(Q_{in})}$$

Required pressure drop across the motor, $\Delta P = \dfrac{2\pi NT}{Q_{in} n_{0a}}$

$$= \frac{2\pi \times \left(\frac{255}{60}\right) \times 90}{\frac{30 \times 10^{-3}}{60} \times 0.75} = 6.4 \text{MPa}$$

Volumetric efficiency of the motor, $\eta_v = \dfrac{DN}{Q_{in}} = \dfrac{0.105 \times 10^{-3} \times \frac{255}{60}}{\frac{30}{60} \times 10^{-3}}$

$= 0.8925 = 89.25\%$ (Ans)

(7) The torque output, T_α of an engine is given by $T_\alpha = 18000 + 8400 \sin 2\alpha - 4600 \cos 2\alpha$ N-m, where α is the angle moved by the crank from inner dead centre. If the resisting torque is constant, find the horse-power developed by the engine at 200 rpm and the excess energy for designing the flywheel at $\alpha = \pi/4$.

Ans:

$T_\alpha = 18000 + 8400 \text{ Sin } 2\alpha - 4600 \cos 2\alpha$ N m

Average Torque = $T_{ave} = \dfrac{1}{2\pi} \int_0^{2\pi} T_\alpha \, d\alpha$

$$= \frac{1}{2\pi} \int_0^{2\pi} (18000 + 8400 \text{ Sin } 2\alpha - 4600 \cos 2\alpha)\, d\alpha$$

$$= \frac{1}{2\pi}\left[1800\alpha - \frac{8400}{2}\cos 2\alpha - \frac{4600}{2}\text{Sin}2\alpha\right]_0^{2\pi}$$

$$= \frac{1}{2\pi}(18000 \text{ x } 2\pi) = 18000 \text{ N.m}$$

= Change in torque at any given instant

$\therefore$ Horse-power developed by the engine, P =2πNT

$$= 2\pi \text{ x } \frac{200}{60} \times \frac{18000}{1000} = 377 \text{ kW}$$

$\therefore$ $\alpha = \pi/4$, T = 18000 + 8400 sin (2 x π/4)- 4600 cos (2 x π/4)
= 26,400 Joule

$\therefore$ Excess energy = 26400 – 18000 = 8400 J = 8.4 kJ (Ans)

(8) A MF – 1035 tractor operate at 2000 rpm and uses 16.5 litres of fuel per hour. What is the average volume in cubic millimetres of the individual injection ? Assume a compression ratio of 16.7:1 and the engine displacement as 4520 x 10^{-3} liter . What is the ratio of the clearance volume to the volume of an injection ?

Ans:

Engine displacement ,Q_e = 4520 x 10^{-3} lit

Volumetric fuel consumption rate, 16.5 lit/hr

(i) MF 1035 tractor and all other renowned tractors are 4-stroked diesel engine with 3 cylinders except Eicher which has 2 cylinders

Now 16.5 lit/hr = LA N/2 n

$$\Rightarrow \frac{16.5}{60} \times 10^{-3} \frac{\text{m}^3}{\text{min}} = (\text{LA})\left(\frac{2000}{2}\right) \times 3$$

$\Rightarrow$ LA = 9.16 x 10^{-8} m^3 = 91.6 mm^3

(ii) Engine displacement,Q_e = (LA) n N/2 = (V_S) n N/2 = 4520 x 10^{-3} lit

$$\Rightarrow V_s = \frac{4.52 \times 10^{-3} \times 2}{3 \times 2000} = 1.5067 \text{ x } 10^{-3} \text{ m}^3 \text{ x } 10^{-3} = 1.5067 \text{ x } 10^{-6} \text{ m}^3$$

$$r = \frac{V_1}{V_2} = \frac{V_c + V_s}{V_c} = 1 + \frac{V_s}{V_c} = 16.7$$

$$\Rightarrow 1 + \frac{1.5067 \times 10^{-6}}{V_c} = 16.7$$

$\Rightarrow V_c$ = 9.596 x 10^{-8} m^3 = 95.966 mm^3

$\Rightarrow V_c$/LA = 95.966/91.6 = 1.047 (Ans)

(9) A governor is said to be stable when for each speed within the working range, there is only one radius of rotation of the governor balls at which the governor is in equilibrium. What would be the nature of the controlling curve ? If the balls in such a spring-controlled governor are 350 mm apart at a controlling force of 1200 N and 200 mm apart when it is 600 N. At what speed will the governor run when the balls are 250 mm apart if each of them has a mass of 6 kg.

Ans:

The nature of the controlling curve is straight line (Spring-controlled governor.)

First Method

Distance between balls	Rotational radius	At controlling force
$r_1 = 350$ mm	$\Rightarrow r_1 = 175$	$F_1 = 1200$ N
$r_2 = 200$ mm	$\Rightarrow r_2 = 100$	$F_2 = 600$ N

$r = 250/2 = 125$

$$\frac{F - F_2}{F_1 - F_2} = \frac{r - r_2}{r_1 - r_2}$$

$$\Rightarrow F = F_2 + (F_1 - F_2)\left(\frac{r - r_2}{r_1 - r_2}\right)$$

$$= 600 + (1200 - 600)\left(\frac{125 - 100}{350/2 - 100}\right) = 800N$$

$F = m\,\omega^2 r$

$$\Rightarrow F = m\left(\frac{2\pi N}{60}\right)^2 r$$

$$\Rightarrow 800\frac{kgm}{s^2} = 6kg\left(\frac{2\pi N}{60}\right)^2 \times \frac{0.25}{2}$$

$\Rightarrow N = 311.87$ rpm (Ans)

Second Method:

$F = ar + b$

$600 = 0.1a + b$

$1200 = 0.175\,a + b$

$600 = 0.075\,r$

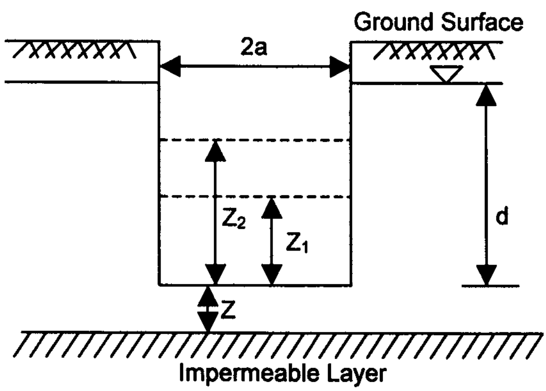
$\Rightarrow a = 8000$

$\Rightarrow b = 600 - 8000/10 = -200$

$\therefore$ F = 8000 x 0.125 – 200 =800 N
(b) F = mrw^2 = mr $4\pi^2 N^2$
$\Rightarrow$ 800 N = 6 x 0.125 x $4\pi^2$ x N^2
$\Rightarrow$ N = 5.19 r/s = 311.4 rpm (Ans)

(10) In a soil where high water table condition (equilibrium water table depth 600 mm below ground level) exists, one 125 mm diameter outer hole is drilled to a depth of 1 m below the ground level. At 25 m below the ground level an impermeable bed is located. If the water table rises from 120 mm to 200 mm in 25 seconds, determine the hydraulic conductivity of the soil. Assuming constant hydraulic conductivity calculate the time required for the water level to rise from 1.0m to 1.5 m level.

Ans:
Diameter of auger hole, 2a = 125 mm, r = 0.0625 m
water table below ground level = 600 mm = 0.6 m
$\Rightarrow$ d = 1 – 0.6 = 0.4 m
z_1 = 0.12 m, Z_2 = 0.2 m



$$\text{(i) } K = \frac{d}{(2d+a)}\frac{a^2}{(0.19t)}\ln\left(\frac{d-Z_1}{d-Z_2}\right)$$

$$\Rightarrow K = \frac{0.4}{(2\times0.4+0.0625)}\frac{(0.0625)^2}{(0.19\times25)}ln\left(\frac{0.4-0.12}{0.4-0.2}\right)$$

=1.28 x 10^{-4} m/s = 11.087 m/day

First method:
Again Z_1' = 1 m, Z_2' = 1.5 m

Assuming K constant

$$\frac{1}{t_2}\times ln\left(\frac{d'-Z_1'}{d'-Z_2'}\right)\times\frac{1}{2}=\frac{1}{t_1}\times ln\left(\frac{d-Z_1}{d-Z_2}\right)\times\frac{0.4}{(2\times 4+0.0625)}$$

$$\Rightarrow\frac{1}{t_2}\times\frac{1}{2}ln\left(\frac{1.9-1}{1.9-1.5}\right)\times\frac{1}{25}ln\left(\frac{0.4-0.12}{0.4-0.2}\right)\times\frac{0.4}{(0.8+0.0625)}$$

$\Rightarrow t_2 = 65$ sec (Ans)

Second method:

It is important to understand that it is a case of penetration up to impermeable layer. Thus neglecting 'r' from denominator

d' = d + z = 0.4 + 1.5 = 1.9 m

$$K=\frac{1}{2}\left[\frac{r^2}{0.19t}\right]\ln\left(\frac{d'-Z_1'}{d'-Z_2'}\right)$$

$$\Rightarrow 1.28\times10^{-4}=\frac{1}{2}\left(\frac{0.0625^2}{0.19\times t}\right)\ln\left(\frac{0.9-1}{1.9-1.5}\right)$$

$\Rightarrow t_2 = 65$ sec (Ans)

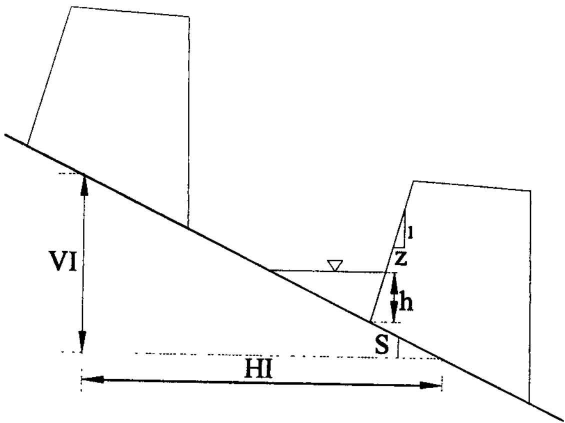
(11) Design the dimensions of a weir used to discharge excess runoff from a contour bund. It is given that the intensity of rainfall for the time of concentration for a ten year return period is 114 mm/h, and constant infiltration rate is 25 mm/h. Land slope = 25 %, top width of bund = 500 mm, height of bund = 600 mm, height of weir crest above ground level = 300 mm, side slope of the bund = 2.5:1, vertical interval of bunds = 750 mm and length of bund = 400 m.

Ans:

I = 114 mm/hr, f = 25 mm/hr, S = 2.5 %

H = 600 mm Z = 2.5 :1, VI = 750 mm, L_B = 400 mm

Weir crest above ground level = 300 mm = H, T = 500 mm



S/100 = VI/HI

$$\Rightarrow HI = \frac{100 \times VI}{S} = \frac{100 \times 750}{2.5} = 30000mm = 30m$$

A = HI x L_B = 30 x 400 = 12000 m^2

R = (I-f)A = (114-25)/1000 x12000 = 1068m^3/hr

$$S = A_w \times L_B = h^2/2\ (Z + 100/S) \times L_B = \frac{0.3^2}{2}\left(2.5 + \frac{100}{2.5}\right) \times 400 = 765\ m^3$$

Excess runoff = R_e = R – S = 1068 – 765 – 765 = 303 m^3

$\Rightarrow 1068m^3 \equiv 1hr$

$$\Rightarrow 303m^3 \equiv \frac{303}{1068} = 0.28\ hr = t$$

$$Q,\ discharge = \frac{R - S}{t} = \frac{303}{0.28} = 1068\ m^3/hr$$

Again assuming rectangular weir is used for discharge,

Q = 1.77 L $H^{3/2}$ = 1.77 x L x $(0.3)^{3/2}$ = 1068/3600 m^3/s

$\Rightarrow$ L = 1.02 m

Adding free board of 15 % of 30 cm to crest height,

total depth of weir = 30 + 15 x 30 = 34.5 cm (Ans)

(12) For irrigation of sugarcane crop furrows are laid 1.0 m apart at a slope of 0.2 %. Maximum size of the non-erosive stream is used for irrigation. Area covered by each furrow is 75 m^2. The stream reached the lower end of the furrow in 30 minutes and the size of the stream was reduced to half and continued for another 30

minutes and the size of the stream was reduced to half. Calculate the average depth of irrigation.

Ans:

S = 10 m, S = 0.2 %, t_1 = 30 min, t_2 = 30 min

A = 75 m^2/furrow, Q_2 = 1.5 l/s

$$Q_1 = \frac{0.6}{S(\%)} = \frac{0.6}{0.2} = 3 \text{ lit/s}$$

Average depth = d = $d_1 + d_2$

$$\Rightarrow d = \frac{Qt_1}{A_1} + \frac{Q_2t_2}{A_2}$$

$$\Rightarrow d = \frac{\left(3\frac{m^3}{s}\times 30\times 60 + 3\times\frac{1}{2}\times 30\times 60\right)^{-3} 10}{75} = 10.8 \text{ cm} \qquad \text{(Ans)}$$

(13) For failure of the downstream slope of earth dam, when does the most critical condition occur ? Write the formula for factor of safety and explain the terms. The down stream section of a dam drawn to a scale of 1 cm = 5 m and from the critical slip circle the following data were obtained :

Area of N rectangle = 20 cm^2, Area of T rectangle = 5 cm^2
Area of U rectangle =7.5 cm^2, Length of area = 15 cm
The effective angle of shear resistance is 25 and cohesion is 0.2 kgf/cm^2. Unit weight of soil is 2000 kgf/m^3 Calculate the factor of safety of the slope.

Ans:

Critical condition for failure of downstream slope of earth dam occurs when the reservoir is full and percolation rate is maximum.i.e. during steady seepage.

Scale of 1 cm = 5 m(given), 1 kgf = 9.81 N

A_N = 20 cm^2= Area of N rectangle

A_T = 5 cm^2 = Area of T rectangle

A_U = 7.5 cm^2 = Area of U rectangle

Length of arc = 15 cm

Angle of shear resistance, $\phi = 25^\circ$

$$\text{Cohesion} = 0.2 \text{ kgf/cm}^2 \times \left[\frac{9.81\times 10^4}{1000}\right] = 19.62 \text{ kN/m}^2$$

γ_{soil} = 2000 kgf/m^3 = 19.62 kN/m^3

$$\sum N(kN) = A_N(cm^2).x^2 \times Y_{soil} = 20\times5^2\times19.62 = 9810kN$$
$$\sum T(kN) = A_T x^2 y = 5\times5^2\times19.6 = 2450kN$$
$$\sum U = A_U x^2 y = 7.5\times5^2\times19.6 = 3675kN$$

L = total length of arc = 15 x 5 = 75m^2, C= 19.62 kN/m^2

$$F = \frac{cL+\tan\phi\sum(N-U)}{\sum T}$$

$$= \frac{19.62\times75\times\tan25(9810-3675)}{2450} = 1.768 \qquad \text{(Ans)}$$

Note: Critical condition for failure of upstream slope of earth dam occurs when reservoir is suddenly emptied without allowing any appreciable change in the water level within the saturated mass of the soil i.e. during sudden draw-down

(14) Define leaching requirement of soil. Give the mathematical expression for leaching requirement. A soil has a field capacity of 25 %, permanent wilting point of 11 % and apparent specific gravity of 1.6. Irrigation is applied after depletion of 40 % of the available moisture to a crop with root zone depth of 600 mm. Electrical conductivity of the saturation extract of the soil is 10 mmho/cm and that of the irrigation water is 2.5 mmho/cm. Determine the leaching requirement and the total depth of irrigation.

Ans:

FC = 25 %, EC_e = 10 mmhos/cm, EC_i = 2.5 mmhos/cm, PWP = 11 %

ρ = 1.6, D = 0.6 m, d_{bi} = 0.6 dfc, d = 0.4 d_{fc}

Leaching requirement is given by the following formula:

$$LR = \frac{d_d}{d_i} = \frac{d_i - d_c}{d_i} = \frac{EC_i}{EC_d} = \frac{EC_i}{2\times EC_e} = \frac{C_i}{C_d}$$

$$LR = \frac{2.5}{2\times10} = 0.125$$

= 12.5 % of the water depth to be passed through the root zone

$$\text{Available moisture} = \left(\frac{M_{fc}-M_{pwp}}{100}\right)\times\rho\times D$$

$$= \left(\frac{25-11}{100}\right) \text{x } 1.6 \text{ x } 60 = 13.44 \text{ cm}$$

$\therefore$ d = 40 % of available moisture = 0.4 x 13.44 = 5.376 cm
$\therefore$ LR = (12.5/100) x 5.376 = 0.672 cm
$\therefore$ Total depth of irrigation = 5.376 + 0.672 = 6.048 cm (Ans)

(15) Wheat crop is grown in an area of 3 ha. The crop is irrigated at IW/CPE ratio of 0.8 and requires an interval of 20 days. The average pan evaporation during the period is observed to be 2.5 mm/day. The irrigation source located at a distance of 300 m is a confined well (diameter 10 cm). The thickness of the aquifer is 10 m and hydraulic conductivity is 4 cm/min. Initial piezometric level is 4 m below the pump level and during pumping it should be restricted to 7 m. The pump has to work against a total head of 10 m at an overall efficiency of 50 %. Compute the cost of electricity consumed for one irrigation assuming the unit electricity charge as Rs 2.00. The radius of influence is 300 m and conveyance efficiency of the channel is 75 %.

Ans:
A = 3 ha, E_c= 75 %, Irrigation Interval = 20 days
Pan evaporation = 2.5 mm/day (Average during that period)
R = 300 m, D = 0.1 m (Confined well) $\Rightarrow r_\omega = 0.05$ m
Aquifer thickness = b = 10 m, K = 4 cm/min
H = 10m, E_{0a} = 50 % (pump)
Initial piezometric level is 4 m below the pump level
Thus, Initially, S = 4 m and during pumping, S=7 m

$$Q_r = \frac{2\pi kbs}{\ln(R/r_w)} = \frac{2\pi \times \frac{4}{100\times 60} \times 10 \times 3}{\ln(300/0.05)} = 0.0144 \text{ m}^3/\text{s}$$

$$\text{Conveyance efficiency} = \frac{W_d}{W_r} = \frac{Q_d}{Q_r} = 0.75$$

$Q_d = E_c \times Q_r$ = 0.75 x 0.0144 = 0.011 m^3/s = 39 m^3/hr
IW/CPE i.e. CU / Cumulative pan evaporation = 0.8
$\Rightarrow$ CU = 0.8 x Pan evaporation = 0.8 x 2.5 = 2 mm/day
For 20 days, CU = 2 x 20 = 40 mm = d
Q_d .t = Ad
$\Rightarrow$ 39 m^3/hr x t (hr) = 3 x 10^4 m^2 x 40/1000 m
$\Rightarrow$ t = 30.77 hr
$E_p = n_{oa}$ = WHP/SHP
$\Rightarrow$ 0.5 = γQH/SHP

$$\Rightarrow \text{SHP} = \frac{\gamma QH}{0.5} = \frac{1000 \times 0.0144 \times 10 \times 9.81}{7.46 \times 0.5} = 3.78HP$$

Units of electricity consumed = kW hrs of electricity consumed=(3.78x0.746)x30.77= 86.76 kW hrs
Cost of electricity =86.76x2= 173.5 rupees (Ans)

(16) Overall heat transfer coefficient of a continuous ice cream freezer is 600 W/m^2-K. The temperature difference between ice cream mix and evaporating refrigeration is 25 K. Speed of two scraper blades inside the freezer is 150 rpm. If density of ice is 917 kg/m^3 and latent heat of crystallization is 334 kJ/kg, calculate the maximum thickness of ice layer.

Ans:
$U = 600$ W/m^2-K $= h$, $\Delta T = 25K = T_f - T_a$
N = 150 rpm (for 2 blade)
$\delta = 917$ kg/m^3, $\lambda_c = \lambda_F = 334$ KJ/kg

First method

$$\delta = \frac{U(\Delta T)t}{\delta\lambda} = \frac{600x25x0.2}{917x334x1000} = 9.79x10^{-6}\text{m}$$

Second method

Time for 1 revolution, t = 60/150 sec = 0.4 sec (for 2 blades)
As 2 blades used, time interval between 2 scalping operations= 0.4/2 = 0.2 sec.

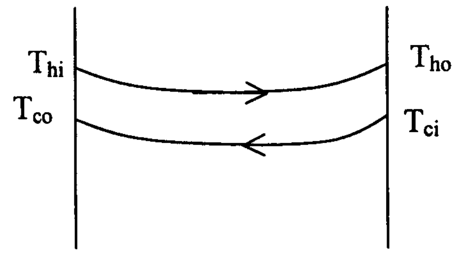
$$t = \frac{\delta\lambda_F}{T_f - T_e}\left(\frac{a}{2h} + \frac{a^2}{8k}\right)$$

$$\Rightarrow t = \frac{\delta\lambda_F}{T_f - T_e}\frac{a}{h}$$

$$\Rightarrow a = \frac{t\left(T_f - T_e\right)xh}{\delta\lambda_F} = \frac{0.2(25)x600}{917x334} = 9.79 \text{ x } 10^{-6}\text{ m} \qquad \text{(Ans)}$$

(17) Water at the rate of 68 kg/min is heated from 35 to 75° C by an oil having a specific heat of 1. 9 kJ/kg K. The fluids are used in a counterflow double pipe heat exchanger, and the oil enters the exchanger at 110° C and leaves at 75° C. The overall heat transfer coefficient is 320 W/m^2-K. Calculate the heat exchanger area, if specific heat of water is 4.18 kJ/kg K.

Ans:



$C_{pc} = 4.18$ KJ/kg-K $\qquad C_{ph} = 1.9$ KJ/kg-K
$T_{ci} = 35°C \qquad T_{ho} = 75°C$
$T_{hi} = 110°C \qquad T_{co} = 75°C$

For counterflow type heat exchanger

$\theta_1 = T_{hi} - T_{co} = 35°C$

$\theta_2 = T_{ho} - T_{ci} = 40°C$

$$\Delta T_m = \frac{40-35}{\ln\left(\frac{40}{35}\right)} = 37.44°C$$

$$Q = M_c\, C_{pc}\, \Delta T_m = \frac{68}{50} \times 4.18 x 40 = 189.493 \text{ kW}$$

$$Q = AU\, \Delta T_m$$

$$\Rightarrow A = \frac{Q}{U\Delta T_m} = \frac{189493}{320 \times 37.44} = 15.816 m^2 \qquad \text{(Ans)}$$

(18) A single effect falling film evaporator runs on a 10 K temperature difference between steam and evaporating liquid. Evaporation takes place at 60° C. The overall heat transfer coefficient is 2200 W/m^2 K. The length and diameter of the tube are 6 m and 0.032 m, respectively. Viscosity of vapur at 60° C is 11.15 x 10-6 Pa-s. Calculate a. Vapour velocity, b. Reynold's number and c. Pressure drop due to vapor flow.

Ans:

$\Delta T = 10°K \qquad T_S = 60°C$ = evaporation temp
$U = 2200$ w/m^2-k $\qquad L = 6m$
$\lambda = 2609.6$ kJ/kg $\qquad D = 0.032$ m
$V_H = 7.671$ m^3/kg $\qquad \mu = 1.15 \times 10^{-6}$ Pa.s

$Q = AU\Delta T = (\pi DL)\, U\Delta T = (\pi \times 0.032 \times 6) \times 2200 \times 10 = 13.27$ kW

$\dot{V} = \dot{m} \times V_H$ = Q/λ x V_H = 13270/2609.6 x 7.671 = 0.039 m³/s

$$\text{Vapour velocity}, V = \frac{\dot{V}}{A} = \frac{0.039}{\frac{\pi}{4}(0.032)^2} = 48.5 \text{ m/s}$$

$$\text{Re} = \frac{\rho D V}{\mu} = \frac{GD}{\mu} = \left(\frac{\dot{m}}{A}\right)\frac{D}{\mu} = \left(\frac{Q}{\lambda A}\right)\frac{D}{\mu}$$

$$\therefore \text{Re} = \frac{13.27x0.032}{2609.6 \times \frac{\pi}{4}(0.032)^2 \times 1.15 \times 10^{-6}} = 175937$$

Other formula to calculate *Re*

$$\text{Re} = \frac{DV}{V_H \mu} = 177{,}341$$

As Re > 2100, flow is turbulent

$$\text{(c) f} = \frac{0.079}{\text{Re}^{0.25}} = \frac{0.079}{(175937)^{0.25}} = 0.0039$$

$$\text{Pressure drop due to flow, } \Delta P = h_f \rho g = \frac{4fLV^2}{2gD}\rho g \; 444 \text{ N/m}^2$$

$$= \frac{4 \times 0.0039 \times 6x(48.5)^2}{2 \times 0.032 \times 7.671} = \quad \text{(Ans)}$$

(19) In drying of certain vegetables the dry bulb and wet bulb temperatures of the air used are 65°C and 36°C respectively. The saturation humidity is 0.035 kg H_2O/ kg of dry air . The humidity ratio of air is 0.023 kg H_2O/ kg of dry air . If molecular weight of air is 28.97 kg / kg mole then obtain the heat and mass transfer coefficients. The constant rate of moisture evaporation is 1.5 kg H_2O/m^2-h.

Ans:

Dry bulb temperature of the air, T = 65°C
Wet bulb temperature of the air, T_w = 36°C
H_s = 0.035 kg H_{20} /kg dry air = H_w = saturation humidity
H = 0.023 kg H_2O /kg dry air = Humidity ratio
M_b = 28.97 kg/kg mole = MM of air

$R_c = 1.5$ kg H_2o/m^2-h

Calculation of heat transfer coefficient, h

Rate of water removal, $\frac{dw_w}{dt} = \frac{q}{\lambda_w} = \frac{hA(T-T_w)}{\lambda_w}$

Drying rate $= \frac{\frac{dw_w}{dt}}{A} = \frac{h(T-T_w)}{\lambda_w}$

$$\Rightarrow 1.5\frac{kg}{m^2-h} = h\frac{(65-36)}{2257}$$

$$\Rightarrow h = 116.74\left[\frac{kg}{hr-m^2}\times\frac{kJ}{kg}\times\frac{1}{^oC}\right] = \frac{116.74}{3.6} = 32.428\frac{W}{m^2-^oC}$$

Calculation of mass transfer coefficient, K_y

$\frac{dW_w}{dt} = \frac{q}{\lambda_w} = \frac{(K_y M_B \lambda_W)A(H_w-H)}{\lambda_w}$ = K_y M_B A (H_W – H)

$\therefore$ $R_c = K_y M_B (H_w - H)$

$\Rightarrow$ 1.5 = k_y x 28.97 x (0.035 – 0.023)

$\Rightarrow K_y = 4.314\frac{kg-mole}{m^2-h}$ (Ans)

(21) The air in room is at 26.7°C and a pressure of 101.325 kPa, and contains water vapour with a partial pressure of 2.76 kPa, calculate (a) humidity ratio (b) saturation humidity and (c) relative humidity.

Ans:

T = 26.7°C, P = 101.325 kpa, P_V = 2.76 kPa

From psychrometric chart, At 26.7°C, P_s = 3.5 KPa

(a) H $= 0.622\ \frac{P_v}{P_a} = 0.622\frac{P_v}{P-P_v}$

$$= 0.622\left(\frac{2.76}{101.325-2.76}\right) = 0.0174 \text{ kg/kg}$$

(b) $H_s = 0.622\left(\frac{Ps}{P-Ps}\right)$

$$=0.622\left(\frac{3.5}{101.3-3.5}\right) = 0.222\frac{Kg\ of\ water\ vapour}{kg\ of\ dry\ air}$$

(c) $\phi = \frac{P_v}{P_s} = \frac{2.76}{3.5} = 0.7885$ (Ans)

(20) One metric ton of granular material is to be ground in a hammer mill with a Bond's energy constant of "0.05 kWh-$\sqrt{mm}$ /kg. If the geometric mean diameter of the material is 3 mm and 80 % of the ground particles pass through a sieve of 300 μ opening what is the energy required in grinding? Median diameter of the ground particle is 200μ.

Ans:

Geometric mean diameter of the particles, D_f=3mm

Opening size through which 80% of the ground particles pass,

D_p = 300μ, μ= 0.3mm

Bond energy constant =0.05 kWh $\frac{\sqrt{mm}}{kg}$

$$E = \frac{P}{f} = K_b\left[\frac{1}{\sqrt{D_P}} - \frac{1}{\sqrt{D_f}}\right]$$

$$\Rightarrow E = 0.05\ \frac{kWh}{kg}\sqrt{mm}\ \left(\frac{1}{\sqrt{0.3}} - \frac{1}{\sqrt{3}}\right)$$

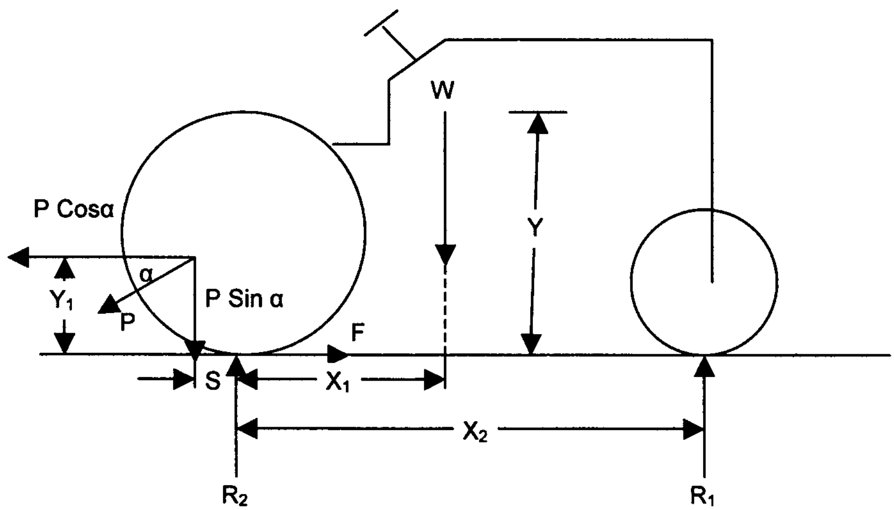
$$\Rightarrow E = 50\frac{kWh}{ton}\sqrt{mm}\ \left(\frac{1}{\sqrt{0.3}} - \frac{1}{\sqrt{3}}\right) = 62.419\ \frac{kWh}{ton}$$ (Ans)

1999

(1) A rear-wheel drive tractor with a total weight of 23 kN has a wheel base of 2100 mm and the centre of gravity is 710 mm ahead of rear axle centre line. The tractor is pulling a level drawbar pull of 15 kN on a concrete surface at a forward speed of 6 km/h and the drawbar height is 485 mm. The axle power is 33.3 kW.

Determine (a) the weight transfer on rear axle, (b) co-efficient of traction, and (c) tractive efficiency.

Ans:



W = 23 kN, V = 1.67 m/s, $Y_1 = 0.485$ m, P = 15 kN ($\alpha = 0$),
$X_1 = 0.71$ m, $X_2 = 2.1$ m, Axle power = 33.3 KW

(a) Weight transfer $= \dfrac{P\cos\alpha . Y_1 + P\sin\alpha . S}{X_2}$

$$= \frac{PY_1}{X_2} = \frac{15 \times 0.485}{2.1} = 3.464 \text{ kN}$$

(b) $R_1 + R_2 = W$ (1)

$WX_1 = PY_1 + R_1 X_2$ (2)

$$R_1 = \frac{WX_1}{X_2} - \frac{PY_1}{X_2}$$

$\Rightarrow R_2 = W - R_1 = W - \dfrac{WX_1}{X_2} + \dfrac{WY_1}{X_2}$ (It thus self includes effect due to weight transfer)

$$\Rightarrow R_2 = \frac{W(X_2 - X_1)}{X_2} + \left(\frac{PY_1}{X_2}\right) = \frac{23(2.1-0.71)}{2.1} + \frac{15\times0.485}{2.1}$$

= 18.688 KN

Note: Here R_2 is known as dynamic load on rear wheel or reaction on rear wheel in working condition

$$\Rightarrow \mu = \frac{P\text{Cos}\alpha}{R_2} = \frac{P}{R_2} = \frac{15}{18.688} = 0.8026$$

(c) Tractive efficiency, $TE = \frac{\text{Drawbar Power}}{\text{Axle power}} = \frac{PV}{\text{Axle power}}$

$$= \frac{15\times1.67}{33.3} = 75.2\%$$ (Ans)

(2) A four-cylinder, four-cycle diesel tractor engine has a cylinder bore of 90 mm and piston stroke of 100 mm. The engine develops 43.5 kW at 2300 rpm when coupled to a dynamometer. At the same speed and with the fuel shut off, the tractor engine required 7.5 kW to motor it. During the test when 43.5 kW was developed, the engine used 15.5 l/h of diesel fuel that contained heat energy of 45 MJ/kg with fuel density of 0.835 kg/l. Determine (a) indicated mean effective pressure and (b) engine thermal efficiency.

Ans:

n = 4, D = 90 cm, L = 100 mm, N = 2300

4-cycle means 4-stroke cycle engine develops 43.5 KW when coupled to a dynamometer

i.e. BHP = 43.5 x 1000/746 = 58 HP

FHP = 7.5 kW = 10 HP

(a) IHP = BHP + FHP

= 58 + 10 = 68 HP = 68 x 0.746 = 51 kW = PLA (N/2).n

$\Rightarrow$ 51x 10^3 kW = [p. x 0.1 x π/4 $(0.09)^2$ x (2300/2 x 60) x 4]

$\Rightarrow$ p = 1045655 N/m^2

(b) Engine thermal efficiency

$$= \frac{641\text{kcal}}{\frac{\text{kg}}{\text{BHP}-\text{hr}} \times \frac{\text{Kcal}}{\text{kg}}} = \frac{641\text{Kcal}}{\frac{0.835\times15.5}{58} \times \frac{45000\ \text{kcal}}{4.2\quad \text{kg}}} = 26.8\%$$ (Ans)

(3) A right-hand disc harrow is operating with disc angles of 15° and 21° respectively for the front and rear gangs. The centres of the two gangs are 2.5m and 4.25m behind a transverse line through the hitch point on the tractor drawbar. The horizontal soil force components are: L_f=3 KN, S_f=2.75 KN, L_r= 3.5 KN, S_r= 4.0 KN, where L_f , L_r are drafts, and S_f and S_r are side drafts of front and rear gangs respectively. Calculate

(a) the amount of offset of the centre of cut with respect to the hitch point

(b) the horizontal pull.

Ans:

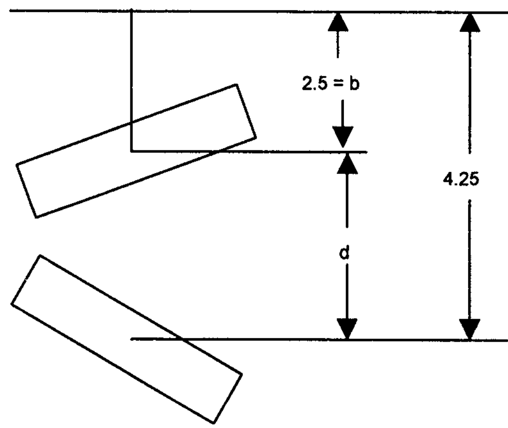
$\theta_f = 15°$, $\theta_r = 21°$,

L_f = 3 kN, L_r = 3.5 KN

S_f = 2.75 kN, S_r = 4 KN

b = 2.5 m, b + d = 4.25 m

$\therefore$ d = 4.25 – 2.5 = 1.75 m



(a) Amount of offset of the centre of cut with respect to the hitch point is given by,

e = b tan θ + (d.S_r/L_r+L_f)

$$= b\,\frac{S_r - S_f}{L_r + L_f} + d\,\frac{S_r}{L_r + L_f} = 2.5\left(\frac{4-2.75}{3+3.5}\right) + 1.75\left(\frac{4}{3+3.5}\right) = 1.557 \text{ m}$$

Note : The centre of the 2 gangs are 2.5 m and 4.25 m behind a transverse line through hitch point

(b) P_x = L_f + L_r = Draft = 3+3.5 = 6.5KN

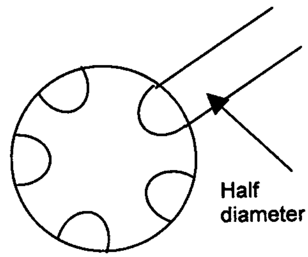
Side draft, P_y = S_r-S_f = 4 - 2.75 = 1.25 KN

Horizontal pull, $P_h = \sqrt{P_x^2 + P_y^2} = \sqrt{6.5^2 + 1.25^2}$ =6.62 KN (Ans)

(4) An animal-drawn 3 x 20 cm wheat seed drill is equipped with a fluted roller type metering mechanism. What will be the exposed length of the fluted roller for each row if the machine is to be calibrated for seed rate of 100 kg/ha assuming there is no slippage

in the ground wheel or in the transmission during field operation? Use : bulk density of seed = 750 kg/m^3, diameter of flute = 9 mm, diameter of ground wheel = 600 mm, number of flutes = 12 and speed ratio of ground wheel to fluted roller = 3.

Ans:



Seed drill width = SZ =3x.2=0.6m
Seed rate =100kg/ha, ρ_{seed}=750 kg/m^3,
Diameter of ground wheel,
D = 600mm = 0.6m
Number of flute = 12,
Flute diameter = 9mm = d = 0.009m
Using seed drill calibration formula

$$\pi DN = L = \frac{10000}{width},$$

where N = Number of revolutions made by the ground wheel
N/N_r= 3, where N_r= Number of revolutions made by the rotor
N = 8842 ⇒N_r = 8842/3 = 2948
Volume of single flute, V={(π/4d^2)xL}/ 2 (here 2 is divided as half diameter is used)
Where L= exposed length of fluted roller (for each row)
Displaced volume swept by flute in 1 revolution i.e. in 12 flute = Vx12
Displacement volume in 2948 rev (in one row) = 12Vx 2848
Volume of seed collected in three row = (100/750)m^3
Volume of seed collected in 1 row = 100/ (750 x 3) m^3

$$\therefore \frac{100}{750\times 3} = \frac{\frac{\pi}{4}d^2 \times L}{2} \text{x } 2948 \text{ x } 12$$

Given, d = 0.009 m ⇒ L = 3.95 cm (Ans)

(5) A hydraulic circuit uses 25 litres of fluid per min. The fluid is supplied by a pump having a fixed displacement of 12.5 cm^3 per revolution driven at 3000 rpm. The pump has a volumetric efficiency of 0.85 and torque efficiency of 0.88. If the system pressure is set at 18 Mpa by the relief valve, calculate (a) the power required to drive the pump and (b) heat generated owing to excess flow passing over the relief valve.

Ans:

Q = 25 lit/min, η_v = 0.85, η_T = 0.88

D = 12.5 cm^3/rev, N = 3000 rpm, P = 18 Mpa

Pump: $\frac{Qout}{DN}\times\eta_T=\eta_v\times n_T=\eta_{aa}=\frac{(\Delta P)Qout}{2\pi NT}$

(a) $Q_{out}=\eta_v$ (DN) = 0.85 (12.5 x 10^{-6} m^3/rev x (300/60) r/s)

= 0.531 lit/sec = 31.1875 l/min

= excess flow rate at Particular condition

Power required to drive the pump, $HP_{in}=\frac{(\Delta P)Qout}{\eta_{oa}}=\frac{(\Delta P)Qout}{\eta_v n_T}$

$$=\frac{18\times10^6\times0.531\times10^{-3}}{0.85\times0.88}\left[\frac{1}{1000}\right]=12.778\ \text{KW}$$

(b) Heat generated owing to excess flow passing over the relief valve = P (ΔQ)

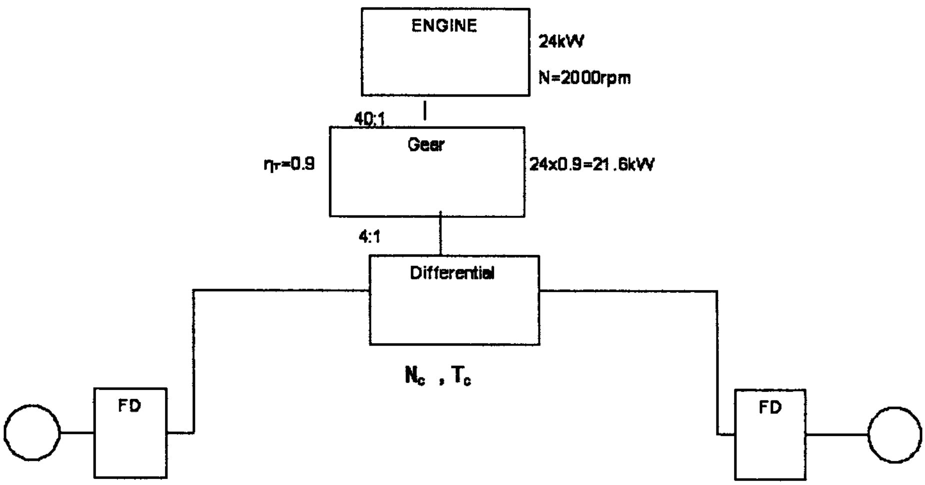
$$=18\ \text{x}\ 10^6\ \text{N/m}^2\ \text{x}\ (31.875-25)\ \text{x}\ \frac{10^{-3}}{60}\frac{m^3}{s}\times\left[\frac{1}{1000}\right]=2.06\ \text{kW}\ \ \text{(Ans)}$$

(6) A tractor engine develops brake power of 24 kW at 2000 rpm. When engaged in first gear, the drive provides a gear reduction ratio of 40:1 through main gearbox and 4:1 through final differential unit. The overall transmission efficiency in the first gear is 90 percent. On a right-hand curve in first gear, the nearest rear wheel travels 40 percent of the crown wheel speed. Determine the torque, speed, and power at the off-side wheel.

Ans:

Right hand curve: $N_{RR}=0.4\ N_C$

(a) T_{LR}=?, (b) N_{LR} = ?, (c) P_{LR} = ?



Gear

$P = 24 \times 0.9 = 21.6$ kw

$N = 2000/40 = 50$ rpm

$21600 = 2\pi(50/60) \times T$

$T = 4125.3$ N .m

Differential

$N_C = 50/4 = 12.5$

$T_C = 4125.3 \times 4 = 16501$ Nm

Right rear wheel

$N_{RR} = 12.5 \times 0.4 = 5$ (nearest wheel)

Left rear wheel

$N_{LR} = 7.5$ rpm (outer or offside wheel)

$T_{LR} = 16{,}501$ Nm

$$P_{LR} = \frac{2\pi \times 7.5 \times 16501}{60 \times 1000} = 12.9 \text{ kW} \qquad \text{(Ans)}$$

(7) A hydraulic sprayer fitted with hollow cone nozzles is required to be calibrated for an application rate of 150 l/ha. The sprayer speed is 6.5 km/h and the nozzle spacing is 50 cm. The available 0.787 mm orifice diameter nozzle is rated at 0.473 l/min at 275 kPa pressure. Calculate

(a) the nozzle flow rate

(b) the pressure required to produce the desired nozzle flow rate and

(c) the droplet size at the desired flow rate if the nozzle produces a VMD of 200μm at 1000 kPa

Ans:

R_V =150 l/ha, V = 6.5 km/hr = 1.8 m/s

S = 0.5 m, Q = 0.473 l/m (at 275 kPa)

Orifice diameter, d =0.787 mm, D_1 = 200 μm at 1000 kPa

$\dot{m} = \rho Q = \rho(AR_v)$

$\Rightarrow Q = nq = AR_v = (nSVE)\, R_V$

$\Rightarrow Q = SVE\, R_v = 0.5 \times 1.8\ (m/s) \times 1 \times 0.15\ m^3/10^4\ m^2 = 0.81$ lit/min

(b) At this flow rate to know the pressure, equate this set of condition with rated set of condition

$$\therefore \frac{Q_2}{Q_1} = \sqrt{\frac{P_2}{P_1}} \Rightarrow \frac{0.81}{0.473} = \sqrt{\frac{P_2}{275}} \Rightarrow P_2 = 806.45 \text{ kPa}$$

(c) At pressure > 600 kpa

$$D\alpha\frac{1}{\sqrt{p}} \Rightarrow \frac{D_2}{D_1} = \sqrt{\frac{P_1}{P_2}} \Rightarrow \frac{D_2}{200\mu m} = \sqrt{\frac{1000}{806.45}} \Rightarrow D_2 = 222.71 \text{ mm} \quad \text{(Ans)}$$

(8) The result of a flow net study gave number of flow paths 6 and number of potential drops 16. The head lost through dam during seepage was 6 m. The coefficient of permeability of soil medium is 5 x 10^{-8} m/s. Compute the seepage loss through the dam. What would be the seepage loss through the dam if the coefficient of permeability in horizontal and vertical directions are respectively 4.5 x 10^{-3} m/s and 1.6 x 10^{-8} m/s ? The number of flow paths, potential drops and head remains same.

Ans:

Number of flow path, $N_f = 6$

Number of potential drop, $N_d = 16$

Head lost = Total head = h = 6m

k = 5 x 10^{-8} m/s

(i) q = $kh\dfrac{N_f}{N_d}$ = 5 x 10^{-8} x 6 x (6/16) = 11.25 x 10^{-8} m^2/s

= 11.25 x 10^{-8} m^3/s per metre length of dam.

(ii) k_x = 4.5 x 10^{-8} m/s, k_y = 1.6 x 10^{-8} m/s

q = k' h N_f/N_d = $\sqrt{k_x k_y}\, h \dfrac{N_f}{N_d} = \sqrt{4.5\times10^{-8}\times1.6\times10^{-8}}\times6\times\dfrac{6}{16}$

= 6.03 x 10^{-8} m^3/s per metre length of dam. (Ans)

(9) Determine the depth of runoff and peak rate of runoff for 25 years recurrence interval for antecedent moisture condition II from an 150 ha watershed. The curve numbers to apply for three 50 ha sub watershed for antecedent moisture condition II are respectively 85, 65 and 75. Six hour 25 year frequency rainfall for the given location is 120 mm. The time of concentration and time to peak of runoff are 30 min and 60 min respectively.

Ans:

A = 150 ha	CN_1 = 85	CN_2 = 65	CN_3 = 75
a_1 = 50 ha	a_2 = 50 ha	a_3 = 50 ha	P = 120 mm
T_c = 30 min,	time to peak= t_p = 60 min		

Weighed curve number $= \dfrac{a_1 CN_1 + a_2 CN_2}{a_1 + a_2}$

$$= \frac{50\times85+50\times65+50\times75}{150} = 75$$

$$CN = \frac{25400}{254+s(mm)}$$

$$\Rightarrow S = \frac{25400}{CN} - 254 = \frac{25400}{75} - 254 = 84.67mm$$

$$Q = \frac{(P-0.25)^2}{P+0.85}$$

$$\therefore Q = \frac{(120-0.2\times84.67)^2}{120+0.8\times84.67} = 56.58\text{mm}$$

$$Q_{peak} = 0.0021\ \frac{Q.A}{t_p} = 0.0021\frac{56.58\times150}{1} = 17.82\frac{m^3}{s}$$ (Ans)

(10) Show that in a rectangular control section at critical flow condition the depth of flow is given by $d_c = (Q^2/(gb^2))^{1/3}$ and $d_c = (2/3)$ E where d_c = critical depth of flow (L), Q = discharge (L^3T^{-1}), b = width of flow (L), g = acceleration due to gravity (LT^{-2}) and E = specific energy (L)

Ans:

(i) A given quantity of water in an open channel may flow at 2 depths having same energy head. When these depths coincide, the energy head is minimum and corresponding depth is termed as critical depth.

Specific energy head , $h_e = h + \frac{v^2}{2g}$

$$\Rightarrow h_e = h + \frac{Q^2}{2A^2 g} = h + \frac{Q^2}{2b^2 h^2 g}$$

where

b = channel width

h = channel depth or flow depth

$\frac{d(h_e)}{dh} = 0$ (At critical depth energy is minimum)

$$\Rightarrow 1 + \frac{Q^2}{2b^2 g} \times (-2) \times \frac{1}{h^3} = 0$$

$$\Rightarrow \frac{Q^2}{gb^2 h^3} = 1$$

$$\Rightarrow h^3 = \frac{Q^2}{gb^2}$$

$$\Rightarrow h = \sqrt[3]{\frac{Q^2}{gb^2}} = d_c$$

Note: h = d_c at critical depth

(ii) $E = h_e = d_c + \frac{Q^2}{2gb^2 d_c^2}$

$\Rightarrow Q^2 = (E - d_c) 2b^2 d_c^2 g$

$\Rightarrow Q = \sqrt{E \times 2b^2 d_c^2 g - 2b^2 d_c^3 g}$

For $\dfrac{dQ}{dh} = 0$

$$\Rightarrow \frac{d}{dh}(\sqrt{E \times 2b^2 d_c^{\,2} g - 2b^2 d_c^{\,3} g}) = 0$$

$$\Rightarrow d_c = \frac{2}{3}E = \frac{2}{3}h_e \qquad \text{(Proved)}$$

(11) Determine the discharge capacity of a parabolic grassed waterway with top width of flow 7.5m, depth of flow 0.3 m and bed slope of 4 percentage. The roughness co-efficient of grass is 0.04. With the passage of time, the roughness coefficient of grass has changed to 0.05. What would be the percentage change in the discharge capacity of channel section ?

Ans:

t = 7.5 m, d = 0.3 m, S = 4 %, n_1 = 0.04 %

n_2 = 0.05 (same channel), $P = t + \dfrac{8d^2}{3t}$, $A = \dfrac{2}{3}td$

(i) $Q = AV = (\frac{2}{3}\ td)\ (\frac{1}{n}\ R^{2/3}\ S^{1/2})$

$$R = \frac{A}{P} = \frac{\frac{2}{3}td}{t + \frac{8d^2}{3t}} = \frac{\frac{2}{3} \times 7.5 \times 0.3}{7.5 + \left(\frac{8 \times 0.3^2}{3 \times 7.5}\right)} = 0.0199$$

$$Q = (\frac{2}{3} \times 7.5 \times 0.3)\left[\frac{(0.0199)^{2/3}(0.04)^{1/2}}{0.04}\right] = 0.055\ m^3/s$$

But Q α 1/n

$$\frac{Q_2}{Q_2} = \frac{n_1}{n_2} \Rightarrow Q_2 = Q_1 \times \frac{n_1}{n_2} = 0.055 \times \frac{0.04}{0.05} = 0.044\ m^3/s$$

Oercent change in Q = $\dfrac{\Delta Q}{Q_1} = \dfrac{0.055 - 0.044}{0.055}$ = 20 %, decrease (Ans)

(12) Fifteen sprinklers with twin nozzles of 5 mm and 4 mm diameter each with coefficient of discharge 0.96, are operating at 2.5 kg/cm^2 pressure. The sprinkler spacing is 12m x 16 m. The

consumptive use rate for a particular crop is 6 mm/day and irrigation interval is 10 days. Determine the (i) discharge of sprinkler (ii) total capacity of sprinkler system (iii) time of operation of sprinkler system.

Ans:

d_1 = 5 mm, C_{d1}= 0.96, P_1 = 2.5 kg /cm^2 = P_2 , S_l x S_m= 12m x 16 m

d_2 = 4mm, C_{d2} = 0.96, n = 15, C_u = 6 mm/day

1.013 kg/cm^2 = 10.33 m, ⇒ 2.5 kg/cm^2 = 25.49 m = h

(i) q = q_1 + q_2

$$=\frac{\pi}{4}C_d\sqrt{2gh}\left(d_1^2+d_2^2\right)=\left(\frac{\pi}{4}d_1^2\right)C_d\sqrt{2gh}+\frac{\pi}{4}d_2^2C_d\sqrt{2gh}$$

$$\Rightarrow q=\frac{\pi}{4}\times 0.96\times\sqrt{2\times 9.81\times 25.49}\left(0.005^2+0.004^2\right)$$

= 6.913 x 10^{-4} m^3/s = 0.6913 l/s

(ii) Q = nq = 15 x 0.6913 = 10.36 l/s

(iii) A = 12 x 16 x 15 = 2880 m^2, $d=\frac{6\times 10}{1000}$=0.06 m

$$Qt = Ad \Rightarrow t = Ad/Q = \frac{2080\times 0.06}{6.913\times 10^{-4}\times 15} = 4.62 \text{ hr} \qquad \text{(Ans)}$$

(13) A 2 ha field crop is irrigated by a tube well having a discharge of 25 l/s. The moisture content at successive depth in the root zone prior to irrigation is given below :

Depth, cm	0-25	25-50	50-75	75-100
Moisture content, %	5.5	6.0	6.5	7.5

The bulk density of the soil is 1.5 g/cc. The moisture at field capacity is 18 cm per metre depth of soil. Determine the (i) moisture content of soil in the root zone at the time of irrigation, (ii) net irrigation requirement (iii) time required to operate the tubewell to bring the soil moisture to field capacity.

Ans:

A = 2 ha, ρ = 1.5 gm/cc, Q = 25 l/s, AMHC = 18 cm/m

Method -1

Note: MC in root zone at time of irrigation is denoted by d_{bi}

AMHC = d_{fc}/D (1)

⇒ d_{fc} = 18 cm/m x 1 m = 18 cm

AMHC = m_{fc} (%) x ρ = M_{fc} (%) (2)

⇒ m_{fc} % = 18/1.5 = 12 %

d = [(12 – 5.5) + (12 – 6.0) + (12 – 6.5) + (12 – 7.5)] x 1.5 x ¼ m
 = 8.43 cm

d = d_{fc} - d_{bi} (3)

⇒ d_{bi} = d_{fc}-d =18-8.43 =9.57 cm

Method -2

M_{bi} = 5.5 x 1.5 x 0.25 + (6.6.5 + 7.5) x 1.5 x 0.25 = 9.57 cm

(ii) net irrigation requirement, d = 8.43 cm

(iii) Qt = Ad ⇒ t = Ad/Q (4)

$$\Rightarrow t = \frac{2\times10^4 \times 0.0843\text{m}}{25\times10^{-3}\,\frac{\text{m}^3}{\text{s}}} = 18.73 \text{ hr} \quad \text{(Ans)}$$

(14) The corrugated plastic tiles are used to carry the design flow from 1000 m of tile spaced 30 m apart. The drainage requirement for optimum plant growth is to lower the ground water table by 250 mm/day uniformly over the entire area. The drainable porosity of soil is 4 percent. The applicable roughness co-efficient is 0.015 and tiles are laid at the grade of 0.3 percent. Determine the (i) drainage coefficient (ii) design flow and (iii) size of tile.

Ans:

L = 30 m, n = 0.015, tile length = 1000 m, S = 0.003

Drainage (drop) = 250 mm/day, Drainable porosity, f = 4 %

A = spacing x length =30 x1000 = 30,000 m^2

(i) Drainage coefficient, DC = drainage drop x drainable porosity

⇒ DC = 250 x 0.04 = 10 mm/day

(ii) $Q\ (m^3/S) = DC \times A = \frac{10\times10^{-3}\text{m}}{24\times3600}\times 30{,}000\text{m}^2 = 3.47 \times 10^{-3}\ m^3/s$

(iii) $R = \frac{A}{P} = \frac{\pi/4D^2}{\pi D} = D/4$

$Q = AV = \frac{\pi}{4}D^2 \times \frac{1}{n}R^{2/3}S^{1/2}$

⇒ $3.47 \times 10^{-3} = \pi/4 \times (1/4)^{2/3} \times 1/n \times S^{1/2} \times D^{8/3}$

⇒ D = 0.1139 m = 11.39 cm (Ans)

(15) A fluid having density of 1030 kg/m^3, viscosity of 1 cp. flows through a horizontal pipe of diameter 5 cm and length 100 m. If

velocity of flow inside the pipe is 1 cm/s and the flow regime is laminar, find the pressure drop in the pipeline in Pascals. What would be the pressure drop in Pascals if the diameter of the pipe is halved ?

Ans:

$\rho = 1300\ kg/m^3$, $\mu = 1$ cp, D = 0.05 m, L = 100 m

1 poise = 1/10 Pa. S = 0.1 Ns/m^2, V = 1 cm/sec = 0.01 m/s

Laminar flow

(i) Pressure drop, $\Delta P = \dfrac{32\mu VL}{D^2}$

$$\Rightarrow \Delta P = \frac{32(10^{-2} \times 0.1)0.01 \times 100}{(0.05)^2} = 12.8\ N/m^2 = 12.8\ Pa$$

(ii) $\Delta P \alpha \dfrac{1}{D^2} \Rightarrow \dfrac{\Delta P_2}{\Delta P_1} = \left(\dfrac{D_1}{D_2}\right)^2 = (2)^2$

$\Rightarrow \Delta P_2 = 4\ (\Delta P_1) = 12.8 \times 4 = 51.2$ Pa (Ans)

(16) What is the basic difference between Biot number and Nusselt number ? In an air blast freezer operating at – 30°C, blocks of fish of 0.0508 m thickness are to be frozen. Initial temperature of the fish is –2.2°C and the moisture content of the fish is 82 percent. The heat transfer co-efficient of the freezer is h=20 W/m^2K. Calculate the freezing time in hour required to freeze the fish blocks. Assume, density of the unfrozen fish as 1050 kg/m^3 thermal conductivity of the frozen fish as 1.025 W/m-K, latent heat of fusion of water to ice as 335 kJ/kg and shape factors for infinite slab, P = ½ and R = 1/8.

Ans:

Biot number (unsteady state heat transfer) $= \dfrac{\text{Internal conductive resistance}}{\text{surface conductive resistance}}$

$$= \frac{x/k}{1/h} = \frac{hx}{k}$$

Nusselt number (Steady state heat transfer)

$$= \frac{\text{heat flow by convection per temperature gradient}}{\text{heat flow by conduction per temperature gradient}} = \frac{hL}{K}$$

$T_e = -30^oC$, h = 20 w/m^2K, fish thickness (a) = 0.0508 m

Initial temp of fish (T_f) = -2.2°C

Moisture content, m = 82 %

Density of unfrozen fish , $\rho = 1050$ kg/m^3
Thermal conductivity of frozen fish, k = 1.025 w/m-k
λ_f = 335 kJ/kg, P = ½, R = 1/8

$$\Rightarrow t_f = \frac{m\rho\lambda_f}{T_f - T_c}\left(\frac{Pa}{h} + \frac{Ra^2}{k}\right)$$

$$\therefore\ t_f = \frac{0.82 \times 1050 \times 335}{-2.2 - (-30)}\left[\frac{0.0508}{2 \times 20} + \frac{1}{8} \times \frac{(0.0508)^2}{1.025}\right]$$

$\therefore \Rightarrow t_f$ = (16.43) x (1000) = 16,200 Sec = 4.565 hr (Ans)

(17) A drop of liquid water is kept at a uniform temperature of 20^0 C and is suspended in atmospheric air by a fine wire. The initial radius is 1.5 mm. The vapour pressure of water at 20°C is 17.54 mm of Hg and the density of liquid water at 20°C is 998.23 kg/m^3. Calculate the time in hour required for complete evaporation of the water droplet. Assume, molecular weight of water as 18.02 kg/kg mole, diffusivity of water vapour in air at 20°C as 2.5 x 10^{-5} m^2/s and universal gas constant R is 8314 m^3 Pa/kg mole K.

Ans:
P_V =17.54 mm of Hg = 17.54/760 = 0.0231 atm = $P_{A1,}$
(P_{A2} = 0, since pure air)
ρ_w = 998.23 kg/m^3 = $\rho_{A,}$ R = 8314 m^3 Pa/kg mole K
molecular mass of water, M_A = 18.02 kg/kg mole
diffusivity of water vapour , D_{AB} = 2.5 x 10^{-5} m^2/s
Suspended in atm $\Rightarrow$ P = 101.325 KPa = 101325 Pa
T = 20 + 273 = 213°K, r_1 = 1.5 mm = Z
It is a case of diffusion through stagnant (non diffusing) gas
As time progress Z varies

$$\Rightarrow t = \frac{\rho_A Z^2 RT}{2M_A D_{AB} P.\ln\left(\frac{P - P_{A2}}{P - P_{A1}}\right)}$$

$$\Rightarrow t = \frac{998.23 \times (0.0015)^2 \times 8314 \times 293}{2 \times 18.02 \times 2.5 \times 10^{-5} \times 1.013 \times 10^5 \times \ln\left[\frac{1-0}{1-0.0231}\right]}$$

= 2565 Sec = 0.712 hr (Ans.)

(18) While crushing a material it is observed that 80 percent of the feed is less than 50.8 mm in size and 80 percent of the product is less than 6.35 mm in size. The power required is 90 kW. Calculate the power required for the same feed if 80 percent of the product is to be less than 3.18 mm.

Ans:

$D_{P1} = 6.35$ mm, $D_{P2} = 3.18$ mm, $P_1 = 90$ kW

$D_{f1} = D_{f2} = 50.8$ mm

Here Bond's law will be applicable because of intermediate particle size

$$E = \frac{P}{f} = K_b\left(\frac{1}{\sqrt{Dp}} - \frac{1}{\sqrt{D_f}}\right)$$

$$\frac{P_1}{P_2} = \left(\frac{\frac{1}{\sqrt{Dp_1}} - \frac{1}{\sqrt{D_{f1}}}}{\frac{1}{\sqrt{Dp_2}} - \frac{1}{\sqrt{D_{f2}}}}\right) = \frac{\frac{1}{\sqrt{6.35}} - \frac{1}{\sqrt{50.8}}}{\frac{1}{\sqrt{3.18}} - \frac{1}{\sqrt{50.8}}} = \frac{0.2565}{0.42}$$

$\Rightarrow P_2 = 147.5$ KW (Ans)

(19) Peas having a size of 5 mm and density of 1160 kg/m^3 are to be dried using air at 93.3°C and 3 atmospheric absolute pressure. The void fraction at minimum fluidizing condition is 0.63. The bed diameter is 0.2 m and the bed contains 5 kg of solids . Calculate the minimum height of the fluidized bed and the pressure drop at minimum fluidization condition. Assume density of air at 93.3°C and 1 atm absolute pressure is 0.964 kg/m^3.

Ans:

Peas (one side)	Air (other side)
$D_P = 5$mm	T = 93.3°C
$\rho_p = 1160$ kg/m^3	$P_1 = 3$ atm

density of air at 93.3°C and 1 atm pre(p_2), $\rho_a = 0.964$ kg/m^3

void fraction at minimum fluidizing condition, $\epsilon_m = 0.63$

bed diameter, D = 0.2 m, solid = 5 kg

(i) PV = MRT

$\Rightarrow P\,(V/M) = RT \Rightarrow P \times 1/\rho = \text{constant}$

$\Rightarrow P_1/P_2 = \rho_1/\rho \Rightarrow 3/1 = \rho_1/0.964 \Rightarrow \rho_1 = 0.964 \times 3 = 2.892$ kg/m^3

Again volume of solids, peas = m/ρ_f = 5 kg/1160 kg/m^3 = 0.0043 m^3
= volume of bed

Cross section of bed = $(\pi/4)D^2 = (\pi/4)(0.2)^2 = 0.03$ m^2

Height of bed = V/A = 0.0043/0.03 = 0.1436 m = L, when $\epsilon = 0$

Again $\frac{L_1}{L_2} = \frac{1-\epsilon_2}{1-\epsilon_1} \Rightarrow \frac{L}{L_m} = \frac{1-\epsilon_m}{1-\epsilon}$

$\Rightarrow \frac{0.1436}{L_m} = \frac{1-0.63}{1-0} \Rightarrow L_m = 0.388\text{m}$

(ii) Pressure drop in minimum fluidization condition,

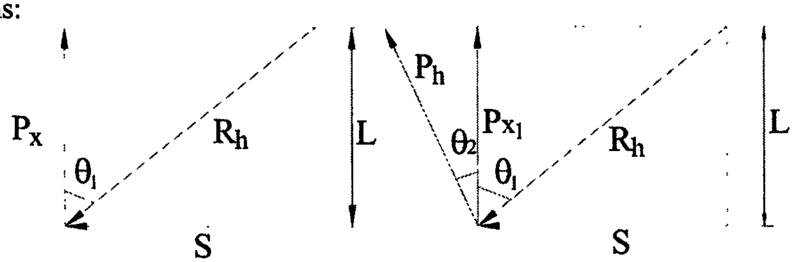
$\Delta P = L_m (1-\epsilon_m)(\rho_p-\rho_a) \times g$

$=0.388\ (1-0.63)\ (1160 - 2.892) \times 9.81 = 1629.58$ Pa $=1.63$ kPa (Ans.)

2000

(1) A left-handed mould board plough bottom has a draft of 1.96 kN when it operates without side draft. The thrust on the landside is 590 KN and the coefficient of soil-metal friction is 0.35. What will be the change in draft if the plough is pulled at an angle of 10° towards the right side of the plough. The useful soil reaction forces remain unchanged.

Ans:



Draft = 1.96 KN (when side draft=0)
Thrust on land side = 590 kN
(a)Without side draft
$P_h = -R_h$
$\Rightarrow P_x = -L = -1.96$ kN $= 1.96$ kN
$\theta_1 = \tan^{-1}(S/L) = \tan^{-1}(590/1960) = 16.75°$
S = 590 N
$R_h = \sqrt{L^2 + S^2} = \sqrt{1960^2 + 590^2} = 2046.87\text{N}$
(b) Plough is pulled at 10° towards right of plough
$\theta_2 = 10°$
$\text{Cos}\ \theta_2 = Px_1/P_h$
$\text{Cos}\ (\theta_1 + \theta_2) = R_h/P_h$

$$P_{x1} = P_h \cos\theta_2 = \frac{R_h \cos\theta_2}{\cos(\theta_1 + \theta_2)} = \frac{2046.87 \times \cos 10}{\cos 26.87} = 2257N$$

Change in draft = 2.257 kN – 1.96 kN = 0.29 kN (Ans)

(2) A sprayer having 0.4 litre per minute nozzle discharge rate and 50 cm width of coverage is required to apply 0.8 kg of active ingredient per hectare. If one kilogram of active ingredient is contained in 120 litres of spray solution, determine the speed of travel of the sprayer.

Ans:

Q = 4 lit/min, R_m = 0.8 kg/ha, Width of coverage, S = 0.5 m

1 kg equivalent to 120 lit

According to sprayer formula, (nsvE)Rm = A Rm = $\overset{g}{m}$ = ρQ = ρ (nq)

⇒ 0.5 (m)x V(m/s) x $0.8/10^4$ (kg/m^2) = 1/120 kg/lit x 4/60 lit/s

⇒ V = 1.38 m/s (Ans)

(3) Frequency of oscillation of a 1700 kg tractor when suspended from a pivot is 0.35 Hz. If the distance between the centre of gravity (CG) and the pivot is 1.3 m, calculate the moment of inertia of the tractor about an axis passing through its CG.

Ans:

M = 1700 kg , f = 0.35 Hz , R_0 = 1.3 m

$$T = 1/f = 2\pi\sqrt{\frac{I_0}{WR_0}}$$

$$\Rightarrow \frac{1}{0.35} = 2\pi\sqrt{\frac{I_0}{1700 \times 9.81 \times 1.3}}$$

⇒ I_0 = 4482.97 kg m^2 = Moment of Inertia about pivot

Moment of Inertia of tractor about an axis passing through its CG

= $I_t = I_0 - M_t R_0^2$ = 4482.97 – 1700 x 1.3^2 = 1609.4 kg – m^2 (Ans)

(4) Diameter and stroke length of the piston of a diesel engine are 10 cm and 12 cm respectively. If the clearance volume is 56 cm^3. estimate the temperature of air at the end of compression stroke. Temperature of ambient air is 10°C and the ratio of specific heat is 1.38.

Ans:

D = 10 cm, L = 12 m, V_c = 56 cm^3, r = V_1/V_2

Temperature of ambient air, T_1 = 10°C, C_p/C_v = K = 1.38
$V_s = (\pi/4)D^2 \times L = (\pi/4) \times (0.1)^2 \times 0.12 = 942\ cm^3$
Compression Ratio = 1 + V_s/V_c = 1 + 942/56 = 17.83

$$\text{Also}\ \frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1-k} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1-k}$$

$$\Rightarrow \frac{T_2}{283} = \left(\frac{1}{17.83}\right)^{1-1..38}$$

$\Rightarrow T_2 = 845.71°\ K = 572°C$ (Ans)

(5) A tractor having 130 cm tread, travels along a 30 m diameter test path. The CG of the tractor is at a height of 0.85 m from the ground. Calculate the speed of travel at which the tractor will experience a sideways overturning.

Ans:
T =130 cm, Height of the CG, Y = 0.85m

$$R = \frac{\text{Diameter of test path}}{2} = \frac{30}{2} = 15\text{cm}$$

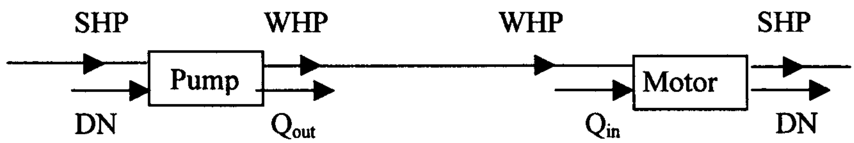
$$(m_t\ \frac{U_m^2}{R}\cos\gamma)Z_{cg} = \frac{T}{2}W_t = \frac{T}{2}(M_t g)$$

$$\Rightarrow U_m = \sqrt{\frac{g(\frac{T}{2})R}{Z_g \cos\gamma}} = \sqrt{\frac{9.81\times(\frac{1.3}{2})\times 15}{0.85\times 1}} = 10.6\ m/s \quad \text{(Ans)}$$

(6) A hydraulic pump having 37.5 cm^3 displacement per revolution develops 15 Mpa at 88 percent volumetric efficiency. At 3000 rev/min, the pump supplies oil to a torque converter, whose shaft rotates at 60 rev/min and has 85 percent overall efficiency. Calculate the torque available at the shaft of the converter.

Ans:
D = 37.5 cm^3/rev, N = 60 rpm, P = 15 Mpa,
n_{oa} = 85 %, n_v = 88 %, N(pump) = 3000 rpm

Concept used
(i) $Q_{out} = Q_{in}$
(ii) HP out of Pump = HP into Motor



Pump

$$(Q_{out}/DN) \times n_T = n_v \times n_T = n_{oa} = \left(\frac{\Delta P Q_{out}}{2\pi NT}\right)$$

$Q_{out} = 0.88 \times 37.5 \times 3000/60 = 1650\ cm^3/S$
$\Delta P\ Q_{out} = 15 \times 10^{-6} \times 1650 \times 10^6 = 24.75$ KW

Motor

$$\frac{DN}{Q_{in}} \times n_T = n_v n_T = n_{aa} = \frac{2\pi NT}{(\Delta P)Q_{in}}$$

$0.85 = 2\pi \times (60/60) \times T/24750$
$\Rightarrow T = 3348.22$ N.m (Ans)

(7) Root zone depth of wheat crop grown in a sandy loam soil is 100 cm. The volumetric soil moisture contents at field capacity and permanent wilting point are 30 percent and 5 percent respectively. Compute the soil moisture stress factor, when the volumetric moisture content in the root zone reaches 15 percent. Critical value of available soil water is 50 per cent.

Ans:
D = 1 m = 100 cm, M_{fc} = 30 %, M_{pw} = 5 %
Critical value of available soil water = 50 %

Soil moisture stress factor, $K_c = \dfrac{ln(\Delta w + 1)}{ln(100+1)}$

$$\Delta w = \frac{FMC - PWP}{FC - PWP} \times D = \frac{15-5}{30-5} \times 100 = 40$$

$$\therefore K_c = \frac{\ln(\Delta w + 1)}{\ln 101} = \frac{\ln(40+1)}{\ln 101} = 0.8$$ (Ans)

(8) In a 80 m long and 5 m wide border, a stream of 8 litre per second was delivered from the upper end to irrigate wheat crop. The stream was cut off as soon as it had reached the lower end of the

border in 70 minute. Layerwise soil moisture contents before irrigation and at field capacity are given below. Determine the application efficiency, if the root zone depth is 90 cm and the apparent specific gravity of soil is 1.4.

Depth, cm	Moisture content, per cent	
	Before irrigation	At field capacity
0-30	8.7	15.4
30-60	11.8	15.8
60-90	14.6	16.2

Ans:

L = 80m, b = 5m, r = 1.4, Q= 8 lit/s, T = 70 min, D = 0.9 m

d = $\sum (m_{fc} - m_{bi}) \times \rho \times D = (\sum m_{fc} - \sum m_{bi}) \times \rho \times D$

$= [(15.4 - 8.7) + (15.8 - 11.8) + (16.2 - 14.6)] \times 1.4 \times 0.3$

$= 5.166$ cm

Qt = Ad/Ed $\Rightarrow E_a$ = Ad/Qt

$$\Rightarrow E_a = \frac{(400m^2)\times 0.051m}{8\times10^{-3}\frac{m^3}{S}\times 70\times 60} = 0.615 = 61.5\,\% \qquad \text{(Ans)}$$

(9) Bench terraces are to be constructed on a hill having 15 percent slope. If the vertical interval of the terrace is 1.5 m, calculate

(i) length of terrace per hectare

(ii) earthwork

(iii) area lost when the batter slope of the terrace is 1:1

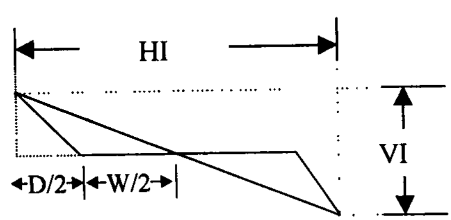
Ans:

It is important to understand that all the 3 bits (i), (ii), (iii) will be solved for batter slope 1:1

(i) $L/ha = \frac{10000}{HI} = \frac{10000}{W+D} = \frac{10000}{10} = 1000$

(ii) $\frac{S}{100} = \frac{VI}{HI} = \frac{1.5}{HI}$

$\Rightarrow \frac{15}{100} = \frac{1.5}{HI} \Rightarrow HI=10$



Again HI = W + D

$\Rightarrow 10 = W + 1.5$
$\Rightarrow W = 8.5$ m

$\therefore$ Earthwork = WD/8 x L/ha = $\dfrac{8.5 \times 1.5 \times 1000}{8}$ =1593.75 m^3

(iii) Percentage area lost =' $\dfrac{S+200}{\dfrac{200}{S}+\dfrac{S}{100}} = \dfrac{15+200}{\dfrac{200}{15}+\dfrac{15}{100}} = 15.94\%$ (Ans)

(10) Water from an unconfined aquifer having transmissivity of 100 m^2 per day is pumped through a fully penetrating well of 30 cm diameter at a rate of 1200 m^3 per day. If the radius of influence is 400 m, compute

(i) the draw down in the well

(ii) the draw down at a radial distance of 25 m from the well

Ans:

T = kH = 1000 m^2/day, R_w = 0.15 m, Q = 1200 m^3/day, R = 400 m

(i)

$$Q = \frac{\pi K(H^2 - h_w^{\,2})}{ln(R/r_w)} = \frac{\pi K(H+h_w)s}{ln(R/r_w)} = \frac{\pi K(2H-S)S}{ln(R/r_w)}$$

$$= \frac{\pi K(2HS)}{ln(R/r_w)} = \frac{2\pi TS}{ln(R/r_w)}$$

$$\therefore Q = \frac{2\pi TS}{\ln(R/r_w)} \Rightarrow 1200 = \frac{2\pi \times 1000 \times S}{\ln(400/0.15)} \Rightarrow S = 1.5067 \text{ m}$$

(ii) $$Q = \frac{2\pi T S}{ln(R/r_w)} = \frac{2\pi T S_1}{ln(R/r_1)}$$

$$\Rightarrow 1200 = \frac{2\pi \times 1000 \times S_1}{ln(400/25)}$$

$\Rightarrow S_1 = 0.52m$ (Ans)

(11) An unconfined cylindrical soil sample failed at an axial load of 140 kPa. The failure plane makes an angle of 55° with the horizontal. Calculate the values of cohesive stress and angle of internal friction of the soil.

Ans:
Unconfined $\Rightarrow \sigma_3 = 0$, $\sigma_1 = 140$ kPa, $\alpha = 55°$
$\alpha = 45 + \phi/2$
$\Rightarrow \phi = 20°$
$\sigma_1 = \sigma_3 \tan^2\alpha + 2C \tan \alpha$
$\Rightarrow \sigma_1 = 2C \tan \sigma_1 = 2C \tan (45 + \phi/2)$
$\Rightarrow 140 = 2C \tan 55°$
$\Rightarrow C = 49$ kPa (Ans)

(12) Determine the most efficient trapezoidal section of a drainage ditch required to carry a peak runoff of 1.6 m³/s. The channel is constructed in alluvial soil having Manning's roughness coefficient of 0.025. The bed slope and side slope of the channel are 1:2500 and 1:1.5 (V:H) respectively.

Ans:
$Q_p = 1.6\ m^3/S$, $n = 0.025$, $S = 1/2500 = 4 \times 10^{-4}$, $Z = H:V = 1.5: 1$
$\theta = \tan^{-1}(1/z) = \tan^{-1}(1/1.5) = 33.69°$

$$b = 2d \tan\frac{\theta}{2} = 2 \times d \times \tan\left(\frac{33.69}{2}\right) = 0.605\ d$$

other method to calculate b:

$$\frac{b + 2zd}{2} = d\sqrt{Z^2 + 1}$$

$$\Rightarrow \frac{b + 2 \times 1.5d}{2} = d\sqrt{1.5^2 + 1}$$

$\Rightarrow b = 0.605\ d$

Again $Q = AV = (bd + Zd^2)\ 1/n\ R^{2/3}\ S^{1/2} = (bd + zd^2)\ 1/n\ (d/2)^{2/3}\ S^{1/2}$

$$\Rightarrow 1.6 = (0.605\ d.d + 1.5\ d^2)\ \frac{1}{0.025}\left(4 \times 10^{-4}\right)^{1/2}\left(\frac{d}{2}\right)^{2/3}$$

$\Rightarrow d = 1.167$ m and $b = 0.605 \times 1.167 = 0.7$ m
$\therefore$ $b = 0.7$ m and $d = 1.167$ m
Adding freeboard = 15 %, depth = 1.15 x 1.167 = 1.34 m. (Ans)

(13) Apple juice containing 10 per cent solids ($c_p = 3.89$ kJ kg^{-1}°C^{-1}) is concentrated to 45 per cent solids (c_p = 2.85kJ kg^{-1}°C^{-1}) in a continuous type evaporator which allows transfer of heat at a rate of 30 kW. The feed enters the evaporator at 60°C and vacuum maintained inside the evaporator allows the juice to boil at 55°C. Find the kilogram of juice that can be concentrated per hour. Enthalpy of water vapour at 55 °C is 2604 kJ/kg.

Ans:

$T_F = 60^0C$, $X_F = 0.1$, $T_B = 55$, $X_p = 0.45$, $Q = 30$ kW

$C_{PF} = 3.89$ kJ/kg-K, $C_{pp} = 2.85$ kJ/kg-K, $H_v = 2604$ kJ/kg

$F \,.\, X_F = P\, X_p$ (1)

$F = P + V$ (2)

$F\, h_f + S\, h_S = Ph_p + V\, h_v + C\, h_c$ (3)

$Fh_f + S\,(h_s - h_c) = Ph_p + V.h_v$

$F.h_f + S\lambda = Ph_p + V.\, h_V$

$\Rightarrow F.\, C_{PF}(T_F - 0) + Q = P\, C_{pp}\,(T_p\text{-}0) + Vh_v$ (4)

Using equation (1)

$\Rightarrow F\,(0.1) = P\,(0.45)$

$\Rightarrow P = 0.22F$

Using equation (2)

$V = F - P = F - 0.22\,F = 0.78\,F$

using equation (4)

$\therefore$ F x 3.89 x (60 – 0) + 30 = 0.22F x 2.85 x (55-0) + 0.78 F x 2604

$\Rightarrow$ F x 233.4 – F (34.485 + 2031.12) = -30

$\Rightarrow$ F = 0.016 kg/s = 58.9 kg/h (Ans)

(14) Shelf life of a food stored at 30 °C is 7 days. Assuming that Q_{10} value of deteriorative reactions occurring in the food is 1.8, estimate the shelf life when it is stored at 10°C.

Ans:

$Q_{10} = 1.8$, $T_1 = 30°C$, $T_2 = 10°C$, $F_1 = 7$ days

$$\therefore \frac{F_2}{F_1} = Q_{10}^{\left(\frac{T_1 - T_2}{10}\right)}$$

$$F_2 = 7 \times 1.8^{\left(\frac{30-10}{10}\right)} = 11.68 \ \textit{days}$$ (Ans)

(15) Calculate the effectiveness of an oil expeller, which yields 37 kg oil containing 5 percent solid impurities from 100 kg mustard seed. The oil content of mustard seed is 38 percent.

Ans:

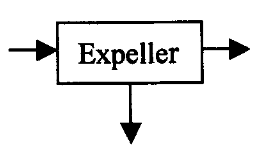
First method

Seed, F = 100 kg

Oil = 38 kg

Solid = 62 kg

$X_{SF} = 0.62$



P = 37 kg (oil outlet)

$X_{SP} = 0.05$

Solid = 37 x 0.05 = 1.85

Oil = 37 – 1.85 = 35.15

Liquid = 2.85 kg(impurity outlet)

Solid = 60.15 kg

$F.\,X_{SF} = P.X_{SP} + R.X_{SR}$ (1)
$F = P + R$ (2)
$\Rightarrow 100 \times 0.62 = 37 \times 0.05 + R.X_{SR}$
$R\,X_{SR} = 60.15$ = solid amount
Note
X_s = solid fraction
X = fraction of desired material
X_F = mass fraction of desired material (oil) in feed = 0.38
X_p = mass fraction of desired material (oil) in Product = 0.95
X_R = mass fraction of desired material (oil) in rejected = 2.85/6.3
= 0.0452

$$E = \frac{PR}{F_2} \times \frac{X_p(1-X_R)}{X_F(1-X_F)} = \frac{37 \times 63}{10000} \times \frac{0.95(1-0.0452)}{0.38(1-0.38)} = 89.74\ \%$$

Second Method

Expeller effectiveness for oil extraction , $\eta_{oil} = \dfrac{37 - 37 \times 0.05}{38} = 0.925$

Expeller effectiveness for impurity extraction ,

$$\eta_{impurity} = \frac{62 - 37 \times 0.05}{62} = 0.97$$

Oil Expeller effectiveness , $\eta = \eta_{oil} \times \eta_{impurity} = 0.925 \times 0.97 = 89.73\ \%$ (Ans)

(16) Calculate the static pressure drop in air flowing through a grain bed of 10 cm thickness. The grains are spherical (6mm diameter) with 1200 kg/m^3 true density and 800 kg/m^3 bulk density. The superficial air velocity through the bed is 2 m/min. The density and viscosity of air are 1.2 kg/m^3 and 1.85 x 10^{-5} Pa.s respectively.

Ans:
Grain bed thickness, ΔL = 10 cm
Particle diameter, D_p = 6 mm
True density, ρ_p = 1200 kg/m^3
Bulk density, ρ_b = 800 kg/m^3
Superficial air velocity through bed , V' = 2 m/min
ρ = 1.2 kg/m^3
μ = 1.85 x 10^{-5} Pa.s

$$\text{Now}\ \frac{\Delta P(\rho)}{(G')^2}\frac{D_p}{\Delta L}\frac{\epsilon^3}{1-\epsilon} = \frac{150}{Re} + 1.75 \qquad (1)$$

Porosity (%) $= \in = \left(1 - \dfrac{\textit{Bulk density}}{\textit{particle density}}\right) \times 100$

$= (1 - 800/1200) \times 100 = 33.33\ \% = 0.33$

$$Re = \frac{\rho\left(D_p V'\right)}{\left(1-\in\right)\mu} = \frac{1.2\left(\frac{kg}{m^3}\right)6\times10^{-3}\times\frac{2}{60}\left(\frac{m}{s}\right)}{1.85\times10^{-5}\frac{kg}{m-s}\times\left(1-0.33\right)} = 19.36$$

This is expression for Re for air flow through packed bed

G = mass velocity based on empty cross section of bed

$G' = \rho V' = 1.2 \times 2/60 = 0.04\ kg/m^2\text{-}s$

Now static pressure drop, ΔP can be calculated from equation (1).

(17) Calculate specific volume and absolute humidity of air at 50°C and 15 percent relative humidity at atmospheric pressure. Saturation vapour pressure of water at 50°C is 12.35 kPa.

Ans:

Temperature = 50°C, P_s = 12.35 kPa, P = atm pre = 101.325 kPa

RH = ϕ = 15 % = P_v/P_s

$P_v = \phi P_s = 0.15 \times 12.35 = 1.8525$

(a) $H = 0.622\ \left(\dfrac{Pv}{P-Pv}\right) = 0.622\left(\dfrac{1.8525}{101.325-1.8525}\right) = 0.01158$

(b)$V_H = (0.00283 + 0.00456H)\ (t + 273)\ m^3/kg$

$\Rightarrow V_H = (0.00283 + 0.00456 \times 0.01158)\ (50 + 273)\ m^3/kg$

$= 0.93115\ m^3/kg$ (Ans)

(18) In spherical grain kernel, the moisture content C_r (kg moisture per kg kernel) varies linearly with radius r (metre) as $C_r = 0.05 + 0.36\ r$. Calculate the average moisture content in a kernel of 0.008 m diameter.

Ans:

Moisture content C_r (kg of moisture/kg of kernel) varies linearly with radius , r (metre)

as $C_r = 0.05 + 0.36r$

$$C_r\,(avg) = \frac{1}{r}\int_0^r (0.05 + 0.36r)dr = \frac{1}{r}\left[0.05r + 0.36\frac{r^2}{2}\right]_0^r = 0.05 + 0.18\ r$$

when r = D/2 = 0.008/2 = 0.004

C_r (avg) = 0.05 + 0.18r = 0.05 + 0.18 x 0.004 = 0.05072 (kg/kg) (Ans)

(19) Assuming that Raoult's law is applicable, estimate the water activity of an aqueous solution containing 65 percent sucrose and 2 percent common salt (NaCl). If the critical water activities for bacteria, yeast and mould are 0.9, 0.8 and 0.7 respectively, find out the type of organism against which the solution is stable. Molecular weight of sucrose is 342.

Ans:

First method

For non-ideal solution $a_w = \gamma x_w$

for Ideal Solution $a_w = x_w,\ \gamma = 1$

Molecular mass of sucrose = 342 and Molecular mass of Nacl = 58.5

Consider 100 gm of fruit solution

Sucrose = 65 gm $\Rightarrow n_s = 65/342 = 0.19$

Nacl = 2 gm $\Rightarrow n_{nacl} = 2/58.5 = 0.034$

Water = 33 gm $\Rightarrow n_w = 33/18 = 1.83$

First considering all the sucrose dissolves in all of the water present

$$X_{w1} = \frac{n_{wa}}{n_w + n_s} = \frac{1.83}{1.83 + 0.19} = 0.9059 = a_{w1}$$

$$\text{for Nacl, } X_{w2} = \frac{n_w}{n_w + n_{Nacl}} = \frac{1.83}{1.83 + 0.034} = 0.9059 = a_{w2}$$

$a_w = a_{w1} X\ a_{w2} = 0.9059 X\ 0.9817 = 0.89$

Second method

$$a_w = \frac{n_w}{n_w + n_s + n_{Nacl}} = \frac{1.83}{1.83 + 0.034 + 0.19} = 0.89$$

Critical water activity for bacteria = 0.9, for yeast = 0.8, for mould = 0.7

So solution is stable against bacteria (Ans)

2001

(1) A multiple disc clutch has 5 steel and 4 bronze discs. The outside and inside diameters of the contact surface are 100 mm and 50 mm respectively. If the coefficient of friction is 0.2 and the maximum average permissible normal pressure is 300 kN/m^2, what is the required axial force, and how much power can the clutch deliver at 500 rpm? Assume uniform wear.

Ans:

$Z = (5+4)-1 = 8$, $D_0 = 100mm = 0.1m$, $D_i = 0.05m$,
$\mu = 0.2$, $P = 300\ kN/m^2$, $N = 500rpm$

Uniform wear $\Rightarrow r_m = (\frac{D_0 + D_i}{4}) = 0.0375$

(i) Axial force, $F = PA = (300x10^3)x(\pi x0.05x(\frac{0.1+0.05}{2}) = 1178.1\ N$

(ii) Power delivered by the clutch $= 2\pi NT = 2\pi N(Fr_m\mu Z)$

$= 2\pi \times \frac{500}{60} \times 1178.1 \times 0.0375 \times 0.2 \times 8 \times (\frac{1}{1000}) = 3.67kW$ (Ans)

(2) A hydraulic motor is required to develop a torque of 125 Nm at a maximum speed of 600 rpm. The maximum pressure drop across the motor is to be 150 bar. The torque and volumetric efficiencies are both 0.9. Determine
(a) the motor displacement in litre/second, and
(b) the flow required in the motor in litre/minute.

Ans:

$T = 125Nm$, $N = 600rpm$, $\Delta P = 150bar = 150\ kg/cm^2 = 150x9.81x10^4 N/m^2$

Motor :

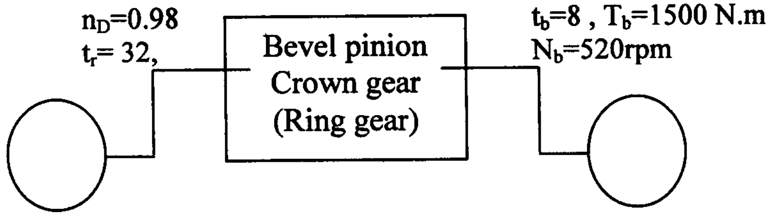
(a) $\frac{DN}{Q_{in}} \times n_T = n_v n_T = n_{aa} = \frac{2\pi NT}{(\Delta P)Q_{in}}$

$\Rightarrow Q_{in} = \frac{2\Pi \times \frac{600}{60} \times 125}{150 \times 9.81 \times 10^4 \times 0.9 \times 0.9} = 6.58 \times 10^{-4} m^3/s = 0.658$ lit/s

(b) $Q_{in} = 0.658$ lit/s $= 39.53$ lit/min (Ans)

(3) The differential in the rear axle of a farm tractor has a ring gear with 32 teeth driven by a bevel pinion with 8 teeth. Each side gear is connected to a rear axle through a final drive unit that provides a 5:1 speed reduction. If the input torque to the bevel pinion is 1500 Nm and the input speed is 520 rpm, calculate the torque and power in each rear axle when the left wheel encounters poor traction and begins turning 50 % faster than the right wheel. Assume differential efficiency as 0.98.

Ans:



(a) For straight travel
At ring gear:

$t_b N_b = t_R N_R$ (1)

$\Rightarrow 8 \times 520 = 32 \times N_R$

$\Rightarrow N_R = 130$rpm

$2\pi N_b T_b \times \eta_D = 2\pi N_R T_R$ (2)

$\Rightarrow 520 \times 1500 \times 0.98 = 130 \times T_R$

$\Rightarrow T_R = 5880$ N.m

At rear wheel:

$$N_{RR} = \frac{130}{5} = 26rpm = N_{RL}$$

$$T_{RR} = \frac{5880}{2} \times 5 = 14700N \cdot m = T_{RL}$$

when left turns 50% faster due to poor traction:

$N_{RL} = 1.5 \times 26 = 39$ rpm

$N_{RR} = 26$ rpm (Ans)

(4) The total draft of a 3-bottom 30 cm mould board plough when ploughing 20 cm deep at 5 km/h was 12 kN.
(a) Calculate the specific draft in N/cm^2
(b) What is the actual power requirement ?
(c) If the field efficiency is 80 %, what is the rate of work in hectare per hour?

Ans:

Draft =12 kN , d = 20cm , V= 5km/hr, FE=80%

(a) Specific draft, $L_u = \dfrac{12}{3 \times 0.3 \times 0.2} = 66.7 \dfrac{kN}{m^2}$

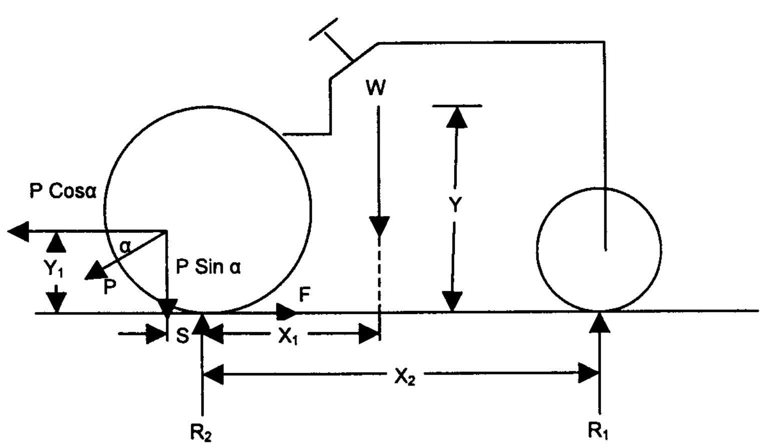
(b) Power = FV = $\dfrac{12 \times 5}{3.6} = 16.67\ kW$

(c) Field Efficiency, $FE = \dfrac{AFC}{TFC} = \dfrac{AFC}{nW_T V} = \dfrac{AFC}{3 \times 0.3 \times \dfrac{5}{3.6}} = 1\ \text{m}^2/\text{sec}$

$= 0.36\ \dfrac{ha}{hr}$ (Ans)

(5) A rear wheel-drive tractor is operating on a level ground. The static weight of the tractor is 25 kN and wheel base is 2100 mm. The centre of gravity is located 800 mm ahead of the rear axle. The drawbar force applied to the tractor is inclined downward from the horizontal at an angle of 15° and is located 750 mm behind and 125 mm below the rear axle centre. The rolling radius of each drive wheel is 600 mm. Assume the rear and front wheel reactions pass through their respective axle centre. Determine
(a) the steady-state horizontal pull required to maintain just 20 % of tractor static weight on front axle
(b) the corresponding coefficient of traction

Ans:
$W = 25$ KN, $X_2 = 2.1$ m, $X_1 = 0.8$ m, $\alpha = 15^0$, $S = 750$ mm $= 0.75$ m
rolling radius of each drive wheel, $r = 0.6$ m
Height below rear axle centre =125mm = 0.125 m
$\Rightarrow Y_1 = 0.6 - 0.125 = 0.475$
$R_1 = 20/100 \times W = 20/100 \times 25 = 5$ KN
(a) $R_1 + R_2 = W + P\sin\alpha$ (1)
$P\cos\alpha . Y_1 + P\sin\alpha . S + R_1 X_2 = W X_1$ (2)



Solving equation (1) and (2) simultaneously
$5 + R_2 = 25 + P\sin 15$
$P\cos 15 \times 0.475 + P\sin 15 \times 0.75 + 5 \times 2.1 = 25 \times 0.8$
$\Rightarrow P = 14.55$ KN
& $R_2 = 20 + 14.55 \sin 15 = 23.7658\ KN$
Steady-state horizontal pull, $P\cos\alpha = 14.55 \times \cos 15^0 = 14.054$ KN
(b) Coefficient of traction, $\mu = \dfrac{P\cos\alpha}{R_2} = \dfrac{14.054}{23.766} = 0.5913$ (Ans)

Checking for R_2 by direct use of formula

$$R_2 = W - W\frac{X_1}{X_2} + P\sin\alpha + \frac{P\cos\alpha.\gamma_1 + P\sin\alpha.S}{X_2}$$

$$= 5 - 25 \times \frac{0.8}{2.1} + 14.55\sin 15 + 14.55\cos 15 \times 0.475 + \frac{14.55\sin 15 \times 0.75}{2.1}$$

$$= 25 - 9.52 + 3.76 + 4.52 = 23.76$$

(6) A cut and throw forage harvester has a cylindrical cutter head 600 mm in width and 700 mm in diameter. It has eight knives and rotates at 900 rpm. It is to harvest corn at a feed rate of 60 Mg/h while producing an average length of cut of 5 mm. Calculate
(a) the required peripheral speed of the feed rolls, and
(b) the maximum height of the throat area if the density between the rolls is 300 kg/m^3.

Ans:

W = 0.6 m, D = 0.7 m, $\overset{g}{m} = 60$ mg/hr
L = 5 mm, N = 900 rpm, n = 8
(a) Peripheral speed of feed rolls, V'= πD'N' = NLn
= (900/60) × (5/1000) × 8 = 0.6 m/s

(b) we know $\overset{g}{m} = \rho Q = \rho VA = \rho(NLn)(WH)$

$$\Rightarrow \frac{60 \times 103}{3600}\frac{kg}{s} = 300 \times \left(\frac{900}{60} \times \frac{5}{1000} \times 8\right) \times 0.6 \times H$$

$\Rightarrow H = 0.154$ m (Ans)

(7) A field sprayer having a horizontal boom with 20 nozzles spaced 40 cm apart is to be designed for a maximum application rate of 650 liter/ha at nozzle pressure of 500 kPa and forward speed at 5 km/h.
  (a) Determine the required pump capacity in litres/min assuming 10 % of the flow is bypassed under the above maximum conditions.
  (b) What discharge rate per nozzle is required under the above conditions?
  (c) At what height above the tops of the plants should the boom be operated if 50 % overlap is desired with nozzles having 60 degree spray angles?

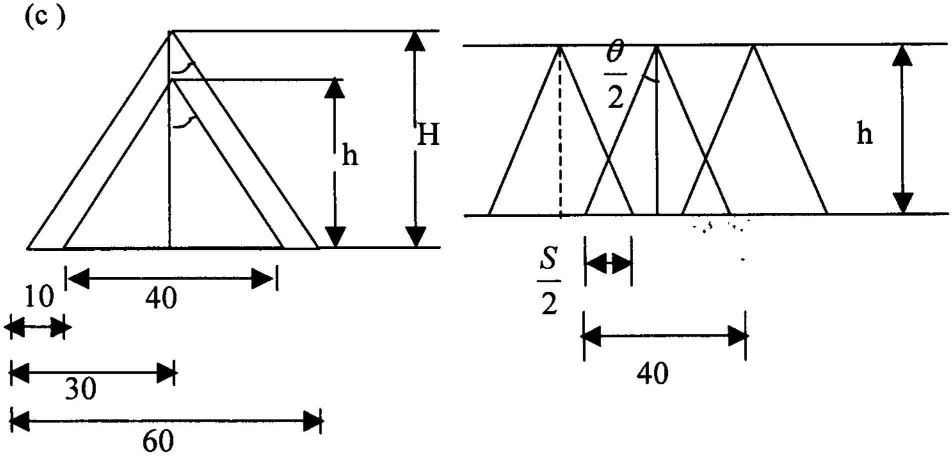
Ans:
n = 20, S = 40 cm, R_V = 650 lit/ha, P = 500 kPa, V = 5 km/h

(a) we know $m = \rho nq = \rho Q = \rho(AR_V) = \rho(nsVE)R_V = (nsVE)R_m$
$Q = AR_V = (nsVE)R_V$
$= 20 \times 0.4 \times (5/3.6) \times (650/10{,}000)$ lit/m^2 = 0.72 lit/s = 43.33 lit/min

$$Q_P \times 0.9 = Q \quad \Rightarrow Q_P = \frac{Q}{0.9} = \frac{43.33}{20} = 48.15 \frac{lit}{\min}$$

(b) Discharge rate per nozzle, $q = \dfrac{Q}{n} = \dfrac{43.33}{20} = 2.167 \dfrac{lit}{\min}$

(c)



Spray angle, $\theta = 60^0$, H = height when overlap 50%,
h = height when no overlap

$$\tan\frac{\theta}{2} = \frac{20}{h} = \frac{30}{H}$$

$$\Rightarrow \tan 30 = \frac{20}{h} = \frac{30}{H}$$

$$\Rightarrow h = \frac{20}{\tan 30} = 36.64cm$$

$$\Rightarrow H = \frac{30}{\tan 30} = 51.96cm$$ (Ans)

(8) The peak of a flood hydrograph due to a 6-h storm is 470 m^3/s. The mean depth of rainfall is 8.0 cm. Assuming an average infiltration loss of 0.25 cm/h and a constant base flow of 15 m^3/s, estimate the peak discharge of a 6-h unit hydrograph for this catchment.

Ans:

P = 8 cm, W_{index} = 0.25 cm/h, Base flow = 15 m^3/S

$$W_{index} = \frac{\sum P - ER}{\sum t} \Rightarrow 0.25 = \frac{8 - ER}{6} \Rightarrow ER = 6.5cm$$

Peak of DRH = Peak of flood hydrograph – base flow
= 470 – 15 = 455 m^3/s

Peak discharge of unit hydrograph $= \frac{\text{Peak of DRH}}{\text{ER}} = \frac{455}{6.5} = 70\ m^3/s$ (Ans)

(9) A confined horizontal aquifer of thickness 15 m and permeability K=20 m/day connects two reservoirs M and N situated 1.5 km apart. The elevations of the water surface in reservoirs M and N measured from the top of the aquifer are 30.0 m and 10.0 m respectively. If the reservoir M is polluted by a contaminant suddenly, how long will it take the contaminant to reach the reservoir N ? assume porosity of aquifer, n = 0.3.

Ans:

H = 15 m, K = 20 m/day, n = 0.3
ΔL = 1.5 km, Δh = 30 – 10 = 20 m

$$\text{Porosity, } n = \frac{V}{V_a} = \frac{ki}{\Delta L/\Delta t} = \frac{k\,\Delta h/\Delta L}{\Delta L/\Delta t}$$

$$\Rightarrow n = K\frac{\Delta h}{\Delta L} \times \frac{\Delta t}{\Delta L}$$

$$\Rightarrow \Delta t = \frac{n\Delta L^2}{K\Delta h} = \frac{0.3 \times (1500)^2\, m^2}{20\dfrac{m}{day} \times 20m} = 1.25 day \times 1500 = 1687.5 day$$

$= 4.62$ yrs (Ans)

(10) Calculate the "Rainfall Erosivity Index" for the following storm data.

Time since the beginning of storm (min)	0	10	20	30	40	50	60
Cumulative Rainfall (mm)	0	5	9	16	22	30	34

Ans:

Δt (min)	10	10	10	10	10	10
ΔP (mm)	5	4	7	6	8	4
I (mm/hr)	30	24	42	36	48	24

$I \leq 76$ mm/hr $\Rightarrow E_i = 0.119 + 0.0873\, I$ MJ/ha mm

E_i (MJ.ha mm)	0.248	0.239	0.26	0.255	0.266	0.239
$E_i \times \Delta P$ (MJ/ha)	1.24	0.956	1.82	1.53	2.128	0.95

$E = \sum (E_i \times \Delta P) = 8.624$ MJ/ha
Rainfall erosivity index = $E.I_{30}$
$I_{30} = 21/30 \times 60 = 42$ mm/hr
$\therefore$ REI $= E \times I_{30} = 8.624 \times 42 = 362.2$ MJ.mm/ ha. hr (Ans)

(11) Design a trapezoidal open ditch to drain 500 ha of land having a drainage coefficient of 3 cm. The soil is silt loam (side slope = 1.5:1; maximum permissible flow velocity = 0.5 m/s) and

maximum permissible slope of the channel bed is 0.1 %. Assume Manning's n = 0.04.

Ans:

A = 500 ha, DC = 3 cm, Z = 1.5:1, n = 0.04

V_{max} = 0.5 m/s (Permissible) = V

S_{max} = 0.1 % (Permissible) = S

$\therefore$ DC = 3 cm i.e. D = 3 cm in 24 hr

$$\Rightarrow DC\ (m/day) = \frac{Q\left(m^3/day\right)}{A\left(m^2\right)}$$

$\Rightarrow Q\left(m^3/day\right) = 10^4\ m^2 \times 500 \times 0.03$ m/day = 1.736 m^3/sec.

Q = AV $\Rightarrow$ A = Q/V = 1.736/0.5 = 3.47 m^2

Again V = 1/n $R^{2/3}$ $(0.001)^{1/2}$ $\Rightarrow$ R = 0.5029 m = A/p

$$\Rightarrow P = A/R = \frac{3.47}{0.5029} = 6.89\ m$$

$A = bd + zd^2 = 3.47$ (1)

$P = b + 2d\sqrt{z^2+1} = 6.89$ m (2)

$Bd + 1.5\ d^2 = 3.47$

$B + 2d\sqrt{3.25} = b + 3.6\ d = 6.89$

$\Rightarrow b = 6.89 - 3.6\ d$

$6.89\ d - 3.6\ d^2 + 1.5\ d^2 = 3.47$

$\Rightarrow 2.1\ d^2 - 6.89\ d + 3.47 = 0$

$$D = \frac{-(-6.89) \pm \sqrt{(6.89)^2 - 4\times 2.1\times(+3.47)}}{2\times 2.1}$$

$$= \frac{6.89 \pm 4.28}{4.2} = 2.65 \text{ or } 0.62\ m$$

b = 6.89 – 3.6 x 2.65 = negative ($\Rightarrow$ not applicable)

b = 6.89 – 3.6 x 0.62 = 4.658 m

$\therefore$ Bottom width of the channel, b = 4.658 m,

depth of the channel, d = 0.62 m

Top width of the channel, T=b + 2dZ

= 4.658 + 2 x 0.62 x 1.5 = 6.518 m (Ans)

(12) Determine the application uniformity, C_u for the following depths of infiltration in cm measured around a field.

4.0	4.0	3.4
3.9	3.5	2.7
2.6	3.3	2.6
3.7	2.8	3.2

Ans:

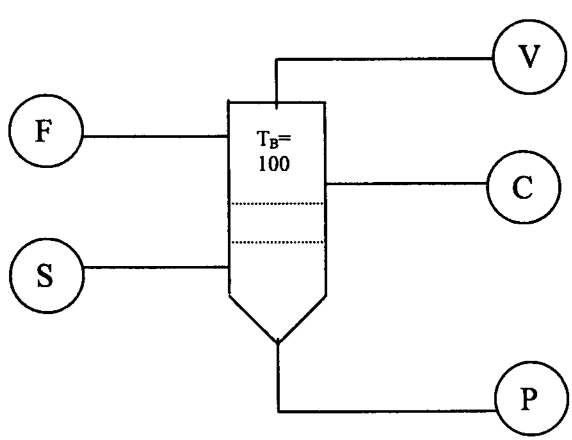
Average depth of infiltration, d = Σd/n = 39.7/12 = 3.3 m

$$\bar{y} = \frac{\Sigma(\bar{d} - d)}{n} = (7+.7+1+.6+.2+.6+.7+0+.7+.4+.5+0.1)./12 = 0.44 \text{ m}$$

$$\text{Application uniformity, } C_u = 1 - \frac{\bar{y}}{\bar{d}} = 1 - \frac{0.44}{3.3} = 86.66\% \qquad \text{(Ans)}$$

(13) A single effect evaporator concentrates pineapple juice at 101.3 kPa (atmospheric pressure) from 10 to 50 % total soluble solids (weight basis). Saturated steam at 205 kPa is used as indirect heating medium. Calculate the vapour (V) and product (P) flow rates, and steam consumption (S) for a feed rate (F) of 7 kg/s. Assume only latent heat of condensation is available for heating the feed that enters at its boiling point at 100 °C. The enthalpies of saturated steam, condensate and vapour produced are 2707, 503 and 2676 kJ/kg respectively. The heat capacity value for both feed and output liquid is 4.187 kJ/kg-K and the latent heat of vapourization at 100°C is 2257 kJ/kg

Ans:



Feed (F):
$C_{PF} = 4.187$ KJ/kg, $F = 7$ kg/S
$X_F = 0.1$, $T_F = 100°C$
Condensate (C) :
$H_c = 503$ KJ/kg
Product (P):
$X_p = 0.5$, $C_{pp} = 4.187$ KJ/kg-°K
Vapour (V):
$H_V = 2676$kJ/kg
Saturated steam (S):
$H_s = 2707$ KJ/kg , $P_S = 205$kPa
$F = P + V$ (1)
$F X_F = P.X_p$ (2)
$P = 1.4$ kg/s
$V = F - P = 7 - 1.4 = 5.6$ kg/s
$F. H_F + S. h_s = V. h_V + P. h_p + C. H_c$ (3)
$\Rightarrow F. h_F + S (h_s = h_c) = V. h_v + P.h_p$
$\Rightarrow F. h_F + S. \lambda = V. h_v + p\ h_p$
$\Rightarrow F. C_{PF} (T_F\text{-}0) + S\lambda = V. h_V + P. C_{pp} (T_p\text{-}0)$
$\Rightarrow (7 \times 4.187 \times 100) + (S \times 2257 = (5.6 \times 2676 + (1.4 \times 4.187 \times 100)$
$\Rightarrow S = 5.6$ kg/s (Ans)

(14) A 5 m long screw conveyor with 30 cm screw diameter, 15 cm shaft diameter and 28 cm screw pitch rotates at 300 rpm. Calculate the delivery capacity of this screw conveyor (m^3/h) if the actual capacity is 50 % of the theoretical capacity. Also calculate the actual power required for transportation of wheat (bulk density 770 kg/m^3) if the material factor is 0.4 and power transmission efficiency is 50 %.

Ans:
Length (L) = 5 m, $\rho = 770$ kg/m^3
Screw diameter (D) = 30 cm = 0.3 m
Shaft diameter (d) = 0.15 m, Screw Pitch (s) = 0.28 m, N = 300 rpm
Material factor (F_1) = 0.4,
$Q_{ac} = Q_{th} \times \psi = (AV) \times \psi = \pi/4\ (D^2 - d^2) \times SN \times \psi$
Here $\psi = 50\ \% = 0.5$
$\therefore Q_{ac} = \pi/4\ (0.3^2 - 0.15^2) \times 0.28 \times 300/60 \times 0.5 = 133596\ m^3/hr$
Power = $\rho QL\ F_1\ F = 770 \times 133.596 \times 5 \times 0.4 \times 1 = 0.56$ KW
Actual power required = Power/n_T = 0.56/0.5 = 1.12 KW (Ans)

(15) A basket centrifuge, used for cream separation from milk, has inner and outer diameters of 30 and 32 cm respectively. This centrifuge develops an rpm of 7000 in 90s. The density of basket material is 7850 kg/m^3 and the height of the centrifuge is 40 cm. What horse power motor is needed to start the empty centrifuge ?

Ans:

$D_i = 30$ cm $\Rightarrow R_i = 15$cm, $\rho_B = 7850$ kg/m^3 , N = 7000 rpm, T = 90S

$D_0 = 32$ cm $\Rightarrow R_0 = 16$cm , Height of centrifuge, L = 40 cm

Note: rpm of 7000 in 90 sec

Energy required, $E = (\rho_B L)(N^2\pi^3)(R_0^4 - R_i^4)$ (1)

Putting respective values in equation (1)

E= 197.596 kJ

$\Rightarrow$ Horse power of motor, P = E/t = 197.596/90 = 2.1955 kW

=2. 943 HP (Ans)

(16) Spherical soyabeans of 3 mm diameter are packed in a cylinder of 30 cm height. The pressure drop while blowing air through the packed soyabean column is 24.5 kPa. The pressure reading at the top outlet of the bed is 2 bar. The velocity of air in the empty cylinder is 2.25 m/s. Viscosity of air is 2 x 10^{-5} Pa-s. Obtain the porosity of the bed. Temperature of air is 30°C. Molecular mass of air is 28.97 kg/kg mole.

Ans:

$D_p = 3$mm, $\mu_a = 2 \times 10^{-5}$ Pa.S, V = 2.25 m/s

Height of bed = 0.3 m = ΔL, Pressure drop= ΔP = 24.5 kPa

Pre reading at top outlet of bed = $P_2 = 2$ bar $= 2 \times 10^5$ N/m^2

$M_B = 28.97$ kg/kg mole, $T_a = 30$°C

$P_1 = P_2 + \Delta P = 2 \times 10^5/1000 + 24.5 = 224.5$ kPa.

$P_{av} = (P_1 + P_2)/2 = (224.5 + 200)/2 = 212.25$ kPa.

$PV = MRT \Rightarrow P = (M/V)RT = \rho RT$ (1)

$$\Rightarrow \rho_{av} = P_{av}/RT = \frac{212250}{\frac{8314}{28.97} \times 303} = 2.44 kg/m^3$$

$G' = \rho V' = \rho_{av} V'$ (2)

$\therefore G' = 2.44 \times 2.25 = 5.49$ kg/m^2-s

$$Re = \frac{\rho D_p V'}{(1-\epsilon)\mu} = \frac{D_p G'}{(1-\epsilon)\mu} = \frac{3\times 10^{-3} \times 5.49}{(1-\epsilon)\times 2.5 \times 10^{-5}} \quad (3)$$

$$\frac{\Delta P \rho}{(G')^2} \times \frac{D_P}{\Delta L} \times \frac{\epsilon^3}{1-\epsilon} = \frac{150}{\text{Re}} + 1.75 \qquad (4)$$

Now substitute value of Reynolds's number, Re from equation (3) into equation (4) and calculate value of porosity, ϵ of the bed.

(17) A cold storage room is to be constructed with an inner layer of 5 mm wood board, a middle layer of corkboard and an outer layer of 10 mm of brick. Air inside the cold storage is to be maintained at 5°C. The maximum air temperature outside the cold storage is expected to reach 50°C. Thermal conductivities for wood, corkboard and brick are 0.15, 0.043 and 0.69 W/m-K respectively. The convective heat transfer coefficients of inside and outside air are 100 and 10 W/m^{2}K respectively. What thickness of corkboard is needed to keep the heat loss to 10 W/m^2 ?

Ans:

$L_1 = 5$ mm, $L_3 = 10$ mm, $T_i = 5°C$, $T_0 = 50°C$

$K_1 = 0.15$ W/m-k, $K_2 = 0.043$ w/m-k, $K_3 = 0.69$ w/m-k

$h_i = 100$ w/m^2 – k, $h_0 = 10$ w/m^2 – k, $Q = 10$ w/m^2

$$Q/A = \frac{T_i - T_0}{\frac{1}{h_i} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \frac{1}{h_0}}$$

$$\Rightarrow 10 = \frac{50-5}{\frac{1}{100} + \frac{5\times10^{-3}}{0.15} + \frac{L_2}{0.043} + \frac{10\times10^{-3}}{0.69} + \frac{1}{10}}$$

$\Rightarrow L_2 = 186.7$ mm (Ans)

2002

(1) A silo of 8 m diameter and 20 m height is loaded with grains of mass density 800 kg/m^3. If static coefficient of friction and pressure ratio both are 0.4 then what is the lateral pressure at the bottom of the silo if the latter is completely filled? What will be the percentage change in lateral pressure if the silo is filled up to 75% of its total height?

Ans:

$D = 8$ m, $H = 20$m, $\omega = 800$ kg/m^3, $K = P_L/P_V = 0.4$, $\mu' = 0.4$

Completely filled condition, $h = 20$ m

75 % filled condition, h = 15 m

Both case h > D $\Rightarrow$ Deep bin

(i) h = 20 m, R = $D/_4 = 8/_4 = 2m$

Lateral pressure at the bottom of the silo,

$$P_L = \frac{\omega R}{\mu'}\left(1 - e\frac{-\mu' kh}{R}\right) = \frac{800 \times 2}{0.4}\left(1 - e^{\frac{-0.4 \times 0.2 \times 20}{2}}\right) = 2795\frac{kg}{m^2}$$

(ii) h = 15 m

$$P_L = = \frac{800 \times 2}{0.4}\left(1 - e^{\frac{-0.4 \times 0.4 \times 15}{2}}\right) = 2795\frac{kg}{m^2}$$

$\therefore$ Percentage change in lateral pressure $= \dfrac{3192 - 2795}{03192} = 12.43\%$ (Ans)

(2) A steel pipe of 25 mm ID and 30 mm OD is carrying steam at 121^{0}C. The convective heat transfer coefficient due to steam flow is 5000 W/m^2–K. The steel pipe has a glass wool insulation of 10mm thickness on the outside. The near stagnant air at 30^{0}C on the outside of the insulation provides a heat transfer coefficient of 10 W/m^2 – K. Thermal conductivities of steel and insulation are 43 and 0.031 W/m–K respectively. Calculate the overall heat transfer resistance based on inside surface area of the pipe. What is the quantity of heat lost for every metre length of the pipe?

Ans:

h = 5000 w/m^2-K, h_0 = 10 w/m^2-k, T_0 = 30°C

K_1 = 43 W/m-k, K_2 = 0.031 W/m-k, T_i = 121°C

D_2 = 20.015 m $\Rightarrow$ r_2 = 0.015 m

D_2 = 25 mm $\Rightarrow$ r_1 = 0.0125 m

r_3 = 0.015 + 0.01 = 0.025 m

$$\text{Heat lost, } Q = \frac{2\pi L(T_i - T_0)}{\frac{1}{K_1}ln\left(\frac{r_2}{r_1}\right) + \frac{1}{K_2}ln\left(\frac{r_3}{r_2}\right) + \frac{1}{h_i r_1} + \frac{1}{h_0 r_3}}$$

Neglecting $1/h_i r_i$

$$\Rightarrow \frac{Q}{L} = \frac{2\pi(121° - 30°)}{\frac{1}{43}\ln\left(\frac{0.015}{0.025}\right) + \frac{1}{0.031}\ln\left(\frac{0.025}{0.015}\right) + \frac{1}{10 \times 0.025}} = 27.9\frac{W}{m}$$

Calculation of overall heat transfer resistance, R_i, is based on surface area of the pipe

$Q = A_iU_i \Delta T = A_iU_i (T_i - T_0) = (T_i - T_0)/R_i$

$$\Rightarrow R_i = \frac{(T_i - T_0)}{Q} = \frac{(121-30)}{27.9} = 3.26\frac{m-^oK}{watt} \qquad \text{(Ans)}$$

(3) Obtain the mass density of water vapour in certain drying operation if thermal conductivity of air is 0.03 W / m – K, density of air is 0.991 W / m^3, specific heat capacity of air is 1 kJ/ kg – K and mass transfer coefficient in equimolar counter – diffusion based on molar concentration gradient is 0.323m/s. Convective heat transfer coefficient is 35 W / m^2 – K.

Ans:

$K_{air} = 0.03$ W/m-k, $\rho_{air} = 0.991$ kg/m^3

C_p air = 1 kJ/kg-K = 1000 J/kg-k, $h_m = 0.323$ m/s

h = convective heat transfer coefficient = 35 w/m^2 – k

$$\alpha = K/\rho C_p \qquad (1)$$

$$\Rightarrow \alpha = \frac{0.03}{0.991\times1000} = 3.03\times10^{-5}$$

$$h/hm = \rho\, C_p\, (\alpha / D_{AB})^{2/3} \qquad (2)$$

$$\therefore \frac{35}{0.323} = 0.991\times1000\times\left(\frac{3.03\times10^{-5}}{D_{AB}}\right)^{2/3}$$

$$\Rightarrow D_{AB} = 8.38 \times 10^{-4}\ m^2/s \qquad \text{(Ans)}$$

(4) Milk pasteurization is carried out either at 85^{0}C temperature for 4 s or at 71^{0}C for 40 s. In both cases the sterilizing value is 8. What are the decimal reduction times for these two processes? Calculate the Z values for reference temperatures of 71^{0}C and 85^{0}C. Also obtain the activation energy value for pasteurization process.

Ans:

Sterilising value = log (N_0/N) = 8 = number of log cycle reduction

(i) $F_1 = D_1 \log_{10} (N_0/N_1)$

$\Rightarrow$ 4 sec = D_1 x (8) $\Rightarrow D_1 = 0.5$ Sec

(ii) $F_2 = D_2 \log_{10} (N_0/N_2) = D_2 \times 8$

$\Rightarrow 40 = D_2 \times 8$

$\Rightarrow D_2 = 5$

(iii) Z = value is constant for a process

$$\frac{D_2}{D_1}=\frac{F_2}{F_1}=\frac{t_2}{t_1}=\frac{K_2}{K_1}=10^{\left(\frac{T_1-T_2}{Z}\right)}=Q_{10}{}^{\left(\frac{T_1-T_2}{10}\right)}=e^{\left[\frac{1}{T_2}-\frac{1}{T_1}\right]}$$

$$\Rightarrow \frac{5}{0.5}=10\left(\frac{85-71}{Z}\right)\Rightarrow 10=10^{\left(\frac{14}{Z}\right)}\Rightarrow Z=14^{o}C$$

(iv) $\dfrac{K_2}{K_1}=e^{\left[\frac{1}{T_2}-\frac{1}{T_1}\right]}=\dfrac{F_2}{F_1}=\dfrac{D_2}{D_1}$

$$\Rightarrow \frac{5}{0.5}=e^{-\frac{Ea}{8314}\left(\frac{1}{(273+85)}-\frac{1}{(273+71)}\right)}$$

$\Rightarrow 10 = e^{-Ea(-1.36 \times 10^{-8})}$

$\Rightarrow \ln 10 = + Ea\ (1.36 \times 10^{-8})$

$\Rightarrow$ Ea = 169.307.7/1000 KJ/kg = 169.31 kJ/kg (Ans)

(5) The values of absolute and saturation humidity of air in a room are 0.22 and 0.04 kg H_2O/kg dry air, respectively. What are the values of partial water vapour pressure, saturation water vapour pressure, relative humidity, humid heat and humid volume? Total pressure of air in the room is 1 atmosphere

Ans:

Atmospheric pressure, P =101.325 kPa and at this pressure, room temperature is 250C

(i) Absolute humidity, $H = 0.022 = 0.622(\dfrac{P_V}{P-P_V})$

$$\Rightarrow 0.022 = 0.622\left(\frac{P_v}{101.325-P_v}\right)\Rightarrow P_v = 3.46\text{kPa}$$

(ii) Saturation humidity, $H_s = 0.04 = 0.622\ \dfrac{P_s}{P-P_s}$

$$\Rightarrow 0.04 = 0.622\left(\frac{P_v}{101.325-P_s}\right)\Rightarrow P_s = 6.122kPa$$

(iii) relative humidity, $\phi = \dfrac{P_v}{P_s}=\dfrac{3.46}{6.122}=0.565$

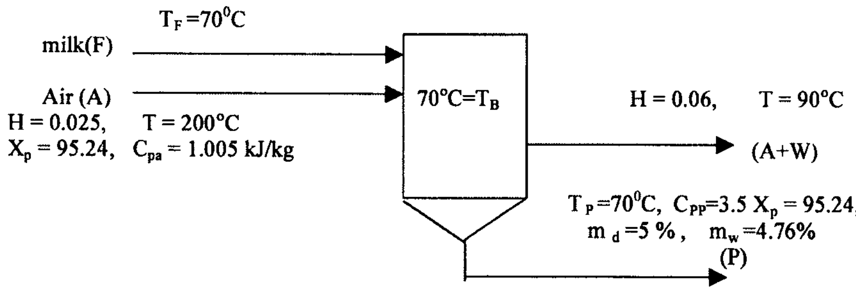
(iv) humid heat, $C_s = 1.005 + 1.88H$ KJ/kg-°K
$= 1.005 + 1.88 \times 0.022 = 1.046$ kJ/kg-°K
(v) humid volume, $V_H = (0.00283 + 0.00456H)(t + 273)$
$= (0.00283 + 0.00456 \times 0.022)(25 + 273)$
$= 0.873\ m^3/kg$ (Ans)

(6) In a spray drying operation 1000 kg/h flow rate of milk at a TS of 50% is dried to a moisture content of 5% on dry basis. Air at 0.025 kg H_2O/kg dry air absolute humidity and 200°C temperature is used for drying. The outlet air humidity and temperature are 0.06 kg H_2O/kg dry air and 90°C respectively. Evaporation temperature is 70 °C. Calculate the quantity of air required per kg of milk if feed is sent at evaporation temperature. Specific heat capacities of dry air, powder and water vapour are 1.005, 3.5 and 1.88 kJ/kg-K respectively. Ambient air temperature is 40°C. Latent heat (ΔH) of evaporation may be obtained from the following Table.

Temperature (°C)	40	70	90	200
ΔH (kJ/kg)	2407.0	2334.0	2283.3	1938.5

Ans:
Mass balance:
$F. X_F = P. X_P$
$1000 \times 0.5 = P \times 0.9524$
$\Rightarrow P = 525$ kg
$\therefore$ Water evaporated (W) = F – P = 1000 – 525 = 475 kg
Alternate method:
Initial moisture content = 1000 – 1000 x 0.5 = 500 kg
$\Rightarrow$ Dry matter = 500 kg
FMC = 500 x 5/100 = 25 kg
$\therefore$ Water evaporated = 500 – 25 = 475 kg

$F = 1000$ kg/hr, $X_F = 0.5$



$F.h_F + A.\ h_A = A.\ h_A + W\lambda + P.\ h_p$

$\Rightarrow F(C_{pm}\ T_m) + A(C_{pa}T_a) = A(C_{pa}\ T_a) + W\ \lambda + P(C_{pp}T)$

$\Rightarrow 1000 \text{ x } (0.93 \text{ x } 4.18 \text{ x } 70) + A\ (1.005 + 1.88\ H_1) \times 200 =$

$A\ (1.005 + 1.88\ H_2) \text{ x } 90 + 473.68 \text{ x } (2334 + 1.88 \text{ x } 70) + 526 \text{ x } 3.5 \text{ x } 70$

Putting $H_1 = 0.025$, $H_2 = 0.06$ in above equation, calculate value of A (kg/hr)

Note

C_p (milk) = 0.93 kcal/kg-°K

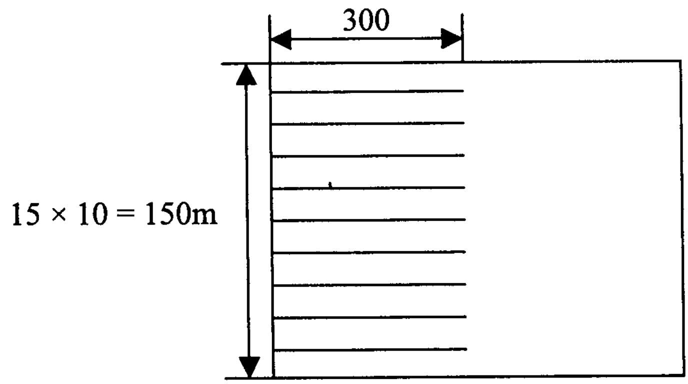
X_F is calculated on wet basis moisture content

(7) A sprinkler irrigation system is designed to deliver a design daily irrigation requirement of 7 mm and a desired depth of 15 mm. Ten 300 metre-long laterals with sprinklers in a 15 m square-spacing pattern are operated simultaneously to irrigate 25 ha field. Determine the maximum time between successive irrigations and the sprinkler system capacity required for a set length of 8 hrs. Assume that 1hour in each set is required to move each lateral and an application efficiency of 80%

Ans:

(i) Length moved = $\dfrac{25 \times 10^4}{150}$ =1666.67 m

Number of moves lengthwise $= \dfrac{1666.67}{300} = 5.56 \cong 6$ moves



Set time = 8 + 1 (move hr) = 9 hours
Total time = 9x 6 = 54 hours

$$\Rightarrow \text{Sprinkler system capacity, } Q = \frac{Ad}{t.E} = \frac{25 \times 10^4 \times \dfrac{15}{1000}}{54 \times 0.8} = 86.8 \ m^3/hr$$

= 24.1 l/s

(ii) Maximum time between successive irrigations,
F(days)=15/7=2.1days

(8) On-line drip emitters are placed at 1 m spacing on a 50 m long 16 mm diameter lateral. The design discharge of each emitter is 1 lph. Using density of water as 0.998 g/cm^3, dynamic viscosity of water 1.002 x 10^{-3} N-s/m^2 at 20^0 C temperature, the reduction factor due to 50 outlets as 0.343 and equivalent length due to loss from the emitter barb as 1 m, determine the (a) Reynolds number, (b) friction factor and (c) head loss due to friction in the lateral pipe.

Ans:

Spacing on lateral = 1 m, L_L = = 50 m,D_L = 16 mm
q = 1 lit/h, ρ_W = 998 kg/m^3, μ_w = 1.002 x 10^{-3} N-S/m^2, L_e = 1m
Reduction factor for 50 outlet, F = 0.343
(a) Velocity of water flow,

$$V = Q/A = \frac{\left(1\times10^{-3}\frac{m^3}{h}\right)\times50}{\frac{\pi}{4}D_L^2} = \frac{\left(10^{-3}\frac{m^3}{s}\times4\right)\times50}{3600\times\pi\times0.016^2} = 0.069 \text{ m/s}$$

Reynolds number, $R_e = \frac{\rho DV}{\mu} = \frac{998\times0.016\times1.38\times10^{-3}\times50}{1.002\times10^{-3}} = 1100$

(b) Friction factor, $4f = 4\times\frac{16}{R_e} = 4\times\frac{16}{1100} = 0.058$

(c) $h_f = \frac{(4f)L_L V_L^2}{2gd_L} = \frac{2.9\times50\times(1.38\times10^{-3})^2\times50}{50\times2\times9.81\times0.016} = 0.044$ m

∴ Head loss due to friction in the lateral pipe = (0.044 x 0.343) + 1
= 1.015 m (Ans)

(9) Calculate the discharge from a confined well of 100 mm diameter if the drawdown measured at radial distances of 20 m and 50 m from the centre of the well are 0.60 m and 0.20 m respectively. Aquifer thickness is 15 m, hydraulic conductivity is 2.5 x 10^{-4} m/s and the radius of influence is 500 m. Also determine the specific capacity of the well.

Ans:
K = 2.5 x 10^{-4} m/s, R = 500 m, b = 15 m, S_1 = 0.6 m
S_2 = 0.2 m, r_1 = 20 m, r_2 = 50 m
D = 0.1 m ⇒ r_w = 0.05 m
(i) Discharge from confined well,

$$Q = \frac{2\pi kbs}{\ln(R/r_w)} = \frac{2\pi TS}{\ln(R/r_w)} = \frac{2\pi kb(H-h_w)}{\ln(R/r_w)} = \frac{2\pi kb(h_2-h_1)}{\ln(r_2/r_1)}$$

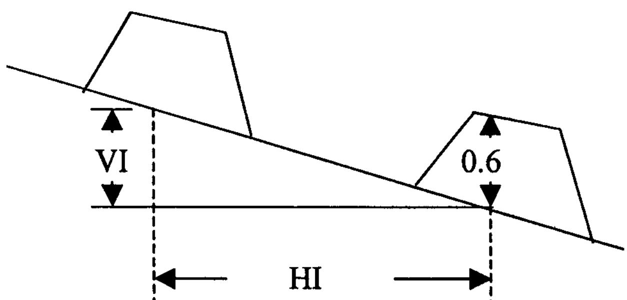
$$= \frac{2\pi\times2.5\times10^{-4}\times15(0.6-0.2)}{\ln(50/20)} = 0.01 \text{ m}^3/\text{s}$$

(ii) Specific capacity = Q/S $= \frac{2\pi kbs}{\ln\left(\frac{R}{r_w}\right)s} = = \frac{2\pi kb}{\ln(R/r_w)}$

$$= \frac{2\pi \times 2.5 \times 10^{-4} \times 15}{\ln\left(\frac{500}{0.05}\right)} = 2.55 \times 10^{-3}\ m^3/s\text{-}m \qquad \text{(Ans)}$$

(10) Determine the excess runoff to be disposed of through the outlet of a contour bund using the following data. Land slope - 2.5%, top width of bund - 0.5 m, height - 0.6 m, height of crest above ground level - 0.3 m, slope of bund - 1.5:1, V.I. - 0.85 m, length of bund - 250 m, intensity of rainfall for a 10 year-recurrence interval and for the time of concentration - 85 mm/h and constant infiltration rate during the peak rainfall - 25 mm/h. Assume no storage behind the bund before the peak rainfall.

Ans:



S = 2.5 % Z = 1.5:1
T = 0.5 m VI = 0.85
H = 0.6 m L = 250 m (of bund)
I = 85 mm/hr f = 25 mm/hr
Height of crest above ground level = h = 0.3 m

$$\frac{S}{100} = \frac{VI}{HI}$$

$$\Rightarrow \frac{2.5}{100} = \frac{0.85}{HI}$$

$$\Rightarrow HI = \frac{0.85 \times 100}{2.5} = 34 \text{ meter}$$

Area of catchment between 2 bunds = HI X L_{Bund}

$\Rightarrow$ A = 34 x 250 = 8500 m^2

$$\text{Runoff}, R = (I\text{-}f) \times A = (I\text{-}f) \times HI \times L_{Bund} = \left(\frac{85-25}{1000}\right) \times 8500 = 510 \text{ m}^3$$

Storage volume, $S = A_w \times L_{Bund}$

$$\Rightarrow S = \frac{h^2}{2}\left(Z + \frac{100}{5}\right) \times L_{Bund} = \frac{0.3^2}{2}\left(1.5 + \frac{100}{2.5}\right) \times 250 = 466.875 \text{ m}^3$$

$$\therefore \text{Excess runoff to be disposed of} = R - S = 510 - 466.875 = 43.125 \text{ m}^3 \text{(Ans)}$$

(11) Water flows at the rate of 8×10^{-8} m^3/s in upward direction through a column of fine sand with coefficient of permeability of 4×10^{-5} m/s. The thickness of the column is 0.2 m and the cross-sectional area is 4×10^{-3} m^2. Find the effective pressure at the bottom and middle of the column if the saturated unit weight of sand is 1800 kg/m^3.

Ans:

$Q = 8 \times 10^{-8}$ m^3/s (up) (negative), $\gamma_{sat} = 1800$ kg/m^3

$K = 4 \times 10^{-5}$m/s, $A = 4 \times 10^{-3}$ m^2 ,Thickness = 0.2 m

Z = distance from top

$$i = Q/KA = \frac{8\times10^{-8}}{4\times10^{-5}\times4\times10^{-3}} = 0.5$$

$$\gamma' = \gamma_{sat} - \gamma_w = \frac{1800\times9.81}{1000} - 9.81 = 7.848 \text{ kN/m}^3$$

Effective pressure, $6' = p' \pm P_s = P' - P_s = z\gamma' - h\,\gamma_w = z\gamma' - iz\gamma_w$

(i) First case, Z = 0.1 m

$\sigma' = 0.1 \times 7.848 - 0.5 \times 0.1 \times 9.81 = 0.29$ kN/m^2

(ii) Second case, Z = 0.2 m

$\sigma' = 0.2 \times 7.848 - 0.5 \times 0.2 \times 9.81 = 0.589$ kN/m^2 (Ans)

(12) In a subsurface drainage system, the peak discharge which has to flow through the tile drain when it just flows full is given by

$Q = 6.715 \times 10^{-4}\, S^{0.5}\, n^{-1}$

Where, Q = discharge, m^3/s,

S = drain bed slope,

n = Manning's roughness coefficient. Calculate diameter of the tile drain system.

Ans:

$$Q = AV = \left(\frac{\pi}{4}D^2\right)\times\left(\frac{1}{n}R^{2/3}S^{1/2}\right) = \frac{\pi}{4}D^2 \times \frac{1}{n}\left(\frac{D}{4}\right)^{2/3} S^{1/2}$$

$\Rightarrow 6.715 \times 10^{-4} \times S^{1/2} \times n^{-1} = \pi/4\, D^2 \times n^{-1} \times (D/4)^{2/3} \times S^{1/2}$

$\Rightarrow D = 0.099$ m (Ans)

(13) Tractors may overturn during high speed turns because of their high centre of gravity. The critical speed (U_m) of a tractor weighing W kg taking a turn at high speed is a function of the radius of the turn (r), the location of the C.G. (X_{cg}, Z_{cy}) and the distance from tractor CG to tipping axis (y). Calculate the critical turning speed at which side tipping would begin with minimum wheel spacing, given that r = 5200 mm, X_{cg} = 658 mm, Z_{cy} = 988 mm, rear tread width = 1253 mm, wheel base = 3450 mm, and W = 25.6 kN.

Ans:

r = radius of turn = 5.2 m, X_{cg} = 0.658 m, Z_{cy} = 0.988 m = Z_{eg}

T = 1.253m, X_2 = 3.45 m, W = 25.6 kN

$$U_m = \sqrt{\frac{g\left(\frac{T}{2}\right)R}{Z_{cg}.\cos\gamma}} = \sqrt{\frac{9.81\times\frac{(1.253)}{2}\times 5.2}{0.988\times 1}} = 5.68 \text{ m/s} \qquad \text{(Ans)}$$

(14) The turning moment diagram of an engine is represented by the following equation.

T = 25000 + 7650 sin2α - 6400 cos2α

Where, T = torque, N-m

α = angle moved by the crank from inner dead centre. Assuming the resisting torque to be constant, compute (a) the power developed by the engine at a mean speed of 200 rpm, (b) the change in torque at any given instant, (c) the angular acceleration of the flywheel at α = π/4 and at the moment of inertia of 45000 N-m^2 of the flywheel.

Ans:

T_α= 25000 + 7650 sin 2 α – 6400 cos 2α

T_α = torque, N.m, N_{mean} = 200 rpm

α = Angle moved by crank from inner dead centre

(b) Change in torque at any given instant is given by

$$T = T_{mean} = 1/2\,\pi \int_0^{2\pi} T_\alpha \, d\alpha$$

$$= 1/2\,\pi \int_0^{2\pi} (25000+7650 \sin 2\alpha - 6400 \cos 2\alpha).d\alpha$$

$= 1/2\ \pi\ (25000\ (2\pi) = 25000$ Nm

(a) Power developed, $P=2\pi NT = 2\pi \times 25{,}000 \times (200/60{,}000) = 523$ KW

(c) At $\alpha = \pi/4$

$T = 25000 + 7650 \times \sin(2 \times \pi/4) - 6400 \cos(2 \times \pi/4)$

$= 25000 + 7650 = 32{,}650$ N.m.

Again, $T = I\ \alpha$

$\Rightarrow 32650 = 45000 \times \alpha$

$\Rightarrow \alpha = 326050$ Nm/45000 N.m^2

$$\Rightarrow \alpha = \frac{32650 \frac{kgm}{S^2} m}{\frac{45000}{9.81} kgm^2} = 7.11 \quad \text{rad/s}^2 \qquad \text{(Ans)}$$

(15) An engine test revealed that the cylinder pressure (P_c) at the end of the compression stroke at normal cranking speeds is approximately related to the atmospheric pressure (P_a) and the compression ratio (r) of the engine in the following way $P_c = P_a .r^{1.28}$. Compute the fuel cut off ratio for diesel in a diesel engine at an absolute cylinder pressure of 3377 kPa and at a gauge pressure of 100 kPa. Assume a thermal efficiency of 32% of the engine.

Ans:

$P_c = P_a\, r^{1.28}$

P_c = cylinder pressure at end of compression = P_2

P_a = atmospheric pressure = 100 kpa = P_1

$\therefore P_2 = 100\, r^{1.28}$

Thermal efficiency of diesel engine = 32%

Ans $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = \left(\frac{V_1}{V_2}\right)^{k-1}$, pressure is in absolute terms

$\therefore 3377 = 100 \times r^{1.28}$ & $K = 1.3$

$\Rightarrow r = 15.637$

$$TE = 1 - \frac{1}{r^{k-1}}\left[\frac{c^k - 1}{K(c-1)}\right] = 0.32$$

$$\therefore 0.32 = 1 - \frac{1}{(15.637)^{1.3-1}}\left[\frac{C^{1.3} - 1}{1.3(C-1)}\right]$$

$$\Rightarrow 0.32 = 1 - \frac{1}{2.28}\left[\frac{C^{1.3}-1}{1.3(C-1)}\right]$$

$$\Rightarrow \frac{C^{1.3}-1}{1.3(C-1)} = 1.55$$

$\Rightarrow C^{1.3} - 2.015C + 1.015C = 0$

$\Rightarrow C^{1.3} - 2C + 1 = 0$

By trial and error method.

C = 12. (Ans)

(16) MF-1035 tractor has a planetary gear drive that has three planet gears each with 18 teeth carried on the carrier. The annular gear which has 54 teeth is held stationary. In the high speed arrangement the power comes into the drive on the Sun gear which also has 18 teeth and rotates clockwise at 1200 rpm giving a forward travel speed of 30 kmph. For the low speed arrangement, power comes out of the gear set on the planet carrier. Determine the forward travel speed in this arrangement. What would be the direction of rotation of the planet carrier?

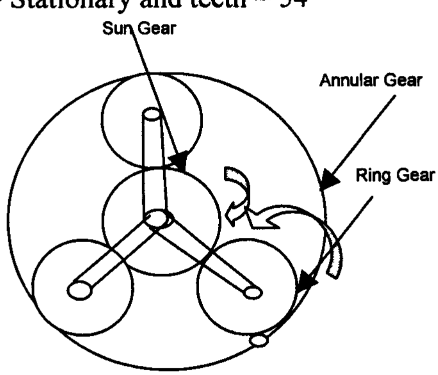
Ans:

Planetary gear drive: Sun gear = input gear = fixed gear

Annular (ring) gear = output gear = carrier gear

3 planet gears each with 18 teeth carried on carrier

An annular gear = Stationary and teeth = 54



Sun gear :

$t = 18 = t_s$, $N = 1200$ rpm, $V_s = 30$ km/hr

$\therefore$ Input – Output ratio = planetary ratio

$$= N_{in}/N_{out} = N_s/N_c = 1 + (t_r/t_s) = 1 + 54/18 = 4$$

$V_s = \pi DN$

$$\Rightarrow \frac{30}{3.6} = \pi \times D \times \frac{1200}{60} \Rightarrow D_s = 1.132 \text{ m and}$$

$D_a = 0.132 + 0.132 + 0.132 = 0.396$ m

Planetary drive:

$N_s/N_C = 1 + t_r / t_s$

$$\frac{1200}{N_c} = 1 + \frac{54}{18} \Rightarrow N_C = 300 \text{ rpm}$$

(i) Forward travel speed of arrangement, velocity of carrier = $\pi \times 0.396 \times (300/60) = 6.22$ m/sec

(ii) Direction of rotation of planet carrier is same as sun gear and planet gear and opposite to ring gear.

(17) A tractor seat is to be designed to give maximum comfort to a tractor driver. The designer wishes to use a spring and damper arrangement to attenuate the vibration levels experienced by the operators. The mass of the operator varies between 50 and 100 kg. The static spring deflection of 100 mm for the seat and operator system could be taken at a tractor chassis frequency of 4.4 Hz. Determine the damping coefficient of the damper used and the undamped natural frequency of the tractor seat at a maximum transmissibility of 0.289.What will happen to the sensitivity of the suspension system at a tractor chassis frequency of 2.5Hz ?

Ans:

Operator mass (M) = 50 to 100 kg

Static spring defection = Δx = 100 mm = 0.1 m

Tractor chassis frequency, η_t = 4.4 Hz

Transmissibility = T = 0.289

(i) undamped natural frequency of the tractor seat,

$$\omega_s = \sqrt{\frac{K}{M}} = \sqrt{\frac{g}{x}} = \sqrt{\frac{9.81}{0.1}} = 9.9 \text{ rad/s}$$

$\omega_t = 2\pi\eta_t = 2\pi \times 4.4 = 27.646$ rad/sec

(ii) $$T^2 = \frac{1 + 4\in^2\left(\frac{\omega_t}{\omega_s}\right)^2}{\left[1 - \left(\frac{\omega_t}{\omega_s}\right)^2\right] + 4\in^2\left(\frac{\omega_t}{\omega_s}\right)^2}$$

$$\Rightarrow 0.289^2 = \frac{1+4\in^2\left(\frac{27.646}{9.9}\right)^2}{\left[1-\left(\frac{27.646}{9.9}\right)^2\right]+4\in^2\left(\frac{27.646}{9.9}\right)^2}$$

$$\Rightarrow 0.289^2 = \frac{1+31.19\in^2}{46.215+\in^2\times 31.19}$$

$\Rightarrow 3.86 + 2.6\in^2 = 1 + 31.19\in^2$

$\Rightarrow \in = 0.316$

(iii) Sensitivity of the suspension system,

$$S = \frac{N_1 - N_2}{\left(\frac{N_1 - N_2}{2}\right)} = \frac{4.4-2.5}{\left(\frac{4.4-2.5}{2}\right)} = 0.55 = 55\,\%$$ (Ans)

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Chapter 5

Objective Type Questions & Solution (1988-2002)

1988

No-1: Give your answers by writing appropriate words against the blanks under each item

1.1 Butter is an emulsion of_____ in_____.

1.2 Hard water when heated forms scales of _____, ________etc.

1.3 When drag force equals the force of gravitation, the falling particle is said to have attained ____velocity.

1.4 Falling rate drying is mainly controlled by a mechanism known as _____.

1.5 Energy required to produce a change in size of a particle is a power function of its_______ before the operation.

1.6 Raoult's Law predicts water activity for dilute binary solutions by giving ______ of water as a function of mole fraction of water in the solution.

1.7 ______separates the discs on a gang of a tandem disc harrow.

1.8 A______ machine is one in which the propelling power unit is an integral part of the implement.

1.9 Theoretical thermal efficiency, η of a diesel cycle engine in terms of compression ratio $C_r = V_1/V_2$ and cut off ratio C_c is given by ________.

1.10 For annual use of machines less than 150 hrs, the annual charge for repair, maintenance and lubrication of disc harrow is ______percent of first cost of machine.

1.11 Average power developed by a pair of Indian bullocks is ______HP.

1.12 Power to drive a metering mechanism of the tractor operated planter is taken from the ______.

1.13 Reynolds number is the ratio of ______force to_______force.

1.14 A geological formation which can absorb but cannot transmit significant amount of water is called______

1.15 Imaginary lines representing equal travel times of overland flow in a watershed are called _______.

1.16 The unit hydrograph resulting from an effective rainfall over an infinitesimally small duration is called ______.

1.17 The flow in a border strip is not only spatially varied but also _______.

1.18 Pipe flow occurs in a culvert if its bed slope is______ than the neutral slope.

1.19 Pitche-atmometer is a device used for measurement of ______.

1.20 Pressure on the base of retaining wall will be fully compressive if the resultant force strikes the base within_______.

No-2: Match group I with group II using appropriate alphabet against each item.

	Group I		Group II
2.1	Lighter component is exposed to a smaller centrifugal force and a shorter residence time in a centrifuge	(A)	Levees
2.2	Lighter component is exposed to a large centrifugal force and a longer residence time in a centrifuge	(B)	Field efficiency
2.3	The outlet pipe of a cyclone is extended into the cylinder to prevent short circuiting of air from	(C)	Cream separation from milk
2.4	The compression ratio of a fan/blower is the ratio of static pressures at	(D)	Semi confined aquifer
2.5	Killing of vegetative micro organisms	(E)	Cloud point
2.6	Killing of heat resistant spores	(F)	Pasteurization
2.7	Measure of functional effectiveness of all agricultural machines	(G)	Proctor test
2.8	The temperature slightly above the solidification at	(H)	Lister plow

	which the separation of wax from oils becomes visible under prescribed conditions is called		
2.9	An indigenous plow is actually a	(I)	Inlet to outlet
2.10	Ratio of theoretical time needed to actual time needed to cover a given land by agricultural machines	(J)	Seasoning
2.11	That temperature at which the oil just flows under prescribed conditions is called	(K)	Performance efficiency
2.12	Double plow side by side without landside is a	(L)	Outlet to inlet
2.13	Specific gravity of soils	(M)	Specific speed.
2.14	Spacing of tile drains	(N)	Multipurpose plow
2.15	Setting time of cement	(O)	Water separation from oil
2.16	Timber	(P)	Vicat needle apparatus
2.17	Compaction	(Q)	Pour point
2.18	Leakage factor	(R)	Pycnometer
2.19	Pumps	(S)	Sterilization
2.20	Flood control	(T)	S.B. Hooghoudt.

No-3: Choose the appropriate answer from the multiple choices given below

3.1 Conversion of manometer height of liquid to pressure requires the knowledge of:

(A) Density of liquid only
(B) Density of water only
(C) Acceleration due to gravity and density of water
(D) Acceleration due to gravity and density of liquid

3.2 Stoke's Law holds good when:

(A) Reynolds number is too large
(B) Laminar flow
(C) Transient flow
(D) Reynolds number may have any value

3.3 When a fan is connected to a gradually expanded outlet, its:
(A) Velocity pressure increases
(B) total pressure decreases
(C) static pressure increases
(D) none of the above

3.4 Pressure loss through meter A being less than that in meter B, discharge coefficient :
(A) of meter B is higher than that of meter A
(B) of meter A is higher than that of meter B
(C) is equal for both A and B
(D) is not a function of pressure loss

3.5 Pressure losses through a butterfly valve are estimated by:
(A) expansion loss
(B) contraction loss
(C) pipe friction loss
(D) contraction and expansion loss

3.6 Convective heat transfer coefficient of a body is dependent partly upon its:
(A) temperature
(B) composition (type of material)
(C) shape and size
(D) none of the above

3.7 Natural convection is associated with:
(A) Prandtl number only
(B) Reynolds number only
(C) Grashof number only
(D) Nusselt number only

3.8 Thermal Death Time (TDT) curve is between:
(A) time Vs temperature
(B) temperature Vs log (time)
(C) time Vs log (number of survivors)
(D) none of the above

3.9 Larger decimal reduction time implies:
(A) microorganisms (m.o.) more heat resistant
(B) m.o. less heat resistant
(C) microbial growth redness with time
(D) no effect on m.o.

3.10 Psychrometric chart is made for:
(A) any pressure
(B) one atmosphere

(C) below one atmosphere
(D) above one atmosphere

3.11 Psychrometric relations developed are valid at only:
(A) any pressure
(B) one atmosphere
(C) below one atmosphere
(D) above one atmosphere

3.12 A room heater will cause the room air:
(A) no difference in relative humidity
(B) a decrease in absolute humidity
(C) an increase in absolute humidity
(D) a decrease in relative humidity

3.13 An undesirable cyclic fluctuation of energy output to input in an engine is controlled by a
(A) rotavator
(B) governor
(C) flywheel
(D) none of the above

3.14 Planters differ from a seed drill in respect of:
(A) kind of power transmission system
(B) kind of metering mechanism
(C) kind of furrow openers used
(D) all the above

3.15 There is_________number of negative plates than the total number of positive plates in a common lead acid rechargeable cell used in tractors:
(A) one less
(B) equal
(C) one more
(D) none of the above

3.16 Hill dropping of seeds can be achieved using:
(A) vertical rotor seed metering device
(B) constant opening type metering device
(C) fluted-wheel type seed metering device
(D) none of the above

3.17 _________of furrow opener is used in hard or trashy ground, and in wet, sticky soils:
(A) stub runner type
(B) full or curved runner type
(C) hoe type

(D) single disc type

3.18 To support the discs on a standard disc plow, _______ are used.
(A) heavy duty bush bearings
(B) large size ball bearings
(C) taper roller bearings
(D) single disk type

3.19 To open the land infested with stones, roots etc. for the first time, the kind of plow to be used is:
(A) mould board plow
(B) disc plow
(C) vertical disc plow
(D) sub-soiler

3.20 Three-bottom, tractor drawn, mounted type mould board plow will have:
(A) landside in the front bottom only
(B) landside in the middle bottom only
(C) landside in the rear bottom only
(D) landside in all the bottoms

3.21 Specific fuel consumption of diesel engine lies between the range of
(A) 0.10 and 0.15 kg/hp/hr
(B) 0.15 and 0.20 kg/hp/hr
(C) 0.20 and 0.25 kg/hp/hr
(D) 0.25 and 0.30 kg/hp/hr

3.22 If the speed of travel of an animal-operated seed drill is doubled the seed rate (kg/ha):
(A) remains the same
(B) is doubled
(C) is halved
(D) changes in proportion to the speed

3.23 Volumetric efficiency of automotive-type engines including tractors should fall within a range of ________ percent, depending on their design and existing operating conditions:
(A) 55-65
(B) 65-75
(C) 75-85
(D) 85-90

3.24 All internal combustion engines are equipped with
(A) battery ignition system
(B) magneto ignition system

(C) spark ignition system
(D) none of the above

3.25 In plains, one rain gauge is sufficient up to an area of
(A) 520 km^2
(B) 260 Km^2
(C) 130 km^2
(D) none of the above

3.26 Supra-rain curve is the graph plotted between:
(A) rainfall intensity Vs time
(B) rainfall Vs runoff
(D) rainfall excess Vs time
(D) rainfall excess Vs index

3.27 Recurrence interval is the average number of years during which at least once an event of a given magnitude may be
(A) equalled
(B) exceeded
(C) equalled or exceeded
(D) none of the above

3.28 Ratio of crop yield to the total amount of water used actually in the field is known as:
(A) application efficiency
(B) water distribution efficiency
(C) crop water use efficiency
(D) field water use efficiency

3.29 pH of the soil is defined as the
(A) logarithmic to the base 10 of the soil moisture tension
(B) Logarithmic to the base 10 of the atmospheric pressure
(C) P^H of soil itself
(D) None of the above.

3.30 Doubling the diameter of screen for a well in an unconfined aquifer, the increase in the discharge is only by about:
(A) 20 %
(B) 10 %
(C) 50 %
(D) 40 %

3.31 Blinding of tiles refers to
(A) trenching the drain
(B) laying the tiles
(C) Joining the tiles
(D) covering the tiles with loose earth

3.32 The dimensions of kinematic viscosity can be expressed as:
(A) $M^oL^oT^{-2}$
(B) ML^oT^{-1}
(C) $M^oL^2T^{-1}$
(D) ML^2T^2
3.33 Plate load test is conducted to determine:
(A) the ultimate bearing capacity of soil
(B) the shear strength of soil
(C) degree of compaction
(D) none of the above
3.34 Artificial gravel pack is not desirable if the respective effective diameter and uniformity coefficient are:
(A) 0.25 mm and 2
(B) 0.10 mm and 1.5
(C) 0.25 mm and 1
(D) none of the above
3.35 In sprinkler irrigation the overlap increases with the
(A) decrease wind velocity
(B) increase in wind velocity
(C) increase in height of sprinkler head
(D) decrease in height of sprinkler head
3.36 The channel capacity for a graded terrace must be
(A) slightly less than peak runoff rate
(B) equal to the peak runoff rate
(C) at least 15 % more than the run off rate
(D) at least twice the runoff rate
3.37 Vegetated water ways in comparison to irrigation canals are laid on
(A) steeper slopes
(B) flatter slopes
(C) same slopes
(D) none of the above
3.38 Energy dissipation below a hydraulic structure is achieved by providing
(A) an open drain downstream
(B) a stilling basin downstream
(C) a large hump upstream
(D) a large pit upstream

No-4: Write T: for TRUE and F for FALSE for the statements below against each question

4.1 Homogenization improves the appearance of milk.

4.2 In analysis of cyclone performance, large cyclones are proved more efficient.

4.3 Planks equation for freezing time considers heat transfer at a single temperature only.

4.4 Freezing improves storage ability of a product by killing micro organisms.

4.5 In the concept of decimal reduction time, a total microbial destruction is ensured.

4.6 Evaporation is an energy intensive process.

4.7 In milk, fat is in continuous phase.

4.8 Equilibrium moisture content of a product.is a constant value at any condition of surrounding atmosphere.

4.9 Though angle of a belt conveyor cannot exceed a certain value in order to strike a balance between its capacity and life.

4.10 If the rate of fluid shear is linearly related to the shear force, the fluid is Newtonian.

4.11 Wet separation is better than dry separation of solid particles, because the residence time of particles is less in the latter case.

4.12 Radiation does not need a conducting medium but needs a convecting medium for its propagation/emission.

4.13 Spark-plug voltage is higher at low engine rpm with less spark gap than at high engine rpm with more spark gap.

4.14 Most essential components necessary in magneto ignition system of a petrol engine are spark-plug, high tension ignition coil, condenser, breaker point assembly, battery, ignition switch.

4.15 At full throttle, the spark advance in degrees (with respect to TDC) is less at high engine speed.

4.16 In a true same, mathematically, a governor controls dN while a flywheel controls dN/dt where dN and dt are the small increments in speed and time respectively.

4.17 Increasing tilt angle within limit (15-25°), disc, plow with penetrate more.

4.18 Tractor-operated reversible plow can be used to plow the land and to open channels for irrigation.

4.19 Pull of an implement is the total horizontal force exerted by a power unit (tractor/animal) and is expressed in Kgf.

4.20 One possible method of changing the seed-rate in a grain drill is to change the speed ratio between the ground wheel and seed-metering shaft.
4.21 Alignment refers to adjustment of the outer end of a conventional reciprocating type mower and is given a lead of 2mm per metre length of cutter bar.
4.22 Shortening the beam length of indigenous plow increases the penetration and draft
4.23 Pitman, in reciprocating type mower is made of wood and alternately it experiences compressive and tensile force
4.24 In an ensilage cutter equipped with flywheel type cutter head, if the speed is doubled the feed rate becomes double but the length of cut remains unchanged.
4.25 Stream gauging station should be located just upstream from the confluence of two streams.
4.26 A 2-hour unit hydrograph means that the stream flow is for two hours.
4.27 Land management is effective in flood control.
4.28 Mole drains are effective in loose sandy soils.
4.29 Interceptor drains are placed perpendicular to the direction of ground water flow
4.30 Quicksand is a type of sand.
4.31 Pressure distribution beneath a rigid footing on a cohesive soil is uniform.
4.32 Spread footing is a type of shallow foundation.
4.33 Specific yield of an aquifer is more than its porosity.
4.34 Cavity wells are non-penetrating.
4.35 In check basin irrigation the size of basin can be larger in clay soils than in sandy soils
4.36 Sprinkler irrigation is suitable for rice crop
4.37 The specific surface area for clay is several times smaller than for silt and sand.
4.38 Archimedean screw lifts water from a well to a field.
4.39 In an open channel, the depth of flow corresponding to minimum energy head is termed as critical depth.

Answers

No-1

(1.1) fat,water, (1.2) $CaSO_4$, $MgSO_4$, (1.3)Terminal, (1.4) diffusion, (1.5) diameter, (1.6) Partial Pressure, (1.7) spool, (1.8) self propelled, (1.9)

$\eta = 1 - \frac{1}{C_r^{k-1}} \frac{C_c^{k-1} - 1}{k(C_c - 1)}$, (1.10)1.5, (1.11) 1 HP, (1.12) P.T.O, (1.13) inertial ,viscous, (1.14) aquiclude, (1.15) isochrone, (1.16) instantaneous, (1.17) unsteady , (1.18) less , (1.19) rate of evaporation, (1.20) b/3

No-2

2.1 (C)	2.2 (O)	2.3 (L)	2.4 (I)	2.5 (F)	2.6 (S)	2.7 (K)
2.8 (E)	2.9 (N)	2.10 (B)	2.11 (Q)	2.12 (H)	2.13 (R)	2.14 (T)
2.15 (P)	2.16 (J)	2.17 (G)	2.18 (D)	2.19 (M)	2.20 (A)	

No-3

3.1 (D)	3.2. (B)	3.3 (C)	3.4. (A)	3.5. (B)	3.6. (B)	3.7 (C)
3.8 (B)	3.9 (A)	3.10 (A)	3.11 (B)	3.12 (B)	3.13 (C)	3.14 (B)
3.15 (C)	3.16 (B)	3.17 (D)	3.18 (C)	3.19 (D)	3.20 (D)	3.21 (C)
3.22 (A)	3.23 (C)	3.24. (A)	3.25 (A)	3.26 (A)	3.27 (C)	3.28 (C)
3.29 (B)	3.30. (B)	3.31. (D)	3.32. (C)	3.33. (A)	3.34. (A)	3.35. (C)
3.36. (C)	3.37. (A)	3.38. (B)				

No-4

4.1 (F)	4.2 (F)	4.3 (T)	4.4 (F)	4.5 (F)	4.6 (F)	4.7 (F)
4.8 (T)	4.9 (T)	4.10 (T)	4.11 (T)	4.12 (F)	4.13 (T)	4.14 (F)
4.15 (T)	4.16. (F)	4.17. (T)	4.18. (F)	4.19 (T)	4.20 (F)	4.21 (F)
4.22 (F)	4.23 (F)	4.24 (T)	4.25 (F)	4.26 (T)	4.27 (F)	4.28 (T)
4.29 (F)	4.30 (F)	4.31 (T)	4.32 (F)	4.33 (F)	4.34 (F)	4.35 (F)
4.36 (F)	4.37 (F)	4.38 (F)	4.39 (T)			

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No 1: Write T for TRUE or F for False for each of the following statements

1.1 Respiration rate of fresh fruits and vegetables is directly related to the temperature of storage space.

1.2 Specific heat of the water component of foods is the lowest among the starch, lipid and protein.

1.3 The degree of heat treatment that is used to pasteurize milk must ensure that all micro organism of facal origin are destroyed.

1.4 Viscosity of a non-Newtonian fluid varies with the flow rate of the fluid through a pipe.

1.5 A hot body having emissivity c_1 is placed inside a large room whose walls have the emissivity c_2. The rate of heat loss from the body will be primarily governed by the value of c_1 rather than c_2.

1.6 Linear dimensions of square sieves used for particle size analysis of ground solids are in the ratio of $\sqrt{2}$ or $\sqrt[4]{2}$.
1.7 The capacity of a cream separator can be increased by increasing the number of discs.
1.8 Milk is required to be heated to about 140°C for its sterilization. A reduction of discolouration of milk will be possible by lowering the rate of heating.
1.9 Oxygen impermeability of food packaging material is more important than its water vapour impermeability.
1.10 Under the same temperature driving force a semi-solid food will freeze faster than it will thaw.
1.11 Compared to indirect type ultra high temperature sterilization of milk, direct steam injection sterilizers give better steam economy.
1.12 Effective butter making requires that cream should be churned at temperature above the freezing point of milk fat.
1.13 Air-water vapour mixture is a better heat transfer medium than the water vapour alone.
1.14 Kick's law governs the amount of energy required for grinding brittle solids.
1.15 As the area increases the average depth of precipitation increase for a particular storm.
1.16 Direct runoff is the sum of overland flow interflow and base flow.
1.17 The base flow of surface streams in the effluent seepage from the drainage basin.
1.18 Terzaghi's analysis of complete bearing capacity failure assumes: failure zones do not extend above the horizontal plane through the base of the footing.
1.19 Active earth pressure is greater than passive earth pressure.
1.20 Jacks are placed across to train the river.
1.21 Effective watershed management controls sedimentation in the reservoir but cannot modulate the flood.
1.22 Herringbone drain system is adapted to areas that have concave surface.
1.23 Intrinsic permeability is dependent on the properties of both medium and fluid.
1.24 Cavity well is constructed in an unconfined aquifer.
1.25 Infiltration rate decreases as the organic matter content of the same soil increases.
1.26 In general, if the shear stress calculated in a beam is greater than 5 kg/cm^2 shear reinforcement is made.

1.27 In a 1:3:6 concrete mixture the sand is 3/10 of the mixture.
1.28 If the ratio between the tight side and slack side tensions is too great, belt slippage will be excessive.
1.29 It is often desirable to set the front gangs of offset disc harrows at a smaller angle than the rear ones.
1.30 The declining balance method depreciates the value of a tractor at the same percentage of the value remaining each year.
1.31 Increasing the rim width of a traction wheel reduces the rolling resistance on a deformable surface at a much faster rate than by increasing its diameter in the same proportion.
1.32 A track-laying tractor employs differential unit similar to that used in a 4-wheel tractor.
1.33 In order to turn a vehicle without skidding, it is required that all the four wheels must turn about the same instantaneous centre.
1.34 Diesel cycle is more efficient than Otto or Dual cycle for the same compression ratio and the same amount of heat supplied.
1.35 In a forced feed lubrication system used in diesel tractors, the oil pressure varies from 2×10^5 to 3×10^5 N/m^2.
1.36 With a good diesel engine, there is often a more reserve of torque than with a good spark ignition engine.
1.37 The drillability of a fertilizer used in fertilizer drills is directly proportional to the angle of repose of the fertilizer.
1.38 Operating pressures below about 140 kPa are undesirable for most hydraulic nozzles used in crop sprayers.
1.39 On an average, the bullocks can exert draft force equal to one-tenth of their body weight.
1.40 In a stationary field chopper employing flywheel type cutter head, the length of cut can be increased by increasing the number of knives.

No 2: Choose the correct answer/answers from the multiple choices below

2.1 Discolouration of dry food is primarily associated with the reactions involving:
- (A) lipid, water and protein
- (B) Carbohydrates, water and protein
- (C) water and carbohydrates

2.2 .The temperature at which the water in a fruit will freeze is dependent on the amount of the following present in the fruit.
- (A) sugar
- (B) fibre

(C) oil
(D) water

2.3 Pressure drop in the following flow measuring device remains constant irrespective of the following present in the fruit
(A) venturi meter
(B) orifice meter
(C) rotameter

2.4 When heat flows in steady state through two metal plates separated by a negligibly small air gap between them, the rate of heat flow will be governed by:
(A) thermal diffusivity of air
(B) thermal diffusivity of metal plate
(C) thermal conductivity of air
(D) thermal conductivity of metal plates

2.5 Moist air at atmospheric pressure is isothermally compressed to a higher pressure. Due to compression the following property of the air will change:
(A) absolute humidity
(B) enthalpy
(C) relative humidity
(D) dew point temperature

2.6 Milk and fruit juice are deaerated before they are allowed to flow through pasteurizer. This is done in order to:
(A) reduce fouling of pasteurizer
(B) increase rate of heat transfer
(C) reduce oxidative deterioration

2.7 A self-recording rain gauge records:
(A) hourly depth of rain
(B) snow melt
(C) cumulative depth of rainfall
(D) onset and cessation of rainfall

2.8 In modified proctor test the water content dry density curve lies above the standard proctor test curve due to increased:
(A) fall of rammer
(B) cylinder diameter
(C) weight of rammer
(D) number of layers

2.9 The basic parameters considered in the design of grassed waterway are:
(A) type of grass

(B) peak discharge
(C) type of soil
(D) channel slope

2.10 Mole drains are:
(A) unlined
(B) approximately egg-shaped earthen channels
(C) formed in loamy sands
(D) effective for more than ten years.

2.11 Potential evapotranspiration depends on
(A) soil properties
(B) relative humidity
(C) type of crop
(D) elevation of the place

2.12 Size of irrigation stream in border irrigation is dependent on
(A) infiltration characteristics of the soil
(B) width of border
(C) depth of water to be applied
(D) slope steepness of the border

2.13 The properties of first class brick are
(A) clean and even surface but not smooth
(B) dull sound
(C) crushing strength in between 35 and 75 kg/cm^2
(D) a little large voids

2.14 A mould board that is used for a greater degree of pulverization is known as:
(A) sod bottom
(B) stubble bottom
(C) general purpose
(D) slat bottom

2.15 The penetration of animal-drawn disc harrows can be increased by:
(A) increasing the disc angle
(B) decreasing the tilt angle
(C) adding more dead weight
(D) all of the above

2.16 The most common metering device used on drop-type fertilizer broadcasters is:
(A) star-wheel type
(B) auger type
(C) an edge-cell, positive feed type

(D) stationary-opening type

2.17 The stability of a 4-wheel tractor up a hill can be improved by increasing the:
(A) hitch angle
(B) grade angle
(C) moment of inertia of entire tractor
(D) moment of inertia of drive wheels

2.18. When the carrier is held in a simple planetary gear drive with the sun gear driving the gear set will provide.
(A) forward reduction
(B) forward overdrive
(C) reverse reduction
(D) reverse overdrive

2.19 Cylinder loss in a combine can be reduced by:
(A) increasing the forward speed of combine
(B) increasing the cylinder peripheral speed
(C) decreasing the concave clearance
(D) all of the above

2.20 The use of a pressurized radiator cap in forced-circulation water cooling system in tractor engines helps in
(A) reducing the evaporation losses
(B) increasing the engine-operating temperature
(C) increasing the boiling temperature of water
(D) increasing the radiator-cooling capacity

No-3. Match the statement in Group I with the most appropriate statement in Group II

	Group – I		Group II
3.1	Drying of wet grain by hot air	(A)	Water activity
3.2	Majority of food spoilage	(B)	Reynolds number
3.3	Low efficiency of spray dryer	(C)	Constant enthalpy process
3.4	Loss of volatile matter due to heat developed	(D)	Microorganisms
3.5	Sugar preservation of food	(E)	High exit air temperature
3.6	Friction factor for flow through a pipe	(F)	Size reduction
3.7	Stream flow routing	(G)	Gibb

3.8	Stability analysis of finite slopes	(H)	Drop spillway
3.9	Least cost control structure at the gully head when drop is more than 5 metres	(I)	Rankine Grashoff
3.10	The conservation structure that can be standardized	(J)	Swedish circle method
3.11	For non-steady state condition, Glover equation for spacing of subsurface drains was modified by	(K)	Muskingum method
3.12	Brigation on volume basis was first introduced in Madras by	(L)	Chute spillway
3.13	In a two-way stab design the deflection at the centre parallel to either side is same was posthulated by	(M)	Schifgaarde
3.14	Backward inclination of kingpin of the tractor front axle.	(N)	Check-row planting
3.15	Accurate placing of single seeds at about equal intervals in rows	(O)	Camber
3.16	Abnormal sound in an engine during the early part of combustion	(P)	Caster
3.17	Inward inclination of kingpin of the tractor's front axle	(Q)	Detonation in S.I. engine
3.18	Accurate and indexed placement of hills to give rows in two perpendicular directions	(R)	Kingpin inclination
3.19	Abnormal sound in an engine during the later part of combustion	(S)	Precision planting
3.20	Outward inclination of tractor's front wheels	(T)	Diesel knock

No 4: Fill the blanks with appropriate word(s) or numeral value(s) against each question

4.1 Density of liquid milk fat is about ______ kg/m^3.

4.2 In-bottle sterilization of milk is done at temperatures ranging between ______and ______.

4.3 The component of milk which as the food for the microbes producing acids is_________.

4.4 Under the same temperature gradient two fluids are gaining heat from a hot solid surface maintained at constant temperature. The property of the fluids which would govern the rate of heat transfer is_______.

4.5 The recommended temperature for the drying of grains for seed purpose is about_______.

4.6 Recirculating type hot air-dryers maintain a high _______of the air inside the dryer.

4.7 The ratio of kilogram of water evaporated per kilogram of steam supplied to a three-effect evaporator without a thermo-compressor will be about _______.

4.8 The three-hour unit hydrograph gives a net rain of _____cm on the entire basin for the rainfall duration of ________ hours.

4.9 Laplace equation assumes that water is _______and ______law for flow through porous media is valid.

4.10 Conservation bench and broadbase terrace are generally constructed on ______ and _____percent of sloppy land.

4.11 Before constructing graded terraces at a foot-hill _____and _____courses have to be constructed respectively.

4.12 Saline soils are those for which the conductivity of the saturation extract is more than _____ mmhos/cm at 25°C and the exchangeable sodium percentage is less than ___.

4.13 The water level in an open well indicates ______of an unconfined aquifer while piezometric level of a confined aquifer indicates ______in the aquifer.

4.14 Design pressure on dry plate clutches vary from _______ to _______ N/m^2.

4.15 About ________times as much air by volume is required to cool an engine as would be required if water were used.

4.16 ASAE standards for PTO speed are ______rev/min and ______rev/min.

4.17 The size of a seed drill is expressed by _______.

4.18 In order to have proper alignment, the outer end of the mower cutter bar is provided with a lead of about ______mm per metre bar length.

4.19 In a combine, the ratio of reel peripheral speed to forward speed under most conditions in upright crops should be______ to______

Answers

No-1

1.1 (T)	1.2 (F)	1.3 (F)	1.4 (T)	1.5 (T)	1.6 (T)	1.7 (T)
1.8 (T)	1.9 (T)	1.10 (T)	1.11 (F)	1.12 (T)	1.13 (F)	1.14 (T)
1.15 (F)	1.16 (F)	1.17 (T)	1.18 (T)	1.19 (F)	1.20 (T)	1.21 (F)
1.22 (T)	1.23 (F)	1.24 (F)	1.25 (F)	1.26 (T)	1.27 (F)	1.28 (T)
1.29 (T)	1.30 (T)	1.31 (F)	1.32 (F)	1.33 (T)	1.34 (F)	1.35 (T)
1.36 (T)	1.37. (F)	1.38 (T)	1.39 (T)	1.40 (F)		

No-2

2.1 (A)	2.2 (A)	2.3 (C)	2.4 (D)	2.5 (B)	2.6 (C)	2.7 (C)
2.8 (C)	2.9 (B)	2.10 (A)	2.11 (B)	2.12 (A)	2.13 (A)	2.14 (B)
2.15 (D)	2.16 (D)	2.17 (C)	2.18 (B)	2.19 (D)	2.20 (C)	

No-3

3.1 (C)	3.2 (A)	3.3 (E)	3.4 (F)	3.5 (D)	3.6 (B)	3.7 (M)
3.8 (J)	3.9 (L)	3.10 (H)	3.11 (G)	3.12 (K)	3.13 (I)	3.14 (O)
3.15 (S)	3.16 (T)	3.17 (R)	3.18. (N)	3.19 (Q)	3.20 (P)	

No-4

(4.1) 0.93kg/m^3, (4.2) 105 ^{0} C,110^{0}C, (4.3) Citric Acid, (4.4) Steady State, (4.5) 43^0 C, (4.6) Energy, (4.7)2.5, (4.8) 1, (4.9) Incompressible, Darcy, (4.10) 2 to 10%, >10% (4.11) Out let,Water, (4.12). 4,15, (4.13) Phreatic Pressure, Hydraulic Pressure, (4.14) 1.4x105,2.4x105 N/m^2, (4.15)50, (4.16) 540,1000, (4.17) Width between two furrow opener X no of furrow opener, (4.18) 20, (4.19) 1.25, 1.50

1990

No-1: Write T for TRUE or F for FALSE for each of the following statements:-

1.1 An increase in wet bulb temperature indicates a lower relative humidity

1.2 All food materials have a particular freezing temperature.

1.3 Pasteurization of milk destroys all microorganisms.

1.4 Thermal resistance in heat transfer is directly proportional to the length of material across which heat transfer takes place.

1.5 A light reflector reduces the total energy received from the light.

1.6 A positive displacement pump is unsuitable for large pressure development.

1.7 Industrial evaporation of fruit juices is less energy intensive than spray drying of the same.
1.8 Stokes Law is applicable in butter-churning operation.
1.9 Constant rate of drying is like open surface evaporation of water.
1.10 Equilibrium moisture content of any product corresponds to a particular relative humidity only.
1.11 Butter has a maximum of 50 % milk fat.
1.12 TDT curve is used in milk homogenization.
1.13 A disc plough penetrates into the ground by suction.
1.14 Internal double run type metering mechanism is used in a planter.
1.15 Flail mowers use high speed swinging knives.
1.16 Ginning is the process of separation of the seed from the lint.
1.17 A swinging draw bar minimizes the effect of the side draft.
1.18 A three point hitch consists of 2 compression links and 1 tension link.
1.19 A two-stroke cycle engine actually develops twice the power as compared to a four stroke cycle engine, size for size.
1.20 Two cylinder V engines use one crack for both the cylinders.
1.21 Inflation pressure of the front wheels of a tractor is higher than those of the rear ones.
1.22 The clutch and brake type steering mechanism is mostly used in crawler tractors.
1.23 Excessive black smoke in an engine is an indication of incomplete combustion.
1.24 Wear out life of disc ploughs and mould board ploughs normally takes 2500 hours.
1.25 Water is present under pressure in unconfined aquifer.
1.26 Stream lines are not always perpendicular to equipotential lines.
1.27 The theoretical suction lift of a pumping system is loss at higher altitude than at sea level for the sonic temperature of water.
1.28 The liquid limit of sandy soil is less than that of loam soil.
1.29 Drainable porosity of clay soil is generally less than that of loam soil.
1.30 The porosity of clay soil is generally lower than that of loam soil.
1.31 Barbed wire fencing is preferred on dairy farms.
1.32 The floor of a deep bin is designed to carry the full weight of the grain contained.
1.33 Contour bunding is suitable for deep black soils.
1.34 The width of a shelter belt is between 50 and 100 m
1.35 Spillway is the most important part of a dam.

1.36 Spurs are classified as permeable and impermeable.
1.37 Basic hydrograph is plotted over 100 arbitrary units of flow and 100 arbitrary units of time.
1.38 For a given watershed the duration of flow varies inversely with the peak flow.
1.39 Runoff rate is of primary interest in the design of flood control reservoirs.
1.40 Land grading, land levelling and land shaping are synonymous.

No-2: Choose the correct answer from the multiple choices below:-

2.1 Convective heat transfer coefficient is expressed by _______ number.
(A) Prandtl
(B) Grashof
(C) Nusselt
(D) None of the above.

2.2 Difference between a Pasteurizer and sterilizer is only in _______
(A) Heating agent used
(B) Temperature attained
(C) Design of equipment
(D) None of the above

2.3 The dimension of thermal diffusivity is ________
(A) MLT^{-2}
(B) $ML^{-1}T^{1}$
(C) $M^{o}LT$
(D) None of the above.

2.4 Diffusion coefficient has a dimension of _________
(A) MLT^{-2}
(B) $ML^{2}T^{-1}$
(C) $M^{o}L^{2}T^{-1}$
(D) None of the above.

2.5 Thermal vapour compression is used in a/an _______
(A) Evaporator
(B) Homogenizer
(C) Pasteurizer
(D) None of the above

2.6 In a precision planter the height of drop of seeds _______
(A) Should be as close to the ground level as is possible
(B) Should be at least 1 m from the ground level
(C) Is not a factor to be considered.

2.7 The cutter bar of a tractor-operated mower ordinarily makes
(A) 800 – 1200 strokes/min
(B) 1600-2000 strokes/min
(C) 2400 – 2800 strokes/min

2.8. In a C.I. engine the compression pressure inside the cylinder is normally in the range of
(A) 15-25 kg/cm^2
(B) 35-45 kg/cm^2
(C) 55-65 kg/cm^2

2.9 In a 4-wheel drive tractor _______ is/are greater, as compared to a two wheel drive tractor
(A) The net tractive coefficient
(B) The tractive efficiency
(C) The net tractive coefficient as well as the tractive efficiency

2.10 The type of restrained three point linkage system in which the depth of the implement is automatically adjusted to maintain a pre-selected constant draft is called
(A) Automatic draft control system
(B) Precision control system
(C) Depth control system
(D) None of the above

2.11 The sound level of an agricultural tractor should not exceed
(A) 110 dB
(B) 100 dB
(C) 90 dB

2.12 The floor area per head in a deep litter poultry house is
(A) 0.1 m^2
(B) 0.4 m^2
(C) 0.8 m^2
(D) 1.2 m^2

2.13 In a gravity dam of base width ' b' the maximum permissible value of eccentricity 'c' is:
(A) b/8
(B) b/4
(C) b/3
(D) b/6

2.14 The dimensionless number of use in geometric similarity is
(A) Mach number
(B) Reynolds's number
(C) Froude number

(D) Nusselt number

2.15 Inflow and outflow method of determination of seepage losses in a channel reach:

(A) Does not correspond to actual running conditions
(B) Gives results which are valid for conditions similar to those under which measurements are made.
(C) Is very inaccurate
(D) Requires normally a reach of about 1000 m

2.16 For the most efficient hydraulic section of a rectangular channel the bottom width is

(A) Equal to the depth
(B) Equal to half the depth
(C) Equal to 150 % of depth
(D) Equal to 200 % of depth

2.17 Water content on volumetric basis may be expressed as: (w is water content on weight basis, v_2 is volume of solids, v is total volume of soil mass and γ_s is particle density)

(A) $w\ v_s\ v/\gamma_s$
(B) $w\ v_s\ \gamma_s/v$
(C) $w\ \gamma_s\ v/v_s$
(D) $w\ \gamma_s\ v\ v_s$

2.18 Relative tolerance of crops to salinity is:

(A) Barley > Alfalfa > Sugarcane >Sweet potato
(B) Barley > Alfalfa > Sweet potato > Sugarcane
(C) Alfalfa > Sweet potato > Barley > Sugarcane
(D) Alfalfa > Barley > Sugarcane > Sweet potato

2.19 While constructing wells generally the bottom one-third portion of aquifer is provided with well screen in:

(A) Tubewell constructed in gravity aquifer
(B) Dugwell constructed in confined aquifer
(C) Tubewell constructed in artesian aquifer
(D) Tubewell constructed in multi aquifer.

2.20 Self priming centrifugal pump has impellor of following type.

(A) Backward curved vane impeller
(B) Radial vane impeller
(C) Forward curved vane impeller
(D) Combination of radial and forward curved vane impeller.

No-3.Match the statement in Group I with the most appropriate statement in Group II

	Group I		Group II
3.1	Relationship between energy consumed and size attained	(A)	Irrigation water measurement
3.2	Vapourization of oil under the influence of heat	(B)	Babit
3.3	Destruction of all microorganisms in food and package	(C)	Energy balance
3.4	Presence of soluble solids and boiling point of solution	(D)	Common rail system of solid injection
3.5	Velocity of gases and velocity of sound	(E)	Electrical conductivity
3.6	Perpendicular distance between the point of share and lower portion of the beam	(F)	Shearing resistance of soil
3.7	A raised ridge, left at the centre of a strip of land, when ploughing is done from centre to side.	(G)	Uniformity coefficient
3.8	A component used for metering of fertilizer in a seed-cum-fertilizer drill.	(H)	Theis equation
3.9	A material used for making of bearings	(I)	Aseptic processing
3.10	One of the methods of fuel injection	(J)	Aquifuge
3.11	A mass that can be added or removed from a tractor for the purpose of changing traction, stability or compacting effect on the surface of the soil.	(K)	Grain pressure
3.12	Euler	(L)	Duhring
3.13	Jensen	(M)	Long column
3.14	Solid granite	(N)	Throat clearance
3.15	Estimation of aquifer parameter	(O)	Bond's law
3.16	Mohr's circle diagrant	(P)	Back furrow
3.17	Quality of irrigation water	(Q)	Match number
3.18	Penman	(R)	Star wheel
3.19	Parshall	(S)	Ballast
3.20	Christiansen	(T)	Smoke point

No 4: Fill in the blanks with appropriate word (s) symbol (s) or numerical value (s)

4.1 Critical thickness of thermal insulation on cylindrical conductor is given by _______ where k is the insulation thermal conductivity and h is the surface heat transfer coefficient.

4.2 The fanning friction factor in the laminar range is given by______

4.3 For a centrifugal pump the pressure developed by the pump varies as the _______of the rotational speed.

4.4 Heat transferred by ________is proportional to the difference of fourth power of the temperature.

4.5 Raout's Law is applicable for ________phase equilibrium.

4.6 An indigenous plough cuts a _______furrow cross-section.

4.7 A paddy transplanter uses either root washed type seedlings or _______seedlings.

4.8 Draft of a plough should not exceed ________ percent of draw bar pull.

4.9 A pitman transmits ________motion to a knife head.

4.10 The thermal efficiency of an S.I. engine is ____than that of a C.I. engine.

4.11 In a fully charged battery, the electrolyte has a specific gravity of ______

4.12 Farmstead should be located on the ______productive part of the farm.

4.13 Tensiometers are recommended for the range of ______ to ______ cm of water tension.

4.14 Triangular hydrograph was developed to speed up ______

4.15 Topographic features such as canyon stream and valleys are caused by ______erosion.

4.16 Drip irrigation is not practicable for ______crop.

4.17 While drilling by direct rotary method no ______is required because the _______ forms a clay lining on the wall of the well which prevents caving.

4.18 Jacob's method is used for estimation of ______and _______of the aquifer.

4.19 Soil materials finer than 0.074 mm are generally analyzed by the method of_______of soil particle by gravity.

4.20 Flooding of plant/roots causes_______in oxygen absorption and other plant_______

Answers

No-1

1.2 (F)	1.2 (T)	1.3 (F)	1.4 (T)	1.5 (F)	1.6 (F)	1.7 (T)
1.8 (T)	1.9 (T)	1.10 (T)	1.11 (F)	1.12 (F)	1.13 (F)	1.14 (F)
1.15 (F)	1.16 (T)	1.17 (T)	1.18 (F)	1.19 (F)	1.20 (T)	1.21 (T)
1.22 (T)	1.23 (T)	1.24 (T)	1.25 (F)	1.26 (F)	1.27 (T)	1.28 (F)
1.29 (T)	1.30 (T)	1.31 (T)	1.32 (F)	1.33 (F)	1.34 (F)	1.35 (T)
1.36 (T)	1.37 (T)	1.38 (T)	1.39 (T)	1.40 (T)		

No-2

2.1 (C)	2.2 (B)	2.3 (D)	2.4 (C)	2.5 (A)	2.6 (A)	2.7 (B)
2.8 (B)	2.9 (C)	2.10 (A)	2.11 (C)	2.12 (B)	2.13 (D)	2.14 (C)
2.15 (C)	2.16 (D)	2.17 (B)	2.18 (A)	2.19 (A)	2.20 (A)	

No-3.

3.1 (O)	3.2 (T)	3.3 (I)	3.4 (L)	3.5 (Q)	3.6 (N)	3.7 (P)
3.8 (R)	3.9 (B)	3.10 (D)	3.11 (S)	3.12 (M)	3.13 (K)	3.14 (J)
3.15 (H)	3.16 (F)	3.17 (E)	3.18 (C)	3.19 (A)	3.20 (G)	

No-4

(4.1) k/h , (4.2) $0.023/Re^{0.2}$, (4.3) square, (4.4) radiations , (4.5) vapour-liquid equilibrium, (4.6) triangular, (4.7) tray, (4.9) reciprocating, (4.10) less, (4.11) 1.278, (4.12) most, (4.13) 0, 880.6, (4.14) area calculation , (4.15) geologic, (4.16) cereal, (4.17) casing, drilling fluid, (4.18) S, T (4.19) sedimentation, (4.20) reduction, nutrients

1991

No-1 Write T for TRUE or F for FALSE for each of the following statements:-

1.1 In an offset disc harrow operating with no side draft, the centre of the tilled strip coincides with the line of pull.

1.2 The depth of operation of an indigenous plough can be increased by bringing the hitch point closer to the operation.

1.3 For a given spray droplet sample, the volume medium diameter (VMD) is larger than the number median diameter (NMD).

1.4 A rasp-bar cylinder with an open-grate concave has greater seed separating capacity than a spike tooth cylinder.

1.5 Increasing the bite length increases the specific energy requirements of rotary tillers.

1.6 As the fuel cutoff approaches zero, the thermal efficiency of the diesel cycle approaches that of the Otto cycle.

1.7 A pressurized radiator tap helps to reduce the evaporation losses by decreasing the boiling temperature of water.
1.8 Neglecting bearing friction, the axis torque in a towed wheel is zero.
1.9 For sandy soils the shares of mould board ploughs are generally made of chilled cast iron.
1.10 The specific fuel consumption of diesel engines is higher than that of petrol engines.
1.11 A heavy flywheel is prepared on a two-stroke cycle engine: compared to a four-stroke cycle engine of the same size.
1.12 The use of a different lock in a wheel tractor is to improve the traction by allowing equal torque to be applied to both the rear wheels.
1.13 A rear furrow wheel provided in a disc plough acts like a landside in a mould board plough.
1.14 A diesel tractor engine normally has less speed variation for a given change in torque than a comparable gasoline engine.
1.15 Precipitation consisting of droplets less than 0.5 mm in diameter is classified as drizzle.
1.16 Storms of high intensity generally last for long duration and cover very large areas.
1.17 Removal of soil by water from small but well defined watershed due to concentration of overland flow is known as gully erosion.
1.18 Vegetated waterways are good for continuous flows
1.19 Irrigation channels are usually laid on milder slopes when compared to vegetated waterways.
1.20 In arid regions under irrigation, the drainage design criteria are determined more by the minimum depth of watertable for optimum crop growth than by the rate of watertable drop.
1.21 The interceptor is not advisable to be placed near the upper edge of a wet area.
1.22 Darcy's law governs flows only when inertial forces predominate.
1.23 Reverse rotary method of well drilling is essentially a suction dredging method in which the cuttings are removed by a suction pipe.
1.24 The kinetic energy gained by water as it falls from the crest in a drop structure need not be dissipated before the flow is discharged into the downstream channel.
1.25 The centrifugal pump used for irrigation will have an impeller with diffuser casing.

1.26 Long and narrow watersheds are likely to have lower runoff rates than more compact watersheds of the same size in a region.
1.27 Conservation benches are laid on much steeper slopes than the bench terraces.
1.28 Reciprocating pumps can be designed for higher heads than centrifugal pumps
1.29 Nusselt number relates heat transfer coefficient to thermal conductivity of the fluid in forced-convection heat transfer.
1.30 Thermal conductivity of frozen foods is much less than that of foods at ordinary temperature.
1.31 No difference exists among counter-current and co-current flow heat exchangers in case of heating by condensing steam.
1.32 Water activity measures the relative humidity of the air surrounding the food product.
1.33 The bulb temperature is the saturation temperature of an air-water vapour mixture, whereas dew point is its adiabatic saturation temperature.
1.34 The oil content of rice bran obtained from parboiled paddy is less than that obtained from raw paddy.
1.35 Disc separators separate grains by size but not by shape.
1.36 In a cyclone separator the larger the weight of immaterial to be separated the more effective is its separation.
1.37 Deep-bed drying technique is followed in mixing type column dryers used for paddy drying.
1.38 Conventional polyethylene sheet is less permeable to oxygen and water vapour than plain cellophane.
1.39 Pneumatic conveyors require more power per unit material handled than other conveyors.
1.40 Bag storage of grains required less space than bulk storage.

No-2: Choose the correct answer from the multiple choices given

2.1 For airborne sounds the reference sound pressure taken to measure the sound pressure level is
(A) 2×10^{-2} N/m^2
(B) 2×10^{-3} N/m^2
(C) 2×10^{-4} N/m^2
(D) 2×10^{-5} N/m^2

2.2 In a force feed lubrication system adopted in the tractor-engines the type of pump generally used is
(A) Centrifugal pump

(B) Gear pump
(C) Rotary vane pump
(D) Plunger pump

2.3 The type of bearing used to support the discs on a standard disc plough is
(A) Bush bearing
(B) Plain roller bearing
(C) Tapered roller bearing
(D) Ball bearing

2.4 The common type of fertilizer metering mechanism used on animal-drawn seed cum fertilizer drills is
(A) star-wheel feed
(B) Auger
(C) Stationary opening
(D) Edge cell vertical rotor

2.5 The method of estimating depreciation which reduces the value of a tractor by an equal amount each year during its useful life is known as
(A) Estimated value
(B) Straight line
(C) Constant percentage
(D) Sum of the digits

2.6 The driving and driven shafts of a Double Hooke's joint make θ^0 degree angle with some common reference plane. If the driving shaft rotates at 1,200 rev/min, the speed of the driven shaft will be
(A) $1200 \cos \theta$
(B) $1200 \sin \theta$
(C) 1200
(D) $1200 \tan \theta$

2.7. Most suitable method of irrigation for potato crop is
(A) Corrugation method
(B) Check basin method
(C) Furrow method
(D) Border method

2.8 The ratio of water stored in the root zone of the plants to water delivered to the field is termed as
(A) Water application efficiency
(B) Water storage efficiency
(C) Water distribution efficiency
(D) Water use efficiency

2.9 A synthetic unit hydrograph can be developed for a basin
(A) Having a rain gauge network but no stream gauging station
(B) Whose stream is being regularly gauged
(C) Over which no rain gauge and stream gauging stations are established
(D) By taking the basin slope as an index

2.10 The wells in which the water levels remain at the watertable level are
(A) Non-artesian wells
(B) Flowing artesian wells
(C) Non-flowing artesian wells
(D) Confined wells.

2.11. The ratio of the volume of voids to the total soil volume is called
(A) Void ratio
(B) Porosity
(C) Dry bulk density
(D) Wet bulk density

2.12 Drop spillways are often used to stabilize
(A) Wind erosion
(B) Sheet erosion
(C) Rill erosion
(D) Gully erosion.

2.13 Froude number is expressed as
(A) $V^2/\sqrt{gD}$
(B) V/gD
(C) $V/\sqrt{gD}$
(D) v/gD^2

2.14 In a fluid flow system velocity at one point only is measured by
(A) Orifice meter
(B) Rotameter
(C) Anemometer
(D) Pitot tube

2.15 The dimension of mass transfer coefficient is
(A) $ML^{-2}\,\theta^{-1}$
(B) $ML^{-1}\,\theta^{-1}$
(C) $ML^{2}\,\theta^{-1}$
(D) $ML\,\theta^{-1}$

2.16 A body whose emissivity is less than one is called
(A) Black body

(B) Grey body
(C) Opaque body
(D) Hollow body painted black inside

2.17 Temperature yielding maximum storage life of food materials decreases in the order.
(A) Potato < Fish < Milk <Orange
(B) Fish < Milk <Orange < Potato
(C) Fish < Potato < Orange < Milk
(D) Milk < Fish < Orange < Potato

2.18 Sterilization of milk is carried out to the extent of destroying
(A) Only pathogenic organisms
(B) Only spoilage organisms
(C) All types of organisms
(D) Only heat resistant organisms

2.19 Type of moisture that can be removed by common drying techniques is
(A) Equilibrium moisture
(B) Total moisture
(C) Free moisture
(D) Bound moisture

2.20 Size reduction of grains is caused by impact in
(A) Attrition mill
(B) Roller mill
(C) Hammer mill
(D) Jaw crusher

3. Match the statement in Group I with the most appropriate statement in Group II and answer them using numbers and alphabets only:

	Group I		Group II
3.1	Octane number	(A)	Stage height
3.2	Confined aquifer	(B)	Width of cut of disc plough
3.3	Heat transfer by combined conduction and convection	(C)	Rigor mortis
3.4	Flow of grains by bulk transfer devices	(D)	Penetration of disc plough
3.5	Storm pattern	(E)	Blanching
3.6	Tilt angle	(F)	Continuously flowing streams

3.7	Screen analysis of mixed particle sizes	(G)	Emitter
3.8	Disc angle	(H)	Shape factor
3.9	Deactivation of enzymes present in vegetables and fruits during processing	(I)	Fluted-wheel metering device
3.10	Flood routing	(J)	Overall heat transfer coefficient
3.11	Off-stream ponds	(K)	Vertical rotor metering device
3.12	Drill seeding	(L)	Shape of hydrograph
3.13	Cetane number	(M)	Twin-fluid nozzles
3.14	Canning of food materials in sealed container	(N)	Detonation in SI engine
3.15	Spray drying of liquid milk to milk powder	(O)	Phreatic surface
3.16	Precision planting	(P)	Piezometric surface
3.17	Gravity aquifer	(Q)	Angle of repose
3.18	Camber	(R)	Diesel knock
3.19	Drip irrigation	(S)	Outward inclination of tractor front wheel
3.20	Stiffening of animal tissue after death	(T)	Thermal death time

4. Fill in the blanks with appropriate word(s): symbol(s) or numeral value(s)

4.1 The degree of soil pulverization by a mould board plough can be measured by _______of soil particles.

4.2 The slippage in a properly designed V-belt drive should not exceed ______to______.

4.3 The ultra low volume sprayers apply ______to ______litres of spray volume per hectare.

4.4 The two possible firing orders for a four-stroke cycle four-cylinder engine are_____ and ________.

4.5 The volumetric efficiency for a naturally aspirated diesel engine is between ___ and ___ percentage.

4.6 The stability of 4-wheel tractor up a hill can be improved by ______the height of line of action of drawbar pull and_______ the wheel base.

4.7 Due to practical limitations caused by ________the CI engines are generally operated at air-fuel ratio _________than the chemically correct ratio.

4.8 The seasonal crop factor for wheat to compute consumptive use from pan evaporation data varies from _______to _______

4.9 An isohyet is a line joining the locations in an area receiving ______amounts of rainfall.

4.10 The term ________denotes the ground water flow reaching the stream.

4.11 The property governing the flows of water through a soil mass is called _______.

4.12 Land capability classificatory consists of ________classes.

4.13 In an open channel flow the energy head is_______corresponding to critical depth.

4.14 During drilling with cable tool method, the tool makes ______ to_____ strokes per minute.

4.15 Fluids for which viscosity is defined by a ________ are called non-Newtonian fluids.

4.16 It is difficult to heat air by steam because air has very low _______

4.17 Deposition of darts in heat exchanger tubes increases ________ to heat transfer.

4.18 During fruit juice concentration by evaporation, steam economy can be improved by_______system.

4.19 Drying of parboiled paddy takes place only in the ________period.

4.20 Distillation of a mixture of two components utilizes difference in their vapour pressure, whereas solvent extraction utilizes difference in _______ of the components.

Answers

No-1

1.1 (F)	1.2 (F)	1.3 (T)	1.4 (F)	1.5 (T)	1.6 (T)	1.7 (F)
1.8 (T)	1.9 (T)	1.10 (F)	1.11 (F)	1.12 (F)	1.13 (T)	1.14 (T)
1.15 (T)	1.16 (F)	1.17 (F)	1.18 (F)	1.19 (T)	1.20 (F)	1.21 (F)
1.22 (T)	1.23 (T)	1.24 (F)	1.25 (F)	1.26 (T)	1.27 (F)	1.27 (F)
1.28 (T)	1.29 (T)	1.30 (F)	1.31 (T)	1.32 (T)	1.33 (F)	1.34 (F)
1.35 (T)	1.36 (F)	1.37 (F)	1.38 (F)	1.39 (T)	1.40 (T)	

No-2.

2.1 (D)	2.2 (B)	2.3 (C)	2.4 (A)	2.5 (B)	2.6 (A)	2.7 (C)
2.8 (A)	2.9 (A)	2.10 (B)	2.11 (B)	2.12 (D)	2.13 (C)	2.14 (D)
2.15 (A)	2.16 (B)	2.17 (D)	2.18 (C)	2.19 (C)	2.20 (C).	

No-3.

3.1 (N)	3.2 (P)	3.3 (J)	3.4 (Q)	3.5 (L)	3.6 (D)	3.7 (H)
3.8 (B)	3.9 (E)	3.10 (A)	3.11 (F)	3.12 (I)	3.13 (R)	3.14 (T)
3.15 (M)	3.16 (K)	3.17 (O)	3.18 (S)	3.19 (G)	3.20 (C)	

No-4.

4.1- mean volume diameter, 4.2- 1 and 2 %, 4.3- 0 and 5, 4.4- 1-2-4-3 and 1-3-4-2 , 4.5 - 85 and 90, 4.6- decreasing and increasing, 4.7- irregular distribution and higher, 4.8- 0.14 and 0.91, 4.9- equal , 4.10- seepage , 4.11-Porosity , 4.12- 8 , 4.13-minimum, 4.14- 40 to 60, 4.15 – Velocity gradient 4.16-thermal conductivity, 4.17-resistance, 4.18- multiple, 4.19- falling rate , 4.20-solubility

1992

No-1: Write T for TRUE or F for FALSE for each of the following statements.

1.1 An animal drawn turn wrest plough is a reversible plough.
1.2 Vertical disc ploughs are used for shallow ploughing.
1.3 An olpad thresher is provided with a rotary drum with pegs.
1.4 An offset disc harrow has one right hand gang and one left hand gang, operating in tandem.
1.5 Stationary opening seed metering device is used in precision planters.
1.6 In a solid cone nozzle an internal axial orifice is provided.
1.7 The diameter of the position is slightly smaller at the top than at the bottom.
1.8 Single cylinder engines have heavier flywheels.
1.9 Tappet adjustment should be made when engine is hot.
1.10 Airless injection is used on automotive and small stationary diesel engines.
1.11 A crawler tractor can transmit high drawbar pull in difficult field conditions.
1.12 A swinging drawbar reduces side draft.
1.13 Hot plug is used in a cold engine.
1.14 Line joining the points of equal depth of water table from ground surface is called isobath.

1.15 A float and siphon type recording rain gauge measures maximum of 10 mm of rainfall at one time.
1.16 Interceptor drains are provided to control the problem of sub-surface drainage.
1.17 Higher the salt concentration in the irrigated soil, lesser is the depth of irrigation water applied.
1.18 The available yield of tubewell can be doubled by doubling its diameter.
1.19 Side bunds are provided to check the flow of water at the ends of a graded bund.
1.20 During levelling operation cut is either equal to or more than the fill.
1.21 Watershed treatment measures do not help in any way in controlling flood downstream.
1.22 Off-stream storage ponds are constructed far away from a continuously flowing stream.
1.23 Land leveling is a pre-requisite for adopting drip system of irrigation.
1.24 Vegetation in a catchment tends to decrease run-off from the catchment.
1.25 In an earthen dam there is no hydrostatic pressure above the phreatic line (seepage line)
1.26 Quicksand is a type of sand and not any phenomenon.
1.27 From the management point of view, the farmstead should be located at the centre of the farm.
1.28 Static friction force is less than kinetic friction force.
1.29 Pitot tube is used for measuring average flow rate in a conduit.
1.30 Equilibrium moisture content is the lower limit that can be obtained in a dehydration operation.
1.31 Fineness modulus indicates the distribution of the fines and coarses in any sample.
1.32 The latent heat of vaporization increases as the temperature of evaporation decreases.
1.33 In grain bins when height of material exceeds a certain limit, no increase in bottom pressure can be detected with the increasing depth of grain.
1.34 Pneumatic conveyor can convey a wide variety of materials and its power requirement is low.
1.35 For extraction of fat from food generally solvent extraction is used

.

1.36 When a highly viscous load of thermally processed, the heat transfer between two points will take more time.
1.37 The rate of which heat is transferred from the air to the water is proportional to the wet bulb depression.
1.38 In vacuum, evaporation rate of water is enhanced due to increase of partial pressure of water, in air compared to vapor pressure of water at a particular temperature
1.39 Wet milling tends to produce tinier particles than those obtainable with dry milling
1.40 Wheat flour (Maida) is produced by further grinding the screening of Atta in a wheat flour mill

No-2: Choose the correct answer (s) from the multiple choices given below.

2.1. Maximum noise level from a tractor near the operator's ear should not exceed
- (A) 85 dB
- (B) 90 dB
- (C) 95 dB
- (D) 100 dB

2.2 The firing order of a 4-stroke 4-cylinder S.I. engine is
- (A) 1 2 4 3
- (B) 1 3 4 2
- (C) 1 4 3 2
- (D) 1 2 3 4

2.3 Standard P.T.O. speed is
- (A) 556 rev/min
- (B) 1000 rev/min
- (C) 1440 rev/min
- (D) 2000 rev/min

2.4. A connecting rod of a tractor engine is made of
- (A) Forged steel
- (B) Cast steel
- (C) Cast iron
- (D) Mild steel

2.5 Heavy draft of a desi plough is due to
- (A) Blunt disc
- (B) Furrows too wide
- (C) Loose bearings
- (D) None of the above

2.6 Puddling is done to
 (A) Reduce percolation of water
 (B) Kill weeds
 (C) Pulverize soil
 (D) Level the field

2.7 Seed metering devices of seed drills include
 (A) Internal double run
 (B) Fluted wheel
 (C) Horizontal plate with cells
 (D) Inclined plate with cells

2.8 Contour bunds are adopted
 (A) In low rainfall regions
 (B) In highly pervious soils
 (C) In high rainfall regions
 (D) Where conservation of moisture is needed

2.9 Penman method is used to compute
 (A) Consumptive use of crops
 (B) Potential evapotranspiration of crops
 (C) Water requirement of crops
 (D) Irrigation water requirement of crops

2.10 If 1 cm of water is added to ground water rise in ground water-table will be (drainable porosity of soil 10 %).
 (A) 1.0 cm
 (B) 10.0 cm
 (C) 0.1 cm
 (D) No change in the level of ground water

2.11 In the Rational formula Q = 0.0028 C.I.A., I is the intensity of rainfall in
 (A) mm per hour
 (B) cm per hour
 (C) m per hour
 (D) cm per minute

2.12 In sprinkler irrigation the overlap increases with the
 (A) Decrease in the height of sprinkler head
 (B) Increase in the height of sprinkler head
 (C) Increase in the wind velocity
 (D) Decrease in the wind velocity

2.13 A soil is saline if
 (A) E.C. of the saturation extract is more than 4 m mhos/cm
 (B) E.C. of the saturation extract is less than 4 m mhos/cm

(C) E.S.P. is less than 15
(D) E.S.P., is more than 15

2.14 The initial infiltration rate is at capacity rate if the intensity of rainfall is
(A) less than the average rate of infiltration
(B) less than the infiltration capacity of the soil
(C) equal to or more than the average rate of infiltration
(D) equal to or more than the infiltration capacity of the soil

2.15 Most cereal foods contain mainly
(A) Protein
(B) Fat
(C) Starch
(D) Vitamins

2.16 Solid food materials are generally
(A) Elastic
(B) Viscoplastic
(C) Viscoelastic
(D) Plastic

2.17 Fluids which become more fluid viscosity decreases with time as they are stirred are known as
(A) Pseudoplastic
(B) Dilatant
(C) Thixotropic
(D) Rheopectic

2.18 Whenever the refrigeration system has to be charged the usual practice is to feed the suction line with the
(A) Compressor stopped
(B) Compressor running
(C) Condenser in operation
(D) Condenser not in operation

2.19 In a godown extra space for alleyways for inspection and disinfection of stacks is provided which is generally about
(A) 30 %
(B) 20 %
(C) 5 %
(D) 1 %

2.20.The efficiency of a cyclone separator increases by
(A) Increasing the air inlet velocity
(B) Decreasing the size of the particles
(C) Reducing the size of the separator

(D) Reducing the air outlet diameter

No-3: Match the statement in Group I with the most appropriate statement in Group II

	Group I		Group II
3.1	Sweep	(A)	Dunnage
3.2	Slip circle method	(B)	Rubber rolls
3.3	Blanket	(C)	Tractor
3.4	Bulk storage	(D)	Stability of slopes
3.5	Governor	(E)	Blanchin
3.6	Hooghoudt	(F)	Earth dams
3.7	Food texture	(G)	Plough
3.8	Bag storage	(H)	Bench terrace
3.9	Soil capability classification	(I)	Friction
3.10	Ground clearance	(J)	Break rolls
3.11	Shoulder bund	(K)	Canning
3.12	Wheat milling	(L)	Rotary tiller
3.13	Standard	(M)	Tubewell
3.14	Vegetable processing	(N)	Watershed management
3.15	Bite length	(O)	Rheology
3.16	Paddy milling	(P)	Drainage
3.17	Thermostat valve	(Q)	Steaming
3.18	Life irrigation	(R)	Regulation
3.19	Fruit processing	(S)	Cultivator
3.20	Parboiling	(T)	Cooling system

No-4: Fill in the blanks with appropriate word(s): symbol(s) or numerical value(s)

4.1 Land wheel fitting with a plough runs on the_________

4.2 During the operation of the cutter bar mower, the knife edges trace a _______ path in relation to the field surface.

4.3 Cone index varies with_______

4.4 In a 4-stroke engine, the connecting rod is subjected to ______and _________alternately.

4.5 Specific gravity of high speed diesel oil is _______ than that of light diesel oil.

4.6 ________number and _______ number are the measures of ignition quality of fuel.

4.7 The capacity of a storage battery is expressed in terms of ________.

4.8 ________ erosion has contributed to the formation of our soils and their distribution on the surface of the earth.

4.9 The longer side of a rectangular well should be ________to the trend of the fracture system to ensure better yield.

4.10 Mole drains are constructed by a _______ plough.

4.11 Herringbone drain system is adopted in the areas that have ________surface.

4.12 Water retention capacity of clay soil is generally ________than that of loam soil.

4.13 Infiltration rate of a soil ________ with the increase in moisture content.

4.14 The water vapour pressure nearly doubles for each_______ increase in temperature.

4.15 Diffusion of liquid moisture occurs when there is a ________ difference between the depths of the solid and the surface.

4.16 Thermal radiation is a form of electromagnetic radiation similar to X-rays, light waves, gamma rays and so on, differing only in _______.

4.17 The method of using the heat of pasteurized milk to warm up cold incoming raw milk is known as _______

4.18 The total emissive power of a black body is proportional to the fourth power of the absolute temperature and is known as _______

4.19 In froze drying the water vapour is removed by_______ from ice.

4.20 Thermal diffusivity for a material can be calculated by knowing its thermal conductivity, specific heat and __________.

Answers

No-1

1.1 (T)	1.2 (T)	1.3 (F)	1.4 (T)	1.5 (F)	1.6 (T)	1.7 (T)
1.8 (T)	1.9 (F)	1.10 (T)	1.11 (T)	1.12 (T)	1.13 (T)	1.14 (T)
1.15 (T)	1.16 (T)	1.17 (F)	1.18 (F)	1.19 (T)	1.20 (T)	1.21 (F)
1.22 (F)	1.23 (F)	1.24 (T)	1.25 (T)	1.26 (F)	1.27 (T)	1.28 (F)
1.29 (F)	1.30 (F)	1.31 (T)	1.32 (F)	1.33 (T)	1.34 (F)	1.35 (F)
1.36 (T)	1.37 (T)	1.38 (T)	1.39 (F)	1.40 (F)		

No-2

2.1 (B)	2.2 (B)	2.3 (B)	2.4 (A)	2.5 (B)	2.6 (A)	2.7 (A)
2.8 (A)	2.9 (B)	2.10 (C)	2.11 (A)	2.12 (B)	2.13 (A)	2.14 (D)
2.15 (A)	2.16 (A)	2.17 (C)	2.18 (B)	2.19 (A)	2.20 (A and D)	

No-3

3.1 (S)	3.2 (D)	3.3 (F)	3.4 (A)	3.5 (R)	3.6 (P)	3.7	(O)
3.8 (I)	3.9 (N)	3.10 (C)	3.11 (H)	3.12 (J)	3.13 (G)	3.14	(E)
3.15 (L)	3.16 (B)	3.17 (T)	3.18 (M)	3.19 (K)	3.20 (Q)		

No-4

4.1- furrow wall, 4.2-parallel, 4.3- depth of penetration, 4.4- tension and compression, 4.5-less, 4.6-Octane and cetane, 4.7- ampere, 4.8-Geological, 4.9-parallel, 4.10- mole, 4.11-concave, 4.12-greater, 4.13-decreases, 4.14-100C, 4.15-moisture, 4.16- Wave length, 4.17-regeneration, 4.18-Stefan- Boltzman loss 4.19- Sublimation 4.20-density

1994

No-1: Choose the correct answer from the multiple choices given below

1.1 A powertiller should preferably be recommended for use in
- (A) primary tillage operation with mouldboard plough
- (B) rotatilling of hard field
- (C) puddling of paddy field with rototiller
- (D) none of the above.

1.2 The calorific value of HSD is
- (A) 10000 kCal/kg
- (B) 10550 kCal/kg
- (C) 11100 kCal/kg
- (D) 11650 kCal/kg

1.3 Wearout life of a tractor-operated cultivator is
- (A) 10000 hours
- (B) 7500 hours
- (C) 5000 hours
- (D) 2500 hours

1.4 In a precision planter the height of drop of seeds from the hopper to the ground surface should be
- (A) at least 90 cm
- (B) at least 45 cm
- (C) as close to the ground surface as possible
- (D) none of the above

1.5 The cutterbar of a tractor-operated mower normally makes
- (A) 800 – 1200 strokes/min
- (B) 1200-1600 strokes/min
- (C) 1600 – 2000 strokes/min
- (D) 2000 – 2400 strokes/min

1.6 In a combine harvester the ratio of reel peripheral speed to forward speed (reel speed index) should normally be in the range of
(A) 1.25 to 1.50
(B) 1.50 to 1.7
(C) 1.75 to 2.00
(D) none of the above

1.7 A tractor seat suspension should have its natural frequency in the range of
(A) 0.5 to 2.0 cycle/s
(B) 2.0 to 4.0 cycle/s
(C) 4.0 to 6.0 cycle/s
(D) none of the above

1.8 Time of freezing of food is longer than that for thawing. The reason for this is
(A) water has higher thermal conductivity than ice
(B) water has higher density than ice
(C) water has lower thermal conductivity than ice
(D) water has higher thermal diffusivity than ice

1.9 Nusselt number is convective heat transfer is equivalent to the following in convective mass transfer
(A) Schmidt number
(B) Prandtl number
(C) Scherwood number
(D) Archimedes number

1.10 A disc type centrifuge has milk inlet at radius R_m cream outlet at radius R_z and skim milk outlet at radius R_2. In order to have a very high separation of milk fat globules from milk, the position of R_m should be
(A) close to R_1
(B) close to R_2
(C) midway between R_1 and R_2
(D) none of the above

1.11 The relationship between friction factor (f) and Reynolds number (Re) of a fluid flowing in laminar regime through a circular pipe can be expressed as : (a and b are constants)
(A) $f = a + b\,(Re)$
(B) $f = a/Re$
(C) $f = a+Re^b$
(D) $f = a+ b/Re$

1.12 A bed of granular material consisting of particles having diameter D and density p is to be fluidized, if the depth of bed is L and bed porosity is p, the pressure drop of a fluid flowing through the bed will be (g is acceleration due to gravity)
(A) $D\rho\,(1\text{-}p)\,g$
(B) $L\rho\,(1\text{-}p)\,g$
(C) $D\rho\,pg$
(D) $L\,\rho pg$

1.13 A refrigerant vapour is to be condensed inside a shell and tube heat exchanger using water as the cooling medium. The water should flow through
(A) Shell side of the heat exchanger
(B) tube side of the heat exchanger
(C) Any of (A) or
(B) above
(D) none of the above

1.14 The effect of temperature (^{o}K) on the viscosity of a liquid food may be expressed as
(A) $\mu = AT^{-B}$
(B) $\mu = Ae^{BT}$
(C) $\mu = Ae^{B/T}$
(D) $\mu = AT^{B}$

1.15 The ratio of the liquid limit minus the natural water, to the plasticity index of a soil is known as
(A) plasticity index
(B) consistency index
(C) shrinkage index
(D) density index

1.16 The formula for estimation of evapotranspiration using only temperature and day length is known as
(A) Thornthwaite formula
(B) Penman formula
(C) Christiansen formula
(D) Blaney-Criddle formula

1.17 The movement of soil particles having sizes in the range of 0.05 to 0.5 mm through a series of bounces is known as
(A) Surface creep
(B) Surface transportation
(C) Saltation
(D) Suspension

1.18 Chow's method of pumping test data analysis for unsteady flow avoids
(A) curve fitting as well as superposition of curves
(B) only superposition of curves
(C) only curve fitting
(D) semi-logarithmic plot of the data

1.19 The following method of surface drainage is most suitable to soils that need the combination of surface and subsurface drainage
(A) Parallel open ditch system
(B) Random field ditch system
(C) Parallel field drain system
(D) Bedding system

1.20 Storage of grain that requires protection from solar heat should use the following as roofing material
(A) Galvanized iron
(B) Asphalt
(C) Aluminum
(D) Asbestos cement

No-2: Fill in the blanks with appropriate word(s); symbol(s) or numerical value(s) against each

2.1 The inflation pressure in rear wheels of a tractor should be in the range of ______kg/cm^2.

2.2 For lubrication of a tractor gearbox, SAE ______oil is normally used.

2.3 A battery should be recharged when the specific gravity of electrolyte falls below______.

2.4 Tilt angle of a disc plough is normally adjusted in the range of _______degrees.

2.5 In sprayers, operating pressures below ______kPa are undesirable for hydraulic nozzles other than flooding type.

2.6 In a combine harvester the peripheral speed of the cylinder ranges between________ m/min.

2.7 The average working speed of a hand-operated chaff cutter fitted with two knives is_____rev/min.

2.8 The unit of filter medium resistance is_____.

2.9 The relationship between the ratio of lateral pressure P and vertical pressure V in a grain silo containing granular materials with an angle of intergranular friction Θ is given by P/V =_________.

2.10 The unit of viscosity in S.I. unit is ________.

2.11 Air is heated from a temperature T_1 to T_2. When the hot air is passed through a dryer, its temperature is reduced to T_3. Efficiency of the dryer is __________

2.12 The height of a fluidized bed and the bed porosity are respectively Z_1 and p_1 at one condition and Z_1 and p_2 at another condition. The relationship between the bed height and bed porosity is _________

2.13 The relationship between apparent viscosity, η, shear rate γ, flow behaviour index n and consistency coefficient b of a non-Newtonian pseudo-plastic fluid is given by_____.

2.14 In the rational method of runoff prediction, rainfall occurs at uniform intensity for a duration at least equal to the ________ of the watershed.

2.15 For a cohesive soil if the slope angle is greater than the angle of internal friction, the slope can be stable unto a depth known as_________.

2.16 If the back face of the retaining wall is forced against the backfill, the pressure is known as ______.

2.17 Cavity well should not be constructed in ______aquifers.

2.18 For application of sub-irrigation method, the ________in the root zone soil should be rapid

2.19 For pumping large volume of water at a low head of two metres ________pump should be used.

2.20 Darcy's law for flow through porous medium is valid for Reynolds number less than _________.

No-3: Write TRUE or FALSE for each of the following statements:-

3.1 The centre of resistance of a 4-bottom 30 cm mould board plough is 60 cm from the wing of the first bottom.

3.2 The cutterbar of a mower is set at about 88° to the direction of motion.

3.3 When a tractor pulls a load, higher the pull, lower is the weight transfer.

3.4 The efficiency of a fan will decrease with the increase in brake horsepower.

3.5 Relative humidity of air in a chamber will increase with the increase in pressure.

3.6 In spray drying of liquid foods the direction of flow of hot air and the liquid inside the chamber is not counter current but is co-current.

3.7 Water activity of a liquid food containing 5 percent common salt by weight will be the same as that of the liquid containing 5 percent sucrose by weight.
3.8 Falling head permeability test is conducted on a soil sample. Time intervals noted for drops of head from h_1 to h_2 and again from h_2 to h_3 are equal. In that case $h_3 = h_2/h_1$.
3.9 The difference between a shallow tubewell and a deep tubewell is not so much on the depth of the tubewell but on the pumping level of water.
3.10 In a trapezoidal channel with a side slope of 1:1, the best hydraulic section is obtained if the bed width is approximately equal to 0.83 times the depth.

No-4: Match the statement in Group-I with the most appropriate statement in Group II

	Group I		Group II
4.1	Sprinkler irrigation	(A)	Freezing
4.2	Subsurface drainage	(B)	Governor
4.3	Contour bund	(C)	Grain storage
4.4	Rate of momentum transfer	(D)	Single auger hole
4.5	Planks equation	(E)	Natural convection
4.6	Centrifugal	(F)	Booster pump
4.7	Ergun's equation	(G)	Stress
4.8	Jenssen's equation	(H)	Disc harrow
4.9	Semi-open pump	(I)	Envelope materials
4.10	Crank throw	(J)	Ramp-cum-waste weir
4.11	Tile drain	(K)	Piston stroke
4.12	Timing gear	(L)	Mole plough
4.13	Grashof number	(M)	Fluidization
4.14	Hoogdoudt's method	(N)	Sewage water
4.15	Spools	(O)	Cam shaft

Answer

No.-1

1.1 (B) 1.2 (B) 1.3 (D) 1.4 (C) 1.5 (C) 1.6 (A) 1.7 (A)
1.8 (C) 1.9 (C) 1.10 (A) 1.11 (B) 1.12 (B) 1.13 (A) 1.14 (C)
1.15 (B) 1.16 (D) 1.17 (C) 1.18 (A) 1.19 (A) 1.20 (B)

No.-2

(2.1) 0. 2 to 1.2, (2.2) 90, (2.3) 1 to 2.25, (2.4) 15- 25, (2.5) 140, (2.6) 1500-1800, (2.7) 35, (2.8) L^{-2}, (2.9) $(1-\sin\theta)/(1+\sin\theta)$, (2.10) deca poise, (2.11) $(T_3-T_2)/(T_2-T_1)$, (2.12) $\frac{z_2}{z_1}=\frac{1-P_1}{1-P_2}$, (2.13) $\eta = b(\gamma)^{n-1}$, (2.14) time of concentration, (2.15) Critical depth, (2.16) Passive pressure, (2.17) unconfined, (2.18) seapage, (2.19) diffuser type centrifugal pump, (2.20) 1

No-3

3.1 (F) 3.2 (T) 3.3 (F) 3.4 (T) 3.5 (F) 3.6 (F) 3.7 (F)
3.8 (F) 3.9 (T) 3.10 (T)

No-4

4.1 (F) 4.2 (L) 4.3 (J) 4.4 (G) 4.5 (A) 4.6 (B) 4.7 (M)
4.8 (C) 4.9 (N) 4.10 (K) 4.11 (L) 4.12 (O) 4.13 (E) 4.14 (D)
4.15 (H)

1995

No-1: Choose the correct answer from the multiple choices given below:-

1.1 The size of a seed drill is expressed by
- (A) amount of seed sown per unit time
- (B) length x width of the machine
- (C) area covered per unit time
- (D) The number of furrow openers x distance between two furrow openers.

1.2 The type of bearing generally used to support the discs on a standard disc plough is
- (A) ball bearing
- (B) tapered roller bearing
- (C) plain roller bearing
- (D) bush bearing

1.3 Brake specific fuel consumption of compression ignition engines normally lies in the ranges
- (A) 100 – 100 g/kW h
- (B) 150 - 200 g/kW h
- (C) 200 - 250 g/kW h
- (D) 250 - 300 g/kW h

1.4 Ballasts are sometimes used on front tyres of a 4-wheel tractor to
- (A) increase traction.
- (B) increase stability
- (C) decrease front wheel slippage
- (D) decrease tractor vibration

1.5 For a given spray sample
- (A) the volume median diameter (VMD) is equal to number median diameter (NMD)
- (B) the VMD is less than the NMD
- (C) the VMD is larger than the NMD
- (D) None of the above

1.6 If one traction member of a track-laying tractor equipped with clutch and brake system completely stopped, the torque of the clutch member is
- (A) reduced to half the value for straight forward travel
- (B) Twice the value for straight forward travel
- (C) Maintained the same as that for straight forward travel
- (D) None of the above

1.7 A power tiller is most suited for
- (A) draft operation with rigid tools
- (B) rotary cultivation
- (C) stationary operation
- (D) transport work

1.8 Cylinder loss in a stationary power thresher can be reduced by increasing the
- (A) cylinder peripheral speed
- (B) concave clearance
- (C) blower speed
- (D) all of the above

1.9 The bearing material that is most susceptible to corrosion is
- (A) babbit
- (B) copper-lead
- (C) aluminium
- (D) aluminium-babbit

1.10 One of the main advantages of disc brakes over drum brakes is that the disc brake
- (A) can stop a vehicle in a shorter distance
- (B) is more heat resistant
- (C) weighs less than drum brakes
- (D) requires less pedal force to stop the vehicle

1.11 Erosion index is based on
- (A) I_{15}
- (B) I_{30}
- (C) I_{45}
- (D) I_{60}

1.12 Interception loss is
- (A) more towards end of a storm
- (B) more at the middle of the storm
- (C) more at the beginning of a storm
- (D) uniform throughout the storm

1.13 The side slopes of a Cippoletti Weir is
- (A) 4 in 1
- (B) 1 in 4
- (C) 4:1
- (D) 4 %

1.14 The soil property for good water yield is
- (A) porosity
- (B) effective size > 0.1 mm
- (C) uniformity coefficient > 3
- (D) uniformity coefficient < 2

1.15 In a radial centrifugal pump, the inlet angle will be designed to have
- (A) relative velocity vector in the radial direction
- (B) absolute velocity vector in the radial direction
- (C) velocity of flow to be zero
- (D) peripheral velocity to be zero

1.16 The Bernoulli's equation is written with usual notations as $P/\gamma + V^2/2g + Z = \text{constant}$. In the equation each of the terms represents energy in
- (A) Kg m/Kg mass of fluid
- (B) m/kg mass of fluid
- (C) Nm/kg mass of fluid
- (D) Nm/N of fluid

1.17 In a horizontal rectangular channel a hydraulic jump with a sequent depth ratio of 5.6 is formed. This jump can be classified as
- (A) weak jump
- (B) oscillating jump
- (C) strong jump
- (D) steady jump

1.18 Soil erosion is more in
- (A) sandy soils
- (B) silty soils
- (C) clay loam
- (D) difficult to say

1.19 Middle third rule is to safeguard against
  (A) sliding
  (B) overturning
  (C) crushing
  (D) none of the above

1.20 A 4-hour unit (1 cm) hydrograph means
  (A) 1 cm depth of rainfall over the entire watershed
  (B) 1 cm depth of rainfall excess over the entire watershed
  (C) a hydrograph resulting from the instantaneous application of 1 cm rainfall excess over the entire watershed.
  (D) That stream flow is for four hours.

1.21 Energy required to grind a material from one size to another is expressed by
  (A) Fick's law
  (B) Newton's law
  (C) Kick's law
  (D) Stoke's law

1.22 One ton of refrigeration is equivalent to a heat load of
  (A) 25 kcal/min
  (B) 50 kcal/min
  (C) 100 kcal/min
  (D) 150 kcal/min

1.23 At 100 % relative humidity, wet bulb temperature of air is
  (A) more than dew point temperature
  (B) less than dew point temperature
  (C) same as dew point temperature
  (D) none of the above

1.24 Freezing temperature of brine is
  (A) lower than water
  (B) higher than water
  (C) higher than CH_3Cl
  (D) higher than Freon-12

1.25 Reciprocating compressor sucks
  (A) low pressure and high temperature refrigerant during suction stroke
  (B) high pressure and high temperature refrigerant during suction stroke
  (C) high pressure and low temperature refrigerant during suction stroke.

(D) low pressure and low temperature refrigerant during suction stroke.

1.26 The specific gravity of skim milk is
(A) lower than whole milk
(B) same as whole milk
(C) higher than whole milk
(D) same as water

1.27 At very low pressure, the thermal conductivity of gases approaches
(A) maximum
(B) zero
(C) negative
(D) total pressure

1.28 When a liquid is placed in a sealed container, molecules of liquid evaporate into the space above the liquid. After equilibrium is reached, this vapour will exert a pressure which is called
(A) partial pressure
(B) absolute pressure
(C) vapour pressure
(D) total pressure

1.29 Heated air is saturated by passing through a spray water chamber. If this air is now cooled, its
(A) relative humidity will increase
(B) relative humidity will decrease
(C) absolute humidity will increase
(D) absolute and relative humidity will not change

1.30 Calorific value of rice husk is approximately
(A) 3000 kcal/kg
(B) 5600 kcal/kg
(C) 7000 kcal/kg
(D) 11,000 kcal/kg

No-2:Fill in the blanks with appropriate word(s); symbol(s) or numerical value(s)

2.1 The type of mould board that results in a greater degree of soil pulverization is known as________

2.2 The drillability of a granular fertilizer used in fertilizer drills is______proportional to the angle of repose of the fertilizer.

2.3 The ratio of drawbar power to the power input to wheel axle is known as ______.

2.4 The pistons of high speed diesel engines are generally made of ________.
2.5 The double Hooke's joint is used to have a _______ of driving and driven shafts.
2.6 ________ terrace is constructed as a soil conservation measure for 8 percent rolling cultivated land having annual rainfall of 1500 mm.
2.7 Drip irrigation is designed to achieve a uniformity coefficient of more than ______ %.
2.8 Mole drain is more effective for ______ type of soils.
2.9 Intrinsic permeability is independent of _______ properties.
2.10 A hyetograph is drawn between time and _______.
2.11 The property of particles of bulk material, when in motion, to wear away the surface they are in contact with is called ______.
2.12 _________ is the process of blowing small quantity of air through the bulk of the agricultural produce for cooling and equalizing the temperature.
2.13 Holding of grain during two drying passes is termed as ________.
2.14 Partial cooking of soaked paddy by heat treatment is ________.
2.15 Functional relationship among 'q' quantities or variables in terms of 'u' fundamental units or dimensions may be written as _______ independent dimensionless groups.

No-3: Match the statement in Group I with the most appropriate statement in Group II and answer them using numbers and alphabets only:

	Group I		Group II
3.1	Transport process	A	Soft-centre steel
3.2	Screw conveyor	B	Perennial stream
3.3	High heating value 39 kJ/l	C	277.4 K
3.4	Frozen milk	D	Arid region
3.5	High heating value 34.5 kJ/l	E	Momentum transfer
3.6	Area velocity method	F	$\frac{1+\sin\theta}{1-\sin\theta}$
3.7	Pressurised engine cooling system	G	$\frac{1-\sin\theta}{1+\sin\theta}$

3.8	Ephemeral stream	H	Gear pump
3.9	Share of M.B. plough	I	Air velocity
3.10	Forced engine lubrication system	J	Mean velocity
3.11	Effluent stream	K	Auger flight
3.12	Chilling milk	L	261.0 K
3.13	Rankine coefficient of active earth pressure	M	Peak flood where no gauging station exists
3.14	Diffusion of molecules	N	High speed diesel
3.15	Mould board of M.B. plough	O	Concentration gradient
3.16	Pneumatic conveyor	P	Centrifugal pump
3.17	Slope area method	Q	Regular grade gasoline
3.18	Rankine's coefficient of passive earth pressure	R	Solid steel

Answers

No-1

1.1 (D)	1.2 (B)	1.3 (C)	1.4 (B)	1.5 (C)	1.6 (B)	1.7 (B)
1.8 (A)	1.9 (A)	1.10 (D)	1.11 (B)	1.12 (C)	1.13 (B)	1.14 (D)
1.15 (A)	1.16 (D)	1.17 (B)	1.18 (A)	1.19 (D)	1.20 (B)	1.21 (C)
1.22 (B)	1.23 (C)	1.24 (A)	1.25 (D)	1.26 (C)	1.27 (B)	1.28 (C)
1.29 (A)	1.30 (A)					

No-2

(2.1) stubble, (2.2) Inversely, (2.3) tractive efficiency, (2.4) Al alloy, (2.5) coupling, (2.6) broadbase, graded terrace, (2.7) 90%, (2.8) clayey, (2.9) fluid, (2.10) intensity, (2.11) abrassiveness , (2.12) aeration, (2.13) tempering, (2.14) parboiling, (2.15) q-u.

No-3

3.1 (E)	3.2 (K)	3.3 (Q)	3.4 (L)	3.5 (N)	3.6 (J)	3.7 (P)
3.8 (D)	3.9 (R)	3.10 (H)	3.11 (B)	3.12 (C)	3.13 (G)	3.14 (O)
3.15 (A)	3.16 (I)	3.17 (M)	3.18 (F)			

1996

No-1:Choose the correct answer from the multiple choices given below

1.1 A perfect gas at 27°C is heated at constant pressure till its volume is doubled. The final temperature of the gas is

(A) 54° C
(B) 327° C
(C) 600°C

(D) 654° C

1.2 Moving the centre of gravity of a tractor towards its front wheel creates the problem of
(A) instability
(B) steering
(C) overturning
(D) none of the above

1.3 A machine element rotates at slow speed, low friction and at a large radial load. The type of bearing chosen should be a
(A) plain bearing
(B) ball bearing
(C) roller bearing
(D) tapered roller bearing

1.4 Planters differ from a seed drill in respect of
(A) kind of power transmission system
(B) kind of metering mechanism
(C) kind of furrow opener used
(D) all the above

1.5 The purpose of registration in a mower is
(A) to get uniform length of cut grass
(B) to run the mower at minimum power
(C) to run the mower at uniform torque
(D) to reduce the occurrence of overload

1.6 The upper limit of a tensiometer for soil moisture tension measurement is
(A) 0.85 centibar
(B) 8.5 centibar
(C) 85 centibar
(D) 100 centibar

1.7 A synthetic unit hydrograph can be developed for a basin having
(A) a stream gauging station
(B) a rain gauge network and no stream gauging station
(C) no rain gauge and stream gauging stations
(D) a run gauge station and information on soil characteristics

1.8 Froud number is the ratio of the
(A) inertial force to the shear force
(B) inertial force to the viscous force
(C) inertial force to the gravitational force
(D) viscous force to the gravitational force

1.9 A soil sample has porosity of 40 percent, its void ratio is
(A) 0.06
(B) 0.28
(C) 0.40
(D) 0.66

1.10 Cypress Creek formula is used to compute
(A) design discharge for flat land
(B) design discharge for sloppy land
(C) design rainfall
(D) discharge from a creek

1.11 In a deep litter poultry house, the floor area provided per bird is usually
(A) 0.1 m^2
(B) 0.4 m^2
(C) 1.0 m^2
(D) 1.4 m^2

1.12 The destruction of all microorganisms in food by thermal processing is known as
(A) pasteurization
(B) sterilization
(C) blanching
(D) scalding

1.13 Sensible heating or cooling process of air-vapour mixture on psychometric chart is represented by
(A) horizontal line
(B) vertical line
(C) inclined line
(D) none of these

1.14 The moisture content of paddy at the time of milling should be in the range of
(A) 9 to 10 %
(B) 11 to 12 %
(C) 13 to 14 %
(D) 16 to 18 %

1.15 Foods are frozen by direct immersion method at a temperature of
(A) –18°C
(B) –28°C
(C) –45°C
(D) –62°C

No-2: Match each of the statements in Group I with the most appropriate statement in Group II

	Group I		Group II
2.1	Destruction of all micro-organisms in food and package	A	Torque
2.2	Bearing material	B	Impact
2.3	Tile drain	C	Bubbler
2.4	Spray drying of liquid foods	D	Fan type nozzle
2.5	Mohr's stress circle	E	Babbit
2.6	Hammer mill	F	Herring bone
2.7	Prony brake dynamometer	G	Twin fluid nozzle
2.8	Dairy barn	H	Aseptic processing
2.9	Power sprayer	I	Stanchion
2.10	Ring basin irrigation	J	Shear strength of soil

Answers

No-1

1.1 (B) 1.2 (B) 1.3 (A) 1.4 (B) 1.5 (A) 1.6 (C) 1.7 (C)
1.8 (C) 1.9 (D) 1.10 (A) 1.11 (B) 1.12 (B) 1.13 (A) 1.14 (C)
1.15 (A)

No-2

2.1 (H) 2.2 (E) 2.3 (F) 2.4 (G) 2.5 (J) 2.6 (B) 2.7 (A)
2.8 (I) 2.9 (D) 2.10 (C)

1997

No-1: Write the correct or most appropriate answer to the following multiple choice questions :-

1.1 The high speed plow is
- (A) sod or breaker bottom
- (B) stubble bottom
- (C) general purpose bottom
- (D) none

1.2 For puddling operation, the tynes used in powertiller are
- (A) C-type
- (B) L-type
- (C) combination of C and L-type
- (D) curved type

1.3 The specific fuel consumption of diesel engine ranges from
(A) 0.10 to 0.15 kg/hp/h
(B) 0.15 to 0.20 kg/hp/h
(C) 0.20 to 0.25 kg/hp/h
(D) 0.25 to 0.30 kg/hp/h

1.4 Use of tractor-drawn disc plow among farmers is limited because
(A) it is recommended for use only in arid and semi-arid regions
(B) it is mainly used to open the barren land infested with starts, roots etc.
(C) it is costly and does not perform successful plowing operations
(D) it leaves the land undulated and less pulverized

1.5 In reciprocating type mower, the knife clip of knife section restricts
(A) horizontal displacement of knife
(B) side displacement of knife
(C) vertical displacement of knife
(D) horizontal and side displacement of knife

1.6 Recommended peripheral velocity of spike-tooth threshing cylinder for wheat crop is
(A) less than 20 m/s
(B) 20 to 25 m/s
(C) 25 to 30 m/s
(D) 30 to 35 m/s

1.7 Shortening of top link length of tractor
(A) increases weight transfer on rear wheel
(B) decreases weight transfer on rear wheel
(C) increases penetration of implement
(D) decreases penetration of implement

1.8 Tractor-drawn listers or middle busters will have two mouldboards per bottom and
(A) one land side
(B) two land sides
(C) three land sides
(D) no land sides

1.9 Water is most commonly used as a cooling medium in IC engines because of its
(A) high heat-transfer property
(B) low heat-transfer properties
(C) easy availability

(D) high freezing point

1.10 Dimension of viscosity of liquid is
(A) $M^{-1}L^{-1}T^{-1}$
(B) $ML^{1}T$
(C) $M^{-1}LT^{-1}$
(D) $ML^{-1}T^{-1}$

1.11 A rainfall with an intensity of 5 mm/h is classified as
(A) light rain
(B) heavy rain
(C) drizzle
(D) moderate rain

1.12 If a 4-h unit hydrograph of a catchment has a peak ordinate of 60 m^3s, the peak ordinate of a 8-h unit hydrograph for the same catchment will be
(A) >60 m^3/s
(B) < 60m^3/s
(C) =60m^3/s
(D) data inadequate

1.13 The number of revolutions of a current metre in 50 seconds time were found to be 12 and 30, when the velocity of flow was 0.25 m/s and 0.46 m/s respectively. What velocity would be indicated by 40 revolutions of the current metre in 60 seconds ?
(A) 0.50 m/s
(B) 0.42 m/s
(C) 0.60 m/s
(D) 0.83 m/s

1.14 USBR II stilling basin is provided, when the hydraulic jump is
(A) strong
(B) steady
(C) oscillating
(D) none of the above

1.15 For a well, yield per unit of draw down is
(A) specific capacity
(B) specific yield
(C) well yield
(D) safe yield.

1.16 According to Kennedy, the critical velocity, V_o in metres, which keeps the channel free from silting or scouring, is
(A) $0.84\ mD^{0.64}$
(B) $0.84\ mD^{0.54}$

(C) $0.55\ mD^{0.64}$
(D) $0.55\ mD^{0.54}$

1.17 The structure, whose discharge depend on the water levels of the supply channel and the water course is known as
(A) none-modular outlet
(B) flexible modular outlet
(C) semi-modular outlet
(D) rigid modular outlet

1.18 The minimum water content in a soil at which the soil just begins to crumble when rolled into 3 mm diameter thread is known as
(A) liquid limit
(B) plastic limit
(C) shrinkage limit
(D) permeability limit

1.19 If the specific gravity and void ratio of a soil sample are G and e respectively, the hydraulic gradient, i can be written as
(A) $i = \dfrac{G-1}{1+e}$
(B) $i = \dfrac{G+1}{1-e}$
(C) $i = \dfrac{1-G}{1+e}$
(D) $i = \dfrac{1+G}{1+e}$

1.20 The ratio of the percentage error in the discharge over a triangular notch and the percentage error in the measurement of head is
(A) 2/3
(B) 3/2
(C) 2/5
(D) 5/2

1.21 Milk, having a viscosity μ is flowing through a circular tube of diameter D. The Reynolds number thus can be expressed as DG/μ is
(A) mass flow rate
(B) mass velocity
(C) volumetric flow rate
(D) linear velocity

1.22 A fluid requires a threshold level of stress to initiate the flow, and then it follows a linear stress-strain relationship. This kind of fluid is known as
(A) pseudoplastic
(B) dilatant
(C) Bingham plastic
(D) Bingham pseudoplastic

1.23 Finned-tube heat exchanger is used for heating air. It helps in
(A) increasing the thermal conductivity of air
(B) increasing the heat transfer by natural convection
(C) decreasing the pressure drop in the heat exchanger
(D) getting more surface area for heat transfer

1.24 Rayleigh number is the product of
(A) Nusselt number and Prandtl number
(B) Grashof number and Reynolds number
(C) Reynolds number and Prandtl number
(D) Grashof number and Prandtl number

1.25 Unsteady state unidirectional heat flow in a solid slab can be expressed as

$i = \frac{\partial T}{\partial \theta} = \alpha \frac{\partial^2 T}{\partial x^2}$, where α is
(A) thermal conductivity
(B) specific heat
(C) thermal diffusivity
(D) overall heat transfer coefficient

1.26 The difference between the values of initial and equilibrium moisture content of a food is known as
(A) unbound moisture content
(B) bound moisture content
(C) free moisture content
(D) critical moisture content

1.27 LSU dryer is basically a
(A) cocurrent flow dryer
(B) countercurrent flow dryer
(C) cross-flow batch dryer
(D) through-flow batch dryer

1.28 Drying of fruit pulp can be accomplished by a
(A) tray dryer
(B) fluidized bed dryer

(C) drum dryer
(D) spray dryer

1.29 If ρ_b and ρ_t are the bulk and true density of grain respectively, then the void fraction in a grain bed can be expressed as
(A) $1- \rho_{b/} \rho_t$
(B) $\rho_{b/} \rho_t$
(C) $\rho_{b/} \rho_t$
(D) $1- \rho_{t/} \rho_b$

1.30 Air is flowing through a bed of grain stored in a silo. If V is the void fraction, then the velocity of air ε is the superficial velocity and through the bed is
(A) V/ε
(B) Vε
(C) V/(1-ε)
(D) V/(1-ε)

No-2: Match the statement in Group I with the most appropriate statement in Group II :-

	Group I		Group II
2.1	Sweep	A	Water
2.2	Steering wheel	B	Size reduction
2.3	Wheel ballast	C	Unconfined wells
2.4	Rocker arm	D	Fluidization
2.5	Top link	E	Seepage analysis
2.6	Micro-tube	F	Valve
2.7	Snyder's method	G	Sterilisation of food
2.8	Saltation	H	Synthetic unit hydrograph
2.9	Theis method	I	Turn buckle
2.10	Flow net	J	Unsteady state heat transfer
2.11	Fourier number	K	Wind erosion
2.12	Adiabatic saturation temperature	L	Camber angle
2.13	Z-value	M	Drip irrigation
2.14	Work index	N	Tandem disc harrow
2.15	Pneumatic transportation of solids	O	Humidification

No-3: Fill in the blanks with appropriate word(s), symbol(s) numerical value(s)

3.1 Best soil pulverization is achieved using ________operated by _______after the plowing operation.

3.2 Ridge-shaped furrow bed is obtained using _______and the ridge height should be less than ________ percent of depth of cut.

3.3 Effective operating time required to cover one hectare by a 3 x 30 cm mounted type mould board plow at 3.5 km/h is_____ min for an overlap of 10 cm between the successive passes.

3.4 The oil bath type air cleaner of tractors uses SAE ______oil while tractor gearbox uses SAE _____ oil.

3.5 Tractor-mounted reciprocating type 2.5 m mower operating at 2.4 km/h will require an alignment of ________mm forward.

3.6 The dilution technique of flow measurement depends on the ________principle whereas the electromagnetic method depends on the ________principle.

3.7 Specific speed of a pump expresses relationship among speed _______and_________.

3.8 Two commonly adopted methods for the construction of the earth dams are_________and _________.

3.9 For Darcy's law to be valid, flow should be _______with Reynolds number _______.

3.10 The first and the last stages of the gully development are________ and _________respectively.

3.11 The shear stress (τ) and shear rate (γ) of a power law fluid is related as $\tau = k\ (\gamma)^n$, where K and n are __________ and __________ respectively.

3.12 The energy emitted from a black body is denoted by $q = \sigma AT^4$, where σ is Stefen's Boltzman const. and its value is _______.

3.13 In filtration of a fruit juice, two resistances are encountered for flow of filtrate across the septum. These are ________and__________.

3.14 The cyclone separator is basically used for separation of _______and _________.

3.15 In a spray dryer, the spraying unit is called _________and this helps in obtaining large_________ to facilitate quick drying of liquid foods.

Answers

No-1

1.1 (C)	1.2 (B)	1.3 (B)	1.4 (D)	1.5 (C)	1.6 (C)	1.7 (D)
1.8 (D)	1.9 (A)	1.10 (D)	1.11 (D)	1.12 (B)	1.13 (A)	1.14 (B)
1.15 (A)	1.16 (C)	1.17 (D)	1.18 (B)	1.19 (A)	1.20 (D)	1.21 (B)
1.22 (C)	1.23 (D)	1.24 (D)	1.25 (C)	1.26 (C)	1.27 (B)	1.28 (C)
1.29 (A)	1.30 (A)					

No-2

2.1 (N)	2.2 (L)	2.3 (A)	2.4 (F)	2.5 (I)	2.6 (M)	2.7 (H)
2.8 (K)	2.9 (C)	2.10 (E)	2.11 (J)	2.12 (O)	2.13 (G)	2.14 (B)
2.15 (D)						

No-3

(3.1) tandem disc harrow, tractor (3.2) ridger, 15 % (3.3) 214 (3.4) 40, 90 (3.5) 50 (3.6) Continuity, Faraday's, (3.7)discharge, head (3.8) rolled fill method, hydraulic fill method (3.9) laminar, <=1 (3.10) channel erosion, stabilization of gully (3.11) consistency index, behavior index, (3.12) Stefan-Boltzman constant, 5.67×10^{-8} (3.13) membrane resistance, transport resistance (3.14) solid, gas (3.15) nozzle, surface area

1998

No-1: Indicate the correct or most appropriate answer to the following multiple choice questions by choosing the corresponding letter A, B, C or D against the sub-question number :-

1.1 The firing order of a 4-stroke 4-cylinder engine is given as
- (A) 1-2-3-4
- (B) 1-3-2-4
- (C) 1-3-4-2
- (D) 1-4-3-2

1.2 The forces resulting from piston assembly movement are given by the formula (symbols have their usual meaning)
- (A) $F = Mr\omega^2 (\cos^2 \theta + \cos 2\theta + \ldots\ldots..)$
- (B) $F = r\omega^2 (\cos^2 \theta + r/L\cos^2 2\theta + r/L \cos^2 3\theta + \ldots\ldots..)$
- (C) $F = M\omega^2 r (\cos \theta + r/L\cos 2\theta + \ldots\ldots..)$
- (D) $F = Mr\omega^2 \cos \theta + r/L\cos^2 2\theta$

1.3 In hydraulic sprayers, the degree of atomization is primarily a function of
- (A) liquid pressure and the nozzle characteristics
- (B) air velocity
- (C) size of the nozzle

(D) size and shape of the atomizer

1.4 The virtual hitch point for a directional implement is usually located

(A) near the front axle

(B) 40 mm towards the rear axle

(C) at the power-take off shaft

(D) between the two lower links.

1.5 The speed regulation (S_R) of a governor is related to the average speed ($\overline{N}$) and the change in speed at load (ΔN) by

(A) $S_R = \dfrac{\Delta N}{\overline{N}}$

(B) $S_R = \dfrac{\overline{N}}{\Delta N}$

(C) $S_R = \dfrac{100\overline{N}}{\Delta N}$

(D) none of the above

1.6 An animal-drawn seed drill has k number of furrow openers 180 mm apart. If the speed of operation is 2.0 kmph the area covered (ha), in 8-h day is given by

(A) 185/100k

(B) 28.8×10^{-2} k

(C) k/656

(D) 1.762 k

1.7 The landside of a mouldboard plough is made of

(A) malleable iron

(B) forged steel

(C) C 45 steel

(D) soft centre steel

1.8 In an epicyclic gear speed reduction unit, the ratio of the number of teeth of the annular gear to the sun gears

(A) 3:1

(B) 4:1

(C) 2.5:1

(D) 4.5:1

1.9 The towed force (T_F) of a pneumatic tyre is given by (symbols have their usual meanings)

(A) $T_F = \dfrac{1.21}{C_n} + 0.046$

(B) $T_F = \frac{1.2}{C_n} + 0.04$

(C) $\frac{T_F}{W} = \frac{1.2}{C_n} + 0.04$

(D) $T_F = 1.25W + 0.04\, C_n$

1.10 For a wheeled tractor with mass M and velocity v the expression for total kinetic energy resulting from the linear motion of the tractor is given by.

(A) $KE = \frac{1}{2} Mv^2$

(B) $KE = Mv^2$

(C) $KE = \frac{1.1}{20} Mv^2$

(D) none of the above

1.11 The main difference between flywheel and governor is that

(A) flywheel is heavier than governor

(B) flywheel is fixed to the crankshaft while governor is not

(C) flywheel stores energy and governor controls engine speed

(D) none of the above.

1.12 The most used and least efficient power outlet of a tractor is

(A) power take-off shaft in the front

(B) power take-off shaft in the rear

(C) drawbar in the rear

(D) none of the above.

1.13 The toe-in provided in a tractor is approximately

(A) 14 to 15 mm

(B) 7 to 10 mm

(C) 18 to 25 mm

(D) 2/3 mm

1.14 The size of a tractor tyre may be represented as

(A) section height x rim width

(B) section height x rim diameter

(C) section thickness x rim diameter

(D) section radius x rim width

1.15 Quicksand condition is created due to

(A) frictionless nature of soil

(B) low value of cohesion of soil

(C) upward seepage force greater than submerged weight of soil

(D) downward seepage pressure

1.16 The minimum wind velocity required to initiate movement of soil particle is know as
(A) critical velocity
(B) threshold velocity
(C) dynamic threshold velocity
(D) intrinsic velocity

1.17 The time of concentration of a watershed is proportional to
(A) $L^{1.77}$
(B) $S^{-0\ 185}$
(C) $L^{1.77}S^{0.385}$
(D) none of the above

1.18 If W is the width of a bench terrace, S is the land slope then for riser slope of 1:1 the vertical interval is given by
(A) $\frac{100-S}{WS}$
(B) $\frac{2WS}{200-S}$
(C) $0.3\left(\frac{WS}{2}+2\right)$
(D) none of the above

1.19 In an irrigation channel the critical depth can be produced by
(A) lowering the bottom and reducing the width
(B) raising the bottom and reducing the width
(C) raising the bottom and increasing the width
(D) lowering the bottom and increasing the width

1.20 The ratio of volume of water added or removed directly from the saturated aquifer to the resulting change in volume of aquifer below the water-table is called
(A) apparent specific yield
(B) specific yield
(C) storage coefficient
(D) specific storage

1.21 Subirrigation is useful in a situation where
(A) saline water is used for irrigation
(B) soil is heavy clay to permit high capillary rise
(C) capillary movement in the root zone is rapid
(D) no hard pan is present below the root zone

1.22 In designing regime canal by using Lacey's theory the velocity depends on several factors except
(A) depth of water
(B) hydraulic mean depth
(C) slope of channel
(D) Lacey's silt factor

1.23 Interceptor drain helps to control waterlogging by
(A) lowering the water table
(B) preventing subsoil water from reaching the area
(C) draining out excess water to natural drains
(D) allowing vertical drainage

1.24 In a dairy farm the 'manager' is meant for
(A) breeding the cattle
(B) feeding the cattle
(C) rearing of the calf
(D) storing the feed for long period

1.25 The difference between a shallow tubewell and a deep tubewell lies on the basis of
(A) depth of the tubewell
(B) position of water-table and pump
(C) type of aquifer
(D) depth of aquifer

1.26 For a constant discharge if the diameter of a pipe is reduced to half other factors remaining unchanged, the frictional head loss will increase by
(A) 4 times
(B) 8 times
(C) 16 times
(D) 32 times

1.27 Darcy's Law is valid under the condition of
(A) Laminar flow with Reynold's number > 10
(B) Reynold's number < 1.0
(C) Newtonian flow
(D) Steady uniform flow

1.28 At field capacity soil moisture tension of sandy soil is approximately equal to
(A) 0.1 bar
(B) 1.0 bar
(C) 10 bar
(D) none of the above

1.29 Unit for measurement of vacuum is
(A) kgf/cm^2
(B) torr
(C) mm of Hg
(D) none of the above

1.30 Ergun's equation is applicable to
(A) turbulent flow
(B) slit flow
(C) porous media flow
(D) laminar flow

1.31 Conduction heat transfer is quantified by
(A) Fourier's law
(B) Laplace flow
(C) Burke-Plummer equation
(D) Blake-Kozney equation

1.32 Specific heat, coefficient of viscosity and thermal conductivity are related in
(A) thermal diffusivity
(B) Prandtl number
(C) Schmidt number
(D) Froude number

1.33 Head transfer coefficient in natural convection increases with increasing
(A) Biot number
(B) Nusselt number
(C) Grashof number
(D) None of the above

1.34 Constant rate of drying is directly proportional to
(A) convective heat transfer coefficient
(B) latent heat of vaporization
(C) wet bulb temperature
(D) none of the above

1.35 Freeze drying time is directly proportional to the _______ of the material being dried.
(A) thickness
(B) square of the thickness
(C) cube of thickness
(D) fourth power of thickness

1.36 Decimal reduction time in microbial destruction is inversely proportional to
(A) Z value
(B) universal gas constant
(C) Initial concentration
(D) reaction rate

1.37 Butter must contain _______ % fat.
(A) 60
(B) 20
(C) 80
(D) 90

1.38 For a constant volume flow rate in a cream separator the squarė of the separate particle diameter is directly proportional to
(A) the speed of the separator
(B) the density difference between skim milk and cream
(C) number of discs
(D) coefficient of viscosity of skim milk

1.39 The temperature for ultra-high-temperature (UHT) sterilization of milk is
(A) 90 to 100 ^{0}C
(B) 100 to 115^{0}C
(C) 135 to 150 ^{0}C
(D) none of the above

1.40 Losses of nutrient during heating of food products are guided by ________ order reaction.
(A) zero
(B) first
(C) second
(D) none of the above

2. Match the statement in Group I with most appropriate statement in Group II :-

Group I	Group II
2.1 Pit man	i) filter
2.2 swirl	ii) MB plough
2.3 Economy	iii) Diesel
2.4 Micron	iv) alignment
2.5 Thermostat	v) atomization
2.6 Bevel gear	vi) Massey Ferguson
2.7 ASTM	vii) deration

2.8 Turbocharger	viii) water
2.9 Blow off spring	ix) Right angle
2.10 Seat	x) cage wheel
2.11 Traction	xi) cylinder
2.12 Mounted	xii) direct injection
2.13 Spike tooth	xiii) vibration
2.14 Laplace equation	xiv) Mohr's circle
2.15 Subsoil tillage	xv) pump selection
2.16 Hydraulic conductivity	xvi) steam function
2.17 Opportunity time	xvii) critical flow
2.18 Shear strength	xviii) drainage
2.19 Propeller	xix) critical height
2.20 Efficiency	xx) auger hole
2.21 Parshall flume	xxi) chisel plow
2.22 Wind	xxii) border irrigation
2.23 Cypress Creak formula	xxiii) diffuser
2.24 Water in oil emulsion	xxiv) R-Value
2.25 Power number	xxv) Fick's Law
2.26 Food spoilage	xxvi) Eutectic temperature
2.27 Water purification	xxvii) Butter
2.28 Heat Exchanger effectiveness	xxviii) water activity
2.29 Heat transfer resistance	xxix) sterilization
2.30 Vapour recompresser	xxx) agitation
2.31 Molecular diffusion	xxxi) chlorine
2.32 Duhring lines	xxxii) NTU
2.33 Activation energy	xxxiii) evaporator
2.34 Instantization	xxxiv) evaporation
2.35 Food freezing	xxxv) Spray drying

Answers

No-1

1.1. (C)	1.2. (C)	1.3. (A)	1.4. (D)	1.5. (A)	1.6. (B)	1.7. (D)
1.8. (A)	1.9. (C)	1.10. (C)	1.11. (C)	1.12. (C)	1.13. (B)	1.14. (C)
1.15. (C)	1.16. (B)	1.17. (B)	1.18. (D)	1.19. (D)	1.20. (C)	1.21. (C)
1.22. (A)	1.23. (B)	1.24. (B)	1.25. (A)	1.26. (D)	1.27. (B)	1.28. (A)
1.29. (C)	1.30. (C)	1.31. (A)	1.32. (B)	1.33. (C)	1.34. (A)	1.35. (B)
1.36. (D)	1.37. (C)	1.38. (D)	1.39. (C)	1.40. (B)		

No-2

2.1. iv	2.2 xii	2.3 viii	2.4 v
2.5 vii	2.6 ix	2.7 iii	2.8. vi

2.9 i	2.10 xii	2.11 x	2.12 ii
2.13 xi	2.14 xvi	2.15 xxi	2.16 xx
2.17 xxii	2.18 xiv	2.19 xxiii	2.20 xv
2.21 xvii	2.22 xix	2.23 xviii	2.24 xxvii
2.25 xxx	2.26 xxviii	2.27 xxxi	2.28 xxxii
2.29 xxiv	2.30 xxxiii	2.31 xxv	2.32 xxxiv
2.33 xxix	2.34 xxxv	2.35 xxvi	

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No-1:Choose the correct answer from the multiple choices given below

1.1 Operating a tractor with restrained links rather than free links
- (A) reduces the vertical load on the rear wheels
- (B) provides lower tractive ability
- (C) results in smaller depth fluctuations caused by ground-surface irregularities
- (D) none of the above.

1.2 The method which depreciates the tractor or machine to zero at the end of its expected life is known as
- (A) estimated value
- (B) sum of the digits
- (C) declining balance
- (D) straight line

1.3 A power tiller is most suited for rotary cultivation because
- (A) it generates negative draft
- (B) its traction requirement is low
- (C) it provides high degree of soil pulverization
- (D) all of the above

1.4 The volumetric efficiency of a turbo-changed diesel tractor engine is typically in the range of
- (A) 90 to 100 percent
- (B) 100 to 150 percent
- (C) 150 to 200 percent
- (D) 200 to 250 percent

1.5 The type of furrow opener recommended for use in hard or trashy ground and also in wet, sticky soils is
- (A) single disc type
- (B) stub runner type
- (C) full or curved runner type
- (D) hoe type

1.6 In axial flow paddy power threshers, a spike tooth cylinder is preferred over a rasp bar cylinder because
   (A) it has more positive feeding action
   (B) it requires less power
   (C) it does not plug as easily
   (D) all of the above
1.7 When differential lock is engaged in a two-wheel drive tractor
   (A) the two axle torques must be equal
   (B) the two axle torques are not necessarily equal
   (C) the power transmitted to both axles must be same
   (D) neither axle can transmit more torque than is permitted by the wheel with the poorest traction
1.8 The type of starting aid generally used in a diesel power tiller is
   (A) glow plug
   (B) thermo start
   (C) decompression lever
   (D) intake manifold surrounded by exhaust manifold
1.9 When the amount of torque to be transmitted is very high and frequency of occurrence of overload is low, the type of safety device that can be employed in a farm machine is
   (A) safety jump clutch
   (B) safety shear pin
   (C) safety friction clutch
   (D) V-belt
1.10 The most common fertilizer metering device used in a seed cum fertilizer drill is
   (A) revolving bottom plate
   (B) vertical rotor with grooves
   (C) adjustable opening with agitator disc
   (D) star wheel
1.11 For tractor conditions the desired temperature drop in the water as it passes from the top of the radiator to the bottom should like in the range of
   (A) 2.5 to 5.5 °C
   (B) 5.5 to 8.5 °C
   (C) 8.5 to 11.5°C
   (D) 11.5 to 14.5 °C
1.12 The lateral stability of a four-wheel tractor in a turning situation can be increased by
   (A) increasing the radius of the turn

(B) increasing the height of the centre of gravity
(C) attaching a front end loader
(D) increasing the total weight of the tractor

1.13 The undamped natural frequency of wheel of tractors generally lies in the range of
(A) 5 to 10 HZ
(B) 10 to 15 Hz
(C) 15-20 Hz
(D) 20 to 25 Hz

14. The theoretical length of cut in a field chopper can be increased by
(A) increasing the number of knives
(B) decreasing the peripheral speed of the feed rolls
(C) increasing the rotational speed of the cutter head
(D) none of the above.

1.15 A line makes an angle 45° to horizontal. The slope of the line is
(A) 1 percent
(B) 50 percent
(C) 90 percent
(D) 100 percent

1.16. The brake horsepower of a centrifugal pump varies directly.
(A) as the speed of the impeller
(B) as the square of the speed of the impeller
(C) as the cube of the speed of the impeller
(D) as the fourth power of the speed of the impeller

1.17 The conjunctive use of water in a basin means
(A) combined use of water for irrigation and hydropower generation
(B) use of water by co-operative farmers
(C) use of water for irrigating both rabi and kharif crops
(D) combined use of surface and ground water resources

1.18 The safe entrance velocity through a well screen is
(A) 0.3 mm/s
(B) 3 mm/s
(C) 30 mm/s
(D) 300 mm/s

1.19 Cavity wells with blind pipe
(A) do not have strainers and water enters from bottom only
(B) do not have strainers and water enters from sides only
(C) have strainers and water enters from bottom only
(D) have strainers and water enters from both bottom and sides

1.20 In a simply supported beam the bending moment at zero shear force will be
(A) zero
(B) maximum
(C) minimum
(D) any value between maximum and minimum

1.21 A saturated soil sample has 42.2 percent water content and unit weight 2.69. The void ratio of the soil sample will be
(A) 0.784
(B) 0.478
(C) 0.874
(D) 0.087

1.22 At optimum soil moisture content, the dry density of soil will be
(A) maximum
(B) average
(C) minimum
(D) zero

1.23 Hydrometry is the
(A) practice of using hydrometer
(B) science of hydrograph analysis
(C) science of measurement of flow
(D) subject of hydrology dealing with rivers

1.24 A unit hydrograph has
(A) one unit of peak discharge
(B) one unit of time base of direct runoff
(C) one unit of rainfall duration
(D) one unit of direct runoff

1.25 Table top bench terraces are suitable for areas receiving
(A) medium uniformly distributed rainfall with medium permeable deep soils
(B) heavy rainfall with permeable deep soils
(C) low rainfall with permeable deep soils
(D) very high rainfall with permeable shallow soils

1.26 Soil detachability increases as the
(A) size of particle reduces
(B) size of particle increases
(C) impact angle of raindrop reduces
(D) length of slope reduces

1.27 In a stall barn, the floor space required for each cow is between
(A) 3.5 and 5.5 m^2

(B) 5.6 and 7.5 m^2
(C) 7.6 and 9.5 m^2
(D) 9.6 and 11.6 m^2

1.28 Paddy is normally stored at
(A) 12 percent moisture content on dry basis
(B) 12 percent moisture content on wet basis
(C) 15 percent moisture content on wet basis
(D) 15 percent moisture content on dry basis

1.29 Dry ice is known as
(A) solidified water kept in moisture free-environment
(B) solidified freon-12
(C) solidified carbon dioxide
(D) solidified nitrogen

1.30 Most spoilage and pathogenic bacteria that contaminate food materials have water activity in the range of
(A) 0.91 to 0.99
(B) 0.86 to 0.90
(C) 0.81 to 0.85
(D) 0.75 to 0.80

1.31 Under the most ideal conditions a bacterium may reproduce itself as often as
(A) every 20 to 30 seconds
(B) every 20 to 30 minutes
(C) every 20 to 30 hours
(D) every 2 to 3 days

1.32 The orange colour of tomato is due to
(A) Chlorophyll A
(B) Anthocyanins
(C) Xanthans
(D) Lycopene

1.33 Presumptive test is found positive for
(A) E. Coli
(B) B. Coli
(C) Lactobacillus bulgaricus
(D) Clostridium botulinum

1.34 The differential speed of rolls of wheat mill is
(A) 2.0:1
(B) 2.5:1
(C) 3.0:1
(D) 3.5:1

1.35 Thermal processing of food material should be based on the head sensitivity of the
- (A) spores of fungi
- (B) vegetative cells of fungi
- (C) spores of bacterial
- (D) vegetative cells of bacteria

1.36 One tonne of refrigeration is equivalent to the heat required to melt one tonne of ice in
- (A) 6 h
- (B) 12 h
- (C) 18 h
- (D) 24 h

1.37 Calorific value of rice husk is approximately
- (A) 1.25×10^4 kJ/kg
- (B) 2.33×10^4 kJ/kg
- (C) 4.65×10^4 kJ/kg
- (D) 4.94×10^4 kJ/kg

1.38 If a fat globule of 4 mm in diameter moves upwards at a velocity of 1.06 mm/h the velocity of fat globule which is twice this size will be
- (A) 2.12 mm/h
- (B) 3.18 mm/h
- (C) 4.24 mm/h
- (D) 5.30 mm/h

1.39 Chhana balls are expanded due to
- (A) Protein denaturation
- (B) differential vapour pressure
- (C) Shortage of lactose
- (D) osmotic pressure

1.40 Energy required to break a drop of liquid into small droplets will depend mainly on
- (A) the surface tension of the liquid
- (B) the viscosity of the liquid
- (C) the density of the liquid
- (D) the heat capacity of the liquid

No-2. Match the statement in group I with most appropriate statement in Group II :

Group I		Group II	
2.1	Mould board	i)	Directional stability
2.2	Camber	ii)	Tapered roller bearing
2.3	High octane Fuel	iii)	Worm and gear
2.4	Disc plough	iv)	Lean mixture
2.5	CI engine	v)	Soft center steel
2.6	Share	vi)	Plain bearing
2.7	Caster	vii)	Compressed natural gas
2.8	High cetane number	viii)	Rich mixture
2.9	SI engine	ix)	Sunflower oil
2.10	Disk harrow	x)	Solid steel
2.11	Hand-chaff cutter	xi)	Tyre wear
2.12	Middle two-third rule	xii)	Ground water flow
2.13	Isochrone	xiii)	Centrifugal pump
2.14	Low head, high discharge	xiv)	Unsteady state flow confined aquifer
2.15	20-40 rule	xv)	Bi-walled pipe
2.16	Point source emitter	xvi)	spiles
2.17	Dupit-Theim's method	xvii)	Overland flow
2.18	High head, low discharge	xviii)	Spurs
2.19	Irrigation water control	xix)	Steady state flow unconfined aquifer
2.20	Theis method	xx)	Propeller pump
2.21	Line source emitter	xxi)	Drainage
2.22	Isobath	xxii)	Soil conservation structure
2.23	Stream bank erosion control	xxiii)	Pressure compensating emitters
2.24	Solid food	xxiv)	Reynolds number
2.25	Alkaline phosphatase test	xxv)	Fick's law
2.26	Ovalbumin	xxvi)	Curd tension
2.27	Ratio of inertia force to gravity force	xxvii)	Milk protein
2.28	Sublimation	xxviii)	Pasteurization
2.29	Molecular transport of heat	xxix)	Drum drying
2.30	Hill test	xxx)	Freeze drying
2.31	Liquid food	xxxi)	Fourier law
2.32	α -lactalbumin	xxxii)	Freeze concentration

2.33	Ration of inertia force to viscous force	xxxiii)	Egg protein
2.34	Molecular transport of mass	xxxiv)	Tray drying
2.35	Freezing	xxxv)	Froude number

Answers

No-1

1.1 (D)	1.2 (B)	1.3 (D)	1.4 (A)	1.5 (A)	1.6 (D)	1.7 (C)
1.8 (C)	1.9 (B)	1.10 (D)	1.11 (B)	1.12 (B)	1.13 (A)	1.14 (D)
1.15 (D)	1.16 (C)	1.17 (D)	1.18 (C)	1.19 (A)	1.20 (B)	1.21 (D)
1.22 (A)	1.23 (C)	1.24 (D)	1.25 (A)	1.26 (B)	1.27 (D)	1.28 (B)
1.29 (C)	1.30 (A)	1.31 (B)	1.31 (B)	1.32 (C)	1.33 (A)	1.34 (B)
1.35 (D)	1.36 (D)	1.37 (A)	1.38 (C)	1.39 (B)	1.40 (C)	

No-2

2.1 v	2.2 xi	2.3 vii	2.4 ii
2.5 iv	2.6 x	2.7 i	2.8 ix
2.9 viii	2.10 vi	2.11 iii	2.12 xxii
2.13 xvii	2.14 xiii	2.15 xxi	2.16 xxiii
2.17 xix	2.18 xx	2.19 xvi	2.20 xiv
2.21 xv	2.22 xii	2.23 xviii	2.24 xxxiv
2.25 xxviii	2.26 xxxiii	2.27 xxxv	2.28 xxx
2.29 xxxi	2.30 xxvi	2.31 xxix	2.32 xxvii
2.33 xxiv	2.34 xxv	2.35 xxxii	

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No-1: Choose the best answer from the choices given below:-

1.1 Cutting speed of cutter bar of a mower is

(A) 35-50 m/s
(B) 10-20 m/s
(C) 2-4 m/s
(D) 0.2-0.4 m/s

Ans (C)

1.2 If the travel speed of a tillage tool is increased, the draft will

(A) increase linearly
(B) decrease linearly
(C) increase quadratically
(D) decrease quadratically

Ans (C)

1.3 Working element of a paddy thresher is

(A) rasp bar

(B) wire loop
(C) spike tooth
(D) angle iron bar
Ans(B)

1.4 A tractor-drawn seed drill operated at 4 kilometre per hour gives 80 kilogram per hectare seed rate. If the tractor speed is increased to 5 kilometre per hour, the new seed rate will be
(A) 64 kilograms per hectare
(B) 70 kilograms per hectare
(C) 80 kilograms per hectare
(D) 100 kilograms per hectare
Ans (C)

1.5 Lowering of a tractor-mounted implement is accomplished by
(A) hydraulic force
(B) tractor weight
(C) implement weight
(D) linkage
Ans (C)

1.6 Power tillers are not generally employed for draft application because of
(A) low horsepower
(B) low speed
(C) low coefficient of traction
(D) non-availability of matching implements
Ans (C)

1.7 The most harmful vibration frequency for a human being is
(A) less than 1 Hz
(B) 1 to 20 Hz
(C) 50 to 20000 Hz
(D) greater than 5000 Hz
Ans (B)

1.8 Theoretical maximum efficiency of a wind rotor is
(A) 55 percent
(B) 67 percent
(C) 85 percent
(D) 90 percent
Ans (A)

1.9 Keeping other factors constant, doubling the diameter of a tube well will increase the discharge by
(A) 10 percent

(B) 25 percent
(C) 50 percent
(D) 100 percent
Ans (A)

1.10 First four classės of land in the land-capability classification are suitable
(A) only for cultivation and not for other uses
(B) for cultivation and other uses
(C) partly for cultivation and mostly for other uses
(D) for uses other than cultivation
Ans (B)

1.11 The albedo depends on
(A) incoming radiation
(B) reflected radiation
(C) incoming and reflected radiation
(D) absorbed radiation
Ans (B)

1.12 Evapotranspiration in a crop field surrounded by dry fallow land will be higher than that surrounded by vegetation due to
(A) conduction of heat
(B) oasis effect
(C) clothesline effect
(D) convection of heat
Ans (B)

1.13 Computation of evapotranspiration by Blaney-criddle method is based on the principle of
(A) aerodynamics
(B) energy balance
(C) empirical approach
(D) combination of the above
Ans (C)

1.14 For a watershed, the universal soil-loss equation computes
(A) annual runoff
(B) average annual soil loss
(C) erodibility factor
(D) average annual rainfall
Ans (B)

1.15 Darcy's law is valid for
(A) laminar and turbulent flow
(B) turbulent flow

(C) laminar flow
(D) transient flow
Ans (C)

1.16 If the impeller speed of a centrifugal pump is doubled, the power consumption will be
(A) the same
(B) doubled
(C) four times
(D) eight times
Ans (D)

1.17 The available net positive suction head of a pump depends on
(A) suction lift
(B) friction loss
(C) vapour pressure
(D) all of these
Ans (D)

1.18 The unit of heat transfer resistance of a material is
(A) $W\ m^{-1}\ {}^{o}C^{-1}$
(B) $m\ {}^{o}C\ W^{-1}$
(C) ${}^{o}C\ W^{-1}$
(D) $W\ m^{o}C^{-1}$
Ans (C)

1.19 The Tyler-standard screen scale is based on standard opening of
(A) 28 mesh (0.589 mm)
(B) 48 mesh (0.295 mm)
(C) 100 mesh (0.147 mm)
(D) 200 mesh (0.074 mm)
Ans (D)

1.20 Centrifugal discharge is used in
(A) belt conveyor
(B) chain conveyor
(C) screw (auger) conveyor
(D) bucket elevator
Ans (D)

1.21 Machine used for dehusking of pulses is
(A) rubber roll dehusker
(B) emery roll dehusker
(C) centrifugal dehusker
(D) under-runner disc sheller
Ans (B)

1.22 Convective heat transfer coefficient h ($W\ m^{-2}\ {}^{o}C^{-1}$) and mass flux M ($kg\ m^{-2}\ s^{-1}$) of a fluid flowing through a pipe under turbulent condition are related as
(A) $h \propto M$
(B) $h \propto M^{0.5}$
(C) $h \propto M^{-0.8}$
(D) $h \propto M^{0.8}$
Ans (D)

1.23 Convective mass transfer coefficient of water vapour in air depends on
(A) velocity of air
(B) viscosity of water vapour
(C) density of water vapour
(D) none of the above
Ans (A)

1.24 The rate $dN/d\Theta$ of inactivation of microbial population N in a given food material is normally proportional to
(A) Θ
(B) N
(C) $-N$
(D) $-N^2$
Ans (C)

1.25 Following component(s), if present in a food material will reduce its water activity.
(A) protein
(B) sucrose
(C) fat
(D) all of the above
Ans (B)

No-2: For each of these sub-questions, four possible answers (A, B, C and D) are given, out of which only one is correct. Mark the answer correctly:-

2.1 A two bladed flywheel type forage cutter rotates at 60 rev/min. At a feed rate of 1.26 m/min, the theoretical length of the cut of the forage will be
(A) 5.3 mm
(B) 10.5 mm
(C) 21.0 mm
(D) 42.0 mm

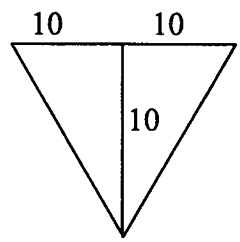
Ans (B)

$V = NLn$

$\Rightarrow 1.26 = 2 \times L \times 60 \Rightarrow L = 10.5\,mm.$

2.2 A cultivator (11 x 30 cm) is operated at a depth of 10 cm. The furrow cross section is a triangle having 90° tip angle. If the unit draft of the soil is 20 kN/m^2. the draft will be

(A) 110 N
(B) 220 N
(C) 2.2 kN
(D) 4.4 kN



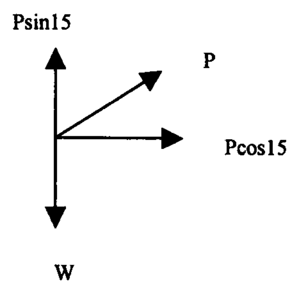
Ans (B)

$A = \left(\frac{1}{2} \times 10 \times 20\right) \times 11 = 0.11\text{m}$

Total draft = 0.11 X 2 = 0.22KN

2.3 A pull of 6.5 kN is exerted on an implement at an angle of 15° with the ground surface. If the weight of the implement is 350 kg, the vertical soil reaction will be

(A) 1.75 kN upward
(B) 3.43 kN downward
(C) 3.43 kN upward
(D) 5.12 kN downward



Ans(A)

Vertical soil reaction=W-Psin15

$= \left(\frac{350 \times 9.81}{1000}\right) - 6.5 \times \sin 15^0$

= 1.7 kN upward.

2.4 A mechanical press can compress 20 bales of cotton per minute. As the bale is compressed through a distance of 22 cm, the compressive force is increased linearly from 0 to 60 kN. The power consumed by the press will be

(A) 132 kW
(B) 6.6 kW
(C) 4.4 kW
(D) 2.2 kW

Ans (C)

x = 22cm = 0.22m.

$$P = 60 \times 0.22 \times \frac{20}{60} = 4.4 \text{ kW}$$

2.5 Cooling system of a 6.8 kW diesel engine running at full load will remove heat at a rate of
(A) 1.63 kcal/min
(B) 6.80 kcal/min
(C) 97.6 kcal/min
(D) 408 kcal/min
Ans (C)

$$6.8 \text{ kw} = 6.8 \text{ KJ/S} = \frac{6.8}{4.18}\frac{KCal}{S} = \frac{6.8}{4.18} \times 60 \frac{KCal}{Min}$$

$$= 97.6 \frac{Kcal}{\min}$$

2.6 Bore and stroke of a single-cylinder engine are 8 cm and 9.6 cm respectively. If the air (density = 1.26 kg/m^3) intake is 0.505 g/cycle, the volumetric efficiency of the engine will be
(A) 76.5 percent
(B) 83.0 percent
(C) 89.0 percent
(D) 118.0 percent
Ans (B)

$$v = \frac{\pi}{4} d^2 L = \frac{3.141}{4} \times (0.08)^2 \times 0.096 = 4.83 \times 10^{-4} m^3$$

$$\text{Air intake} = \frac{0.505}{1000 \times 1.26} = 4 \times 10^{-4} m^3$$

$$\text{Volumetric efficiency} = \frac{4 \times 10^{-4}}{4.83 \times 10^{-4}} = 83\%$$

2.7 The rear wheel diameter of a tractor is 130 cm and its wheel base is 185 cm. If a horizontal pull of 6 kN is applied at a distance of 25 cm below the rear axle, the weight transfer will be
(A) 0.811 kN
(B) 1.30 kN
(C) 3.75 kN
(D) 4.70 kN
Ans: (B)

$D_r = 130$ cm, L=185 cm

$X_1 = \dfrac{130}{2} - 25 = 40\,cm.$

$R_f = \dfrac{WX_1}{L} = \dfrac{6 \times 40}{185} = 1.30kN$

2.8 Vertical reaction on the rear wheels of a tractor is 11.77 kN and each wheel has a ground contact area of 0.165 m^2. If the coefficient of friction between the soil and the material of the wheel is 0.35 and the value of unit cohesion is 7 kN/m^2, the maximum gross thrust will be

(A) 2.96 kN
(B) 4.12 kN
(C) 5.27 kN
(D) 6.43 kN

Ans: (D)

F=AC+w tan ϕ = $(2 \times 0.165) \times 7 + 11.77 \times 0.35 = 6.43$ kN.

2.9 The threshold salinity of a soil is 2.0 mmho/cm and the decrease in alfalfa crop yield is 7.3 percent per unit increase in the salinity. If the average soil salinity is 5.4 mmho/cm, the relative crop yield will be

(A) 70 percent
(B) 75 percent
(C) 80 percent
(D) 85 percent

Ans (B)

2.10. The seasonal gross irrigation requirement of a vegetable crop grown under shallow water-table condition is 25 cm . If the effective precipitation is 30 cm, seasonal crop evapotranspiration is 50 cm and application efficiency of border irrigation system is 60 percent, the contribution from the shallow ground water-table will be

(A) 1 cm
(B) 5 cm
(C) 10 cm
(D) 15 cm

Ans (B)

IR = ET-Rain fall + S

$\Rightarrow$ S = IR – ET + Rainfall = 25 – 50 + 30 = 5cm

2.11 Electrical conductivity (EC) of saturation extract of a soil is 10 mmho/cm. If the EC of irrigation water is 1.2 mmho/cm, the leaching requirement will be

(A) 3 percent
(B) 6 percent
(C) 9 percent
(D) 12 percent

Ans: (B)

$$\frac{EC_i}{EC_d} = \frac{EC_i}{2 \times EC_e} = \frac{1.2 \times 100}{2 \times 10} = 6\%$$

2.12 A watershed of 1000 hectare is discharging through a drain at an average rate of 2 m^3/s. The drainage coefficient of the watershed is

(A) 1.73 cm
(B) 1.93 cm
(C) 2.13 cm
(D) 3.93 cm

Ans: (A)

$$DC = \frac{2 \times (3600 \times 24)}{1000 \times 10^4} = 0.0173m = 1.73cm$$

2.13 A tickle irrigation system has one emitter per plant. If the coefficient of variation is 0.12 and application efficiency is 88.5 percent, the system efficiency will be

(A) 70 percent
(B) 75 percent
(C) 80 percent
(D) 85 percent

Ans: (C)

Emission uniformity, $EU = 1 - \frac{0.8Cv}{n^{0.5}} = 1 - \frac{0.8 \times 0.12}{1^{0.5}} = 0.9.4$

System efficiency, $E = EU \times Ea \times 100 = 0.904 \times 0.885 \times 100 = 80\%$

2.14 Water flow through a 1.2 m long cylindrical soil column having 650 cm^2 cross-sectional area is 800 litre per minute. If the hydraulic head is 1.5 m, the hydraulic conductivity of the soil will be

(A) 16 cm/s
(B) 24 cm/s
(C) 30 cm/s
(D) 36 cm/s

Ans: (A)

$$K=\frac{QL}{Ah}=\frac{0.8\times1.2}{650\times10^{-4}\times1.5}=9.846\text{m/min}=16.4\text{ cm/sec}$$

2.15 The major water course of a 3 square kilometre watershed has a fall of 25 m in 2.5 km. The time of concentration will be

(A) 47.48 min
(B) 51.35 min
(C) 55.21 min
(D) 59.23 min

Ans: (A)

$$T_c=0.0195\,L^{0.77}S^{-0.385}=0.0195\times(2500)^{0.77}\times(0.01)^{-0.385}$$

$= 47.48$ min

2.16 A centrifugal pump running at 1450 rev/min discharges 20 liter per second at 30 m total head. The specific speed of the pump will be

(A) 12
(B) 16
(C) 20
(D) 24

Ans: (B)

$$\eta_s=\frac{nQ^{\frac{1}{2}}}{h^{\frac{3}{4}}}=\frac{1450\times(0.02)^{\frac{1}{2}}}{(30)^{\frac{3}{4}}}=16\text{ rpm}$$

2.17 Partial pressure of nitrogen in a mixture of 7 parts nitrogen and 3 parts oxygen by mass at 200 kPa total pressure is

(A) 175 kPa
(B) 160 kPa
(C) 150 kPa
(D) 145 kPa

Ans: (D)

Partial pressure = molecular fraction $\times$ Total Pressure

$$=\left(\frac{7/28}{7/28+3/32}\right)\times200=145.45\text{ kPa}$$

2.18 Critical speed of a ball mill of 1200 mm diameter filled with 75 mm balls is

(A) 28 rev/min
(B) 38 rev/min
(C) 48 rev/min

(D) 58 rev/min
Ans (B)

$$n_C = \frac{1}{2\pi}\sqrt{\frac{g}{R-r}} = \frac{1}{2\pi}\sqrt{\frac{9.81}{\frac{1.2}{2} - \frac{0.078}{2}}} = 39.93\ rpm$$

2.19 Mass of moisture removed in drying 30 tonnes of wheat from 22 percent to 13 percent (wet basis) moisture content is
(A) 2000 kg
(B) 2700 kg
(C) 3000 kg
(D) 3100 kg
Ans (D)
M = 30 x1000=30,000 kg
Initial moisture content = 30, 000 x 0.22 = 6600 kg
M_d = 30,000 - 6,600 = 23,400 kg
Mass of moisture removed = M_d (W_{d1}-W_{d2}) = 23,400 (28.2-14.94)
= 3102 kg

2.20 At a certain stage of fluidization, the height and porosity of a bed of granular material are 5 cm and 0.4 respectively. If the height is increased to 6 cm by increasing air velocity, the porosity of the bed will be
(A) 0.30
(B) 0.45
(C) 0.50
(D) 0.60
Ans(C)

$$\frac{L_1}{L_2} = \frac{1-\varepsilon_2}{1-\varepsilon_1} \Rightarrow \frac{5}{6} = \frac{1-\varepsilon_2}{1-0.4} \Rightarrow \varepsilon_2 = 0.5$$

2.21 Milk having 1000 kg/m^3 density is homogenized against a pressure of 20 Mpa. The velocity of the milk through the homogenizing valve will be
(A) 100 m/s
(B) 150 m/s
(C) 200 m/s
(D) 1000 m/s
Ans (C)
Pressure head =Velocity head

$$\frac{P}{\rho g} = \frac{v^2}{2g} \Rightarrow V = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2 \times 20 \times 10^6}{1000}} = 200\ m/s$$

2.22 Saturation vapor pressure of water is 31.19 kPa at 70°C and 38.58 kPa at 75°C. The approximate boiling temperature of water maintained under a vacuum of 50 cm of mercury will be
(A) 68°C
(B) 72°C
(C) 77°C
(D) 88°C
Ans (B)

2.23 Buoyant force experienced by a spherical grain of 100 mg weight and 1250 kg/m^3 particle density in water under gravity is
(A) 2×10^{-9} N
(B) 4×10^{-8} N
(C) 6×10^{-6} N
(D) 8×10^{-4} N
Ans (D)

$$V = \frac{100 \times 10^{-6}}{1250} m^3$$

$$U = \frac{100 \times 10^{-6}}{1250} \times 1000 \times 9.81 = 7.84 \times 10^{-4}\ N$$

2.24 Average particle size of wheat flour having 3.53. Fineness Modulus is
(A) 1 mm
(B) 1.1 mm
(C) 1.2 mm
(D) 1.3 mm
Ans (C)
$D_p = 0.0041 \times 2^{FM} \times 2.54 \times 10$ mm
$= 0.0041 \times 2^{3.53} \times 2.54 \times 10 = 1.2$ mm

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No-1: Choose the best answer from the choices given below :-

1.1 The average firing interval for 6-cylinder, 4 cycle engines is
(A) 120°
(B) 180°
(C) 240°

(D) 360°
Ans (A)

1.2 In a modern pressurized tractor engine cooling system the boiling point is raised approximately 1°C for increase in coolant pressure by
(A) 1 kPa
(B) 2 kPa
(C) 3 kPa
(D) 4 kPa
Ans (D)

1.3 The type of clutch generally used to engage/disengage engine power from the transmission in 10-15 hp commercial power tillers is
(A) cone clutch
(B) single plate friction clutch
(C) multiple disc plate clutch
(D) V-belt with idler pulley
Ans (D)

1.4 The most inaccurate method of calculating depreciation for determining the real value of tractor at any time during its useful life is
(A) estimated value
(B) straight line
(C) constant percentage
(D) sum-of-the digits
Ans (B)

1.5 In a country plough, the depth of furrow can be increased by
(A) increasing the downward handle force
(B) increasing the weight of the plough
(C) shifting the hitch point closer to the ploughman
(D) shifting the hitch point away from the ploughman
Ans (D)

1.6 If Q_r and P_r are rated nozzle flow rate and rated nozzle pressure respectively, the desired pressure p for a given nozzle flow rate Q_n can be determined by
(A) $(Q_n/Q_r)\ p_r$
(B) $(Q_n/Q_r)^2\ p_r$
(C) $(Q_n/Q_r)^3\ p_r$
(D) $(Q_n/Q_r)^4\ p_r$
Ans (B)

1.7 The mould board of a mould board plough is usually made of
(A) malleable iron
(B) forged steel
(C) soft-centre steel
(D) mild steel
. Ans(C)

1.8 For proper alignment the amount of lead generally provided in a reciprocating type mower cutter bar is about.
(A) 5 mm per metre of bar length
(B) 10 mm per metre of bar length
(C) 15 mm per metre of bar length
(D) 20 mm per metre of bar length
Ans (D)

1.9. The hydrologic flood-routing methods use
(A) equation of continuity only
(B) equation of motion only
(C) both momentum and continuity equations
(D) energy equation only
Ans (A)

1.10 A plot of rainfall intensity versus time is called
(A) hydrograph
(B) mass curve
(C) hyetograph
(D) isohyet
Ans (C)

1.11 A geological formation which is essentially impermeable for flow of water even though it may contain water in its pores is called
(A) aquifer
(B) aquifuge
(C) aquitard
(D) aquiclude
Ans (D)

1.12 The minimum water content in a soil at which the soil just begins to crumble when rolled into threads 3 mm in diameter is known as
(A) liquid limit
(B) plastic limit
(C) shrinkage limit
(D) permeability limit
Ans (B)

1.13 In a flow net, phreatic line acts as
(A) central streamline
(B) top-most streamline
(C) 100 % hydraulic headline
(D) none of these
Ans (B)

1.14 In a chute spillway, convex vertical curves are provided when the slope changes from
(A) milder to steeper
(B) steeper to milder
(C) both (A) and (B)
(D) none of these
Ans (B)

1.15 For pressure-compensating emitters, the value of exponent x in discharge-operating pressure relationship $Q = k.p^x$ is nearly
(A) 1.0
(B) 0.0
(C) 0.5
(D) 2.0
Ans (B)

1.16 On a sprinkler lateral if number of sprinklers is increased from 10 to 20, then the friction head loss wall
(A) increase
(B) decrease
(C) initially increase and then decrease
(D) remain unchanged
Ans (B)

1.17 Long-term frozen storage of perishables must be carried out below.
(A) 0°C
(B) -10 °C
(C) -18°C
(D) -25°C
Ans (C)

1.18 Maximum energy emitted per unit volume of a blackbody is
(A) directly proportional to wavelength
(B) inversely proportional to wavelength
(C) inversely proportional to absolute temperature
(D) inversely proportional to pressure
Ans (B)

1.19 Pasteurization of milk is necessary for
(A) long shelf-life at room temperature
(B) destruction of all micro organisms
(C) destruction of only pathogenic micro organisms
(D) long shelf-life under refrigeration
Ans (C)

1.20 Highest temperature difference between heating surface and boiling liquid exists in case of
(A) natural convection boiling
(B) nucleate boiling
(C) transition boiling
(D) film boiling
Ans (D)

1.21 Adiabatic humidification is an
(A) isobaric process
(B) isoentropic process
(C) isoenthalpic process
(D) isothermal process
Ans (C)

1.22 In a rubber roll paddy sheller, the direction of rotation and peripheral speeds of the rollers are respectively
(A) same and equal
(B) same and different
(C) opposite and equal
(D) opposite and different
Ans (D)

1.23 Janssen equation is related to
(A) storage silo design
(B) size reduction of particles
(C) grain transportation system
(D) size separation of grains
Ans (A)

1.24 The major protein in wheat flour is
(A) zein
(B) gluten
(C) orygenin
(D) hordenin
Ans (B)

1.25 Under falling rate period, the drying rate is proportional to the difference between
(A) critical and equilibrium moisture contents
(B) initial and equilibrium moisture contents
(C) initial and critical moisture contents
(D) moisture content below critical and equilibrium moisture contents
Ans (A)

No 2 : For each of these sub-questions, four possible answers (A, B, C and D) are given, out of which only one is correct. Mark the answer correctly.

2.1 A fuel contains 84 % carbon and 16 % hydrogen by mass. The necessary air-fuel ratio for chemically correct combustion is
(A) 10.42:1
(B) 15.28:1
(C) 20.36:1
(D) 31.08:1
Ans: (B)

2.2 In a simple planetary gear drive the sun gear is used to give drive to a plant carrier mounted with 3 planetary gears while ring gear is held stationary. If sun gear and all the three planetary gears have 18-teeth each and ring gear has 54-teeth, the gear ratio will be
(A) 1:1
(B) 1.5:1
(C) 3:1
(D) 4:1
Ans: (D)

$$\frac{rpm\ of\ input}{rpm\ of\ output} = 1 + \frac{Nr}{Ns} = 1 + \frac{54}{18} = 4$$

2.3 If in the operator's station on a tractor the measured sound pressure level was 85 dB, the RMS sound pressure in N/m^2 is
(A) 3.56
(B) 35.56
(C) 3.56×10^{-1}
(D) 1.40×10^{-3}
Ans (C)

$$SPL = 20 \log \frac{p}{0.0002}$$

$$85 = 20\log\frac{p}{0.0002} \Rightarrow P = 3.56 \text{ x } 10^{-1}\text{ N/m}^2$$

2.4 If the line of pull on an implement is 12° above the horizontal and is in a vertical plane which is at an angle of 8° with the direction of travel, the side draft force for a pull of 10 kN will be

(A) 0.29 kN
(B) 1.36 kN
(C) 2.06 kN
(D) 9.68 kN

Ans (B)

$S = P\cos\theta\sin\phi = 10 \text{ x } \cos 12^0 \text{ x } \sin 8^0 = 1.36$ KN

2.5 If the turning angles subtended by inner and outer front wheels of a 4-wheel tractor are 45° and 30° respectively and the kingpins of the axle are 140 cm apart, the wheel base of the tractor to avoid skidding of front wheels should be

(A) 102.48 cm
(B) 140.00 cm
(C) 191.26 cm
(D) 331.24 cm

Ans (C)

$$\cot\theta - \cot\phi = \frac{w}{L}$$

$$\cot 30 - \cot 45 = \frac{140}{L}$$

$\Rightarrow$ L = 191.24 cm

2.6 The time required to sow 1 hectare of land with a bullock drawn seeder of size 5 x 20 cm when operating at a forward speed of 2 km/h with 20 % turning loss is

(A) 4 h
(B) 5 h
(C) 6 h
(D) 8 h

Ans (C)

Width, W = 5 x 20 = 100 cm = 1 m

S = 2 Km/hr, Turning loss = 20%

$\therefore$ Actual field capacity $= \frac{WS}{10}\times 0.8 = \frac{1\times 2}{10}\times 0.8 = 0.16\ ha/hr$

$\therefore$ time required to sow 1 ha is 1/0.16 = 6.25 hr

2.7 If air standard efficiency of an Otto cycle engine is 54.1 % an n = 1.4, its compression ratio is

(A) 6:1
(B) 7:1
(C) 8:1
(D) 9:1

Ans: (B) $\eta = 1 - \frac{1}{r^{k-1}}$

$\Rightarrow 0.541 = 1 - \frac{1}{r^{k-1}}$ $\qquad \Rightarrow r = 7$

2.8 Theoretical power extracted by a wind rotor of 4 m diameter in a wind regime with wind velocity of 7.2 km/h and air density of 1 kg/m^3 is

(A) 12.57 W
(B) 25.13 W
(C) 50.26 W
(D) 100.53 W

Ans: (C)

$$A = \frac{\pi}{4} \times D^2 = \frac{\pi}{4} \times 4^2 = 4\pi m^2$$

$$P = \frac{1}{2}\rho A V^3 = \frac{1}{2} \times 1 \times 4\pi \times \left(\frac{7.2}{3.6}\right)^3 = 50.26W$$

2.9 A catchment has an area of 150 ha and a runoff/rainfall ratio of 0.40. If due to a 10 cm rainfall over the catchment stream flow at the catchment outlet lasts for 10 hours, the average stream flow in the period is

(A) 1.33 m^3/s
(B) 16.7 m^3/s
(C) 100 m^3/min
(D) 6 x 10^4 m^3/h

Ans: (C)

$$\frac{\text{runoff}}{\text{rainfall}} = 0.40$$

runoff = 10 x 0.40 = 4 cm.

$$\text{Average stream flow} = \frac{150 \times \frac{4}{100} \times 10^4}{10 \times 60} = 100 \ m^3/min$$

2.10 A 6-h storm had 6 cm of rainfall and the resulting runoff -index remains the same, the runoff due to a 12 cm rainfall□was 3 cm. If the in 9 h will be

(A) 9.0 cm
(B) 4.5 cm
(C) 6.0 cm
(D) 7.5 cm

Ans: (D)

$$\phi = \frac{6-3}{6} = 0.5\, cm/hr$$

$$0.5 = \frac{12-x}{9} \Rightarrow \text{x} = 7.5 \text{ cm}$$

2.11 A triangular Direct-Runoff Hydrograph due to a storm has a time base of 80 h and a peak flow of 50 m^3/s occurring at 20 h from the start. If the catchment area is 144 km^2, the rainfall excess in the storm will be

(A) 20.0 cm
(B) 7.2 cm
(C) 5.0 cm
(D) none of these

Ans: (C)

$$Raifall\ excess = \frac{\frac{1}{2} \times 80 \times 3600 \times 50}{144 \times 10^6} = 5 \text{ cm.}$$

2.12 In a centrifugal pump, if the speed is increased from 1750 rpm to 2000 rpm, the head will change from 50 m to

(A) 38.3 m
(B) 65.3 m
(C) 56.0 m
(D) 100.0 m

Ans: (B)

$$\frac{H_2}{H_1} = \left(\frac{N_2}{N_1}\right)^2$$

$$\Rightarrow H_2 = H_1\left(\frac{N_2}{N_1}\right)^2 = 50 \times \left(\frac{2000}{1750}\right)^2 = 65.3\,m$$

2.13 A centrifugal pump has a cavitation coefficient of 0.3. For a total head of 50.0 m, the net positive suction head at the critical point will be

(A) 12.0 m
(B) 10.0 m
(C) 15.0 m
(D) 166.7 m

Ans (C)

Cavitation coefficient $= \dfrac{NPSH}{H}$

$$\Rightarrow 0.3 = \frac{NPSH}{50}$$

$$\Rightarrow NPSH = 0.3 \times 50 = 15m$$

2.14 The intensity of active earth pressure at a depth of 10 m in dry cohesionless sand with an angle of internal friction of 30° and unit weight of 1.8 t/m^3 is

(A) 4 t/m^2
(B) 5 t/m^2
(C) 6 t/m^2
(D) 7 t/m^2

Ans: (C)

$$P_a = \gamma kH = \left(\frac{1-\sin 30}{1+\sin 30}\right)\times 1.8 \times 10 = 6 \text{ t/m}^2$$

2.15 The sequent-depth in a hydraulic jump formed in a horizontal rectangular channel is 16.48. The Froude number of the supercritical stream is

(A) 8.0
(B) 4.0
(C) 20.0
(D) 12.0

Ans: (D)

$$\frac{d_2}{d_1} = \frac{1}{2}\left(\sqrt{1+8F^2}-1\right)$$

$$\Rightarrow 16.48 = 0.5\left(\sqrt{1+8F^2}-1\right)$$

$$\Rightarrow F = 12\ cm$$

2.16. The field capacity, wilting point and specific dry unit weight of a soil are 25 %, 15 % and 1.5 respectively. For a crop with root zone depth of 80 cm, the storage capacity of the soil will be

(A) 12 cm
(B) 8 cm
(C) 10 cm
(D) 14 cm

Ans (B)

storage capacity = Field capacity – wilting point
$= 80 \times (25 - 10)\% = 8$ cm

2.17 Amount of moisture removed in drying 100 kg wet potato slice from 80 to 8 % (dry basis for both) is

(A) 60 kg
(B) 20 kg
(C) 40 kg
(D) 72 kg

Ans (C)

$$dB = \frac{WB}{1-WB} \Rightarrow 0.8 = \frac{WB}{1-WB} \Rightarrow WB = 0.4444$$

Amount of dry matter = 100 – 44.44 = 55.56

$$Water\ removed = Amount\ of\ dry\ matter \times \frac{dB_1 - dB_2}{100}$$

$$= 55.56 \times \frac{80-8}{100} = 40.0032\,Kg$$

2.18 An air stream (1 atmospheric pressure) at 100°C and 60 % relative humidity has a partial pressure of water vapour equal to

(A) 0.61 bar
(B) 0.53 bar
(C) 0.41 bar
(D) 0.72 bar

Ans: (A)

$$R_H = \frac{p_v}{p_{vs}}$$

$$\Rightarrow 0.6 = \frac{P_v}{101.3}$$

$$\Rightarrow P_v = 60.78KPa$$

2.19 Reynold's number (Dvρ/μ) can also be expressed as (DG/ μ) where G is called

(A) mass flow rate, kg/s
(B) volumetric flow rate, m^3/s
(C) mass velocity, kg/m^2s
(D) average velocity, and m/s

Ans: (C)

2.20 For an air flow rate of 2 m^3/min, the linear air velocity in the inter-granular space in a circular storage bin having 2 m diameter and 0.4 void fraction will be

(A) 1.59 m/s
(B) 1.06 m/s
(C) 0.0265 m/s
(D) 0.0177 m/s

Ans: (A)

$$V = \frac{q}{A \times n} = \frac{2}{\left(\frac{\pi}{4} \times 2^2\right) \times 0.4} = 1.59\, m/s$$

2.21 Butter has a thermal diffusivity of 8.6 x 10^{-8} m^2/s. If the characteristic dimension of butter slab is 2 cm then Fourier number at one hour is

(A) 1.670
(B) 1.292
(C) 0.774
(D) 0.599

Ans (C)

$$\text{Fourier number } = \frac{\alpha_t}{x^2} = \frac{8.6 \times 10^{-8}}{(0.02)^2} \times 3600 = 0.774$$

2.22 Osmotic pressure of salt solution made of one litre water and 10 g sodium chloride at 30°C is

(A) 4.31 bar
(B) 202.65 kPa
(C) 2 bar
(D) 15 mbar

Ans: (A)

$$10 \text{ g Nacl } = \frac{10}{58.5} = 0.1709 gmole$$

= 0.1709 x 10^{-3} Kg mol/litre = 0.1909 Kg mol/m^3

$$\pi = \frac{\eta}{V_m} RT = 0.1709 \times 8314 \times 303 = 430521 \text{ Pa} = 4.13 \text{bar}$$

2.23 The average velocity of 1 mm thick tomato sauce sliding down a vertical wall and having a density of 1075 kg/m^3 and viscosity of 10 cP is

(A) 35 m/s
(B) 3.5 m/s
(C) 0.35 m/s
(D) 0.035 m/s

Ans: (A)

$$V_{av} = \frac{\rho g \partial^2}{3\mu} = \frac{1075 \times 9.81 \times (0.001)^2}{3 \times 10 \times 10^{-3}} = 0.35 m/s$$

2.24 In a countercurrent heat exchanger the hot fluid enters at 90°C and leaves at 70°C. The cold fluid enters at 30°C and leaves at 50°C. The log mean temperature difference is

(A) 70°C
(B) 40°C
(C) 26.4°C
(D) 20°C

Ans: (B)

$\Delta T_2 = 40^0 C, \Delta T_1 = 40^0 C$

If $\Delta T_2 = \Delta T_1$ then $\Delta T_m = \Delta T_2 = \Delta T_1$

So LMTD = 40^0C

2.25 Convective heat transfer coefficient of a stagnant 2 mm thick air layer is 5 W/m^{2}K. The thermal conductivity of the same layer is

(A) 10 W/m-K
(B) 2.5 W/m-K
(C) 0.4 W/m-K
(D) 0.01 W/m-K

Ans: (D)

K = hx = 5 x 2 x 10^{-3} = 0.01 W/m-k

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No 1. For four possible answers (A, B, C and D), mark the most correct one :-

1. 1 Salt is better food preservative than sugar because it

(A) has lower molecular weight

(B) lowers the vapour pressure of food water to a large extent
(C) kills microorganisms better
(D) reduces pH
Ans (B)

1.2 In a multiple effect evaporator concentration of liquid food is difficult in the last effect because
(A) the vacuum level is low
(B) the temperature is low
(C) flow rate is reduced
(D) viscosity of liquid is large
Ans (A)

1.3 Pressure drop in liquid flow through granular materials is best estimated by
(A) Blake-Kozney equation
(B) Burkey – Plummer equation
(C) Ergun equation
(D) Fourier equation
Ans (C)

1.4 Effectiveness of a countercurrent heat exchanger carrying same fluid at the same flow rate in the inner and outer tubes is given by
(A) NTU/(NTU+1)
(B) NTU/(NTU-1)
(C) (NTU+1)/NTU
(D) NTU/(1-NTU)
Ans (A)

1.5 In transient heat transfer problems the dimensionless number used is
(A) Nusselt Number
(B) Prandtl Number
(C) Biot Number
(D) Schmidt Number
Ans (C)

1.6 Constant rate of drying of agricultural produce is independent of
(A) air velocity
(B) thickness of bed
(C) air humidity
(D) air temperature
Ans (B)

1.7 If D is the core diameter in mm then number of brakes on a cone polisher is given by
(A) (100/D) – 2
(B) (D/100) – 2
(C) 2 + (D/100)
(D) (100/D) + 2
Ans (A)

1.8 The equilibrium moisture content at 100% relative humidity is known as
(A) bound water
(B) unbound water
(C) free water
(D) saturation water
Ans (A)

1.9 For a watershed where no conservation practice is followed the value of conservation practice factor (P) to be used in Universal soil loss Equation for estimation of soil loss will be
(A) 0
(B) 0.5
(C) 1.0
(D) 1.5
Ans (B)

1.10 The pressure drop through a media filter used in drip irrigation should not exceed
(A) 70 kPa
(B) 100 kPa
(C) 130 kPa
(D) 160 kPa
Ans (B)

1.11 A hypsometric curve is a plot of
(A) time of concentration and elevation curve of catchment
(B) area and elevation curve
(C) spot rainfall values and isohyets on a basin map
(D) depth of rainfall and elevation of a catchment
Ans (B)

1.12 Mole drains are suitable for
(A) very coarse soil
(B) medium coarse soil
(C) sandy loam soil
(D) fine textured soil

Ans (D)

1.13 Hydraulically most efficient cross-section of open channel is
(A) triangular
(B) rectangular
(C) semi-circular
(D) trapezoidal
Ans (C)

1.14 Cavity well is most suitable under the following conditions
(A) aquifer with fine sand and small thickness
(B) aquifer with coarse sand and small thickness
(C) aquifer with coarse sand and large thickness
(D) aquifer with coarse sand and hard-covering layer
Ans (D)

1.15 For large discharge capacity, a chute spillway inlet should be
(A) rounded rectangular box type inlet
(B) flat rectangular inlet
(C) straight inlet
(D) concave shaped rectangular inlet
Ans (A)

1.16 Two trapezoidal channels A and B have same depth of flow, roughness coefficient and side slopes. The bed slope of channel A is 4 times that of B. The ratio of discharges of A and B is
(A) 4:1
(B) 3:2
(C) 2:1
(D) 1:2
Ans (C)

1.17 Inertia forces are developed due to rotation of an engine crankshaft. The secondary force which is cosine function of twice the crank angle occurs
(A) twice every revolution in a 4-cylinder engine
(B) once every revolution in a 4-cylinder engine
(C) thrice every revolution in a 3-cylinder engine
(D) once every revolution in a 3 -cylinder engine
Ans (A)

1.18 During field preparation using a tractor-drawn 2-bottom MB plough, the wheel outside the furrow has
(A) the best traction
(B) the least traction
(C) zero slip

(D) higher tyre pressure

Ans (B)

1.19 An epicyclic gear train is one, in which the gears, in addition to the motion about their respective axes have

(A) at least two axes fixed
(B) one axis fixed about which other axes revolve
(C) another axis rotating at slow speed
(D) one gear train rotating at high speed

Ans (B)

1.20 The basic difference in a turbocharged engine and a naturally-aspirated engine is that

(A) the inlet air pressure is higher in a naturally aspirated engine
(B) inlet air temperature is lower in a turbocharged engine
(C) inlet air pressure is higher in a turbocharged engine
(D) more volume of air is inducted in the turbocharged engine

Ans. (D)

1.21 The predominant noise heard at the operator's ear in a tractor and other off-highway equipment falls in the frequency range of

(A) 10 to 50 Hz
(B) 125 to 500 Hz
(C) 1000 to 5000 Hz
(D) 0 to 10 Hz

Ans. (B)

1.22 The purpose of the use of lugs in ground wheels of a manually-operated low-land seeder is to

(A) increase traction
(B) remove soil from the wheels
(C) to allow floatation
(D) to increase depth of operation

Ans.(A)

1.23 In a tractor drawn disc plough the type of bearing used is

(A) taper roller bearing
(B) torsion bearing
(C) split bearing
(D) ball-bearing

Ans.(A)

1.24 The total permissible loss in a combine harvester could be of the order of

(A) 6 to 10 percent
(B) 12 to 16 percent

(C) 8 to 9 percent
(D) 1.5 to 3 percent
Ans. (D)

No-2 For each of these sub-questions, four possible answers (A, B, C and D) are given, out of which only one is correct. Mark the answer correctly.

2.1 Total Solid (TS) in fruit juice is to be increased from 15% to 50% in an evaporator. The percentage of initial water to be removed is about
(A) 68
(B) 72
(C) 78
(D) 82
Ans: (D)

$F \times 0.15 = P \times 0.5$

$\Rightarrow P = F \times \dfrac{0.15}{0.5}$

$F \times 0.85 = W + P \times 0.5$

$\Rightarrow F \times 0.85 = W + \left(\dfrac{F \times 0.15}{0.5}\right) \times 0.5$

$\Rightarrow W = 0.7F$

$\therefore$ Percentage of initial water to be removed $= \dfrac{0.7F}{0.85F} = 82.34\,\%$

2.2 A cylindrical object having a length equal to the diameter has a sphericity of
(A) 0.757
(B) 0.823
(C) 0.874
(D) 0.952
Ans: (B)

Volume of cylinder $= \pi r^2 h = \dfrac{\pi d^3}{4} (\because h = d)$

Let D_e be the vol. of sphere having same volume of cylinder

$\Rightarrow \dfrac{\pi D_e^{\ 3}}{6} = \dfrac{\pi d^3}{4}, D_e = \sqrt[3]{1.5}d$

D_c = dia of smallest circumscribing circle $= d\sqrt{2}$

$$\Rightarrow \text{Sphericity} = \frac{D_e}{D_c} = \frac{\sqrt[3]{1.5d}}{d\sqrt{2}} = 0.809$$

2.3 Milk flowing with an average velocity of 0.5 m/s in a pipe of diameter 25 mm has a Froude Number

(A) 0.98
(B) 1.02
(C) 1.27
(D) 1.54

Ans: (B)

$$F = \frac{V}{\sqrt{gd}} = \frac{0.5}{\sqrt{9.81 \times 0.025}} = 1.02$$

2.4 Thermal resistance of 1mm thick stainless steel sheet of 1 m^2 area with a thermal conductivity of 15 W/m-K is

(A) 6.67×10^{-5} K/W
(B) 9.10×10^{-2} K/W
(C) 15 K/W
(D) 15000 K/W

Ans: (A)

$$R = \frac{x}{kA} = \frac{0.001}{15 \times 1} = 6.67 \times 10^{-5}$$

2.5 Three consecutive sieves and a pan retain 20%, 50%, 20%, and 10% of ground material respectively. The fineness modulus of the ground material is

(A) 1.2
(B) 1.8
(C) 2.4
(D) 3.5

Ans: (B)

$$FM = \frac{20 \times 3 + 50 \times 2 + 20 \times 1 + 10 \times 0}{100} = 1.8$$

2.6 A basket centrifuge of 0.5 m diameter rotating with an rpm of 2000 develops a centrifugal constant of

(A) 28.32
(B) 50.97
(C) 203.87
(D) 1117.86

Ans: (D)

$$\frac{F_c}{F_g}=\frac{\frac{mv^2}{r}}{mg}=\frac{v^2}{rg}=\frac{(\frac{\pi DN}{60})^2}{rg}=\frac{(\frac{\pi\times 0.5\times 2000}{60})^2}{0.25\times 9.81}=1117.86$$

2.7 A discharge of 30 m^3/h is obtained from a 0.20 m diameter well installed in an unconfined aquifer with a radius of influence of 500 m. If the diameter is increased to 0.30 m and other parameters are kept constant, the percentage increase in discharge will be

(A) 5
(B) 10
(C) 50
(D) 100

Ans: (A)

$$Q=\frac{\pi k(H^2-h^2)}{\ln(R/r_w)}$$

$$\Rightarrow Q_1\ln(\frac{R}{r_{w_1}})=Q_2\ln(\frac{R}{r_{w_2}})$$

$$\Rightarrow 30\times\ln(\frac{500}{0.1})=X.\ln(\frac{500}{0.15})$$

$$\Rightarrow X=31.50m^3/hr$$

$\therefore$ Percentage increase in discharge $=\frac{31.50-30}{30}\times 100=5\%$

2.8 A centrifugal pump is used to deliver a constant discharge through a 0.20 m diameter pipe with a static head of 13 m, minor head loss of 1 m and frictional head loss of 2 m. If the same discharge is allowed to flow through a 0.10 m diameter pipe with an increase of 2 m in the minor loss and constant friction factor, the power requirement (P) of the pump will be

(A) 1.5P
(B) 2.0P
(C) 5.0P
(D) none of the above.

Ans: (C)

$$h_f=\frac{4fLV^2}{2gd}=\frac{4fL}{2gd}(\frac{Q}{A})^2 \text{ and } A=\frac{\pi}{4}d^2$$

$$\therefore h_f \alpha \frac{1}{d^5}$$

$$\therefore \frac{h_{f2}}{h_{f1}} = (\frac{d_1}{d_2})^5 \Rightarrow h_{f2} = h_{f1} \times (\frac{d_1}{d_2})^5 = 2 \times (\frac{0.2}{0.1})^5 = 64m$$

Initial head = 13 + 1 + 2 =15 and Final head = 13 + 2 + 64 = 79

$$\frac{P_2}{P_1} = \frac{h_2}{h_1} = \frac{79}{16} = 5 \Rightarrow P_2 = 5P_1$$

2.9 The pressures of two nozzles of a sprinkler lateral are 290 and 262 kPa. If the discharge from the first nozzle is 8 x 10^{-4} m^3/s, the discharge from the other nozzle will be

(A) 5.6 x 10^{-4} m^3/s
(B) 6.6 x 10^{-4} m^3/s
(C) 7.6 x 10^{-4} m^3/s
(D) 8.6 x 10^{-4} m^3/s

Ans: (C)

$$\frac{Q_2}{Q_1} = \sqrt{\frac{P_2}{P_1}} \Rightarrow Q_2 = Q_1 \times \sqrt{\frac{P_2}{P_1}} \Rightarrow Q_2 = 8 \times 10^{-4} \sqrt{\frac{262}{290}} = 7.6 \times 10^{-4}$$

2.10 Citrus is planted at a spacing of 5 m x 5m in 1 ha area. The maximum evaporation during summer is 10 mm/day with pan coefficient, crop coefficient and wetting percent of 0.7, 0.8, and 40 respectively. If each plant is irrigated by three emitters of 4 x 10^{-3} m^3/h discharge each, the daily time of operation of the system will be

(A) 16.66 h
(B) 12.66 h
(C) 8.66 h
(D) 4.66 h

Ans: (D)

Daily time of operation

$$= \frac{5 \times 5 \times 0.01 \times 0.4 \times 0.7 \times 0.8\ m^3/day}{3 \times 4 \times 10^{-3}} = 4.66h$$

2.11 The size of maximum non-erosive stream in litres per second for a furrow of 0.3% slope will be

(A) 0.5
(B) 1.0
(C) 1.5

(D) 2.0
Ans (D)

$$Q = \frac{0.6}{s} = \frac{0.6}{0.3} = 2$$

2.12 The minimum wind velocity at 15 m height required to move the erodible soil fraction is 20 km/h and the actual wind velocity is 60 km/h. A shelterbelt of 12 m height is provided for control of wind erosion and the wind direction makes an angle of 60 ^{0} with the perpendicular to the barrier. The spacing of the shelterbelts for full protection will be
(A) 30 m
(B) 34 m
(C) 40 m
(D) 44 m
Ans: (B)

$$d = 17h\,\frac{V_m}{V}\cos\theta = 17\times 12\times\frac{20}{60}\cos 60^0 = 34m$$

2.13 In an irrigated field the seepage from the canal is 15% of the water supplied and the deep percolation from irrigation is 25%. For an irrigation depth of 80 mm in every 8 days, the drainage coefficient is
(A) 4 mm/day
(B) 6 mm/day
(C) 8 mm/day
(D) 10 mm/day
Ans (B)
80 mm in 8 days $\Rightarrow$ 10 mm per day
15% seepage, 25% percolation $\Rightarrow$ Infiltration = 40% = 4 mm/day
$\Rightarrow$ Drainage coefficient = Depth of input – Depth of infiltration
= 10 - 4 = 6 mm/day

2.14 The mean monthly temperature and average percentage of daytime hours of the year of that month for a location are 26^{0}C and 14 respectively. If the crop coefficient is 0.8 the monthly consumptive use by Blaney-Criddle method will be
(A) 200 mm
(B) 225 mm
(C) 250 mm
(D) 275 mm
Ans: (B)

Cu = (0.46T +8.13) PxK = (0.46x 20 + 8.13) x 0.14x0.8 =225mm

2.15 A herd of 100 dairy cows is fed 1300 kg of sillage daily. The thickness of sillage fed each day is 100 mm. If one m^3 of sillage weighs 650 kg, the diameter of pit silo will be

(A) 4.54 m
(B) 5.04 m
(C) 5.64 m
(D) 6.04 m

Ans: (B)

$$\text{Volume} = \frac{1300}{650} = 2\ m^3$$

$$A = \frac{2}{0.1} = 20m^2 \Rightarrow \frac{\pi}{4}d^2 = 20m^2 \Rightarrow d = 5.04$$

2.16 In an offset disc harrow, the amount of offset obtainable without the side draft is a function only of distance (D) between the gangs and the relative magnitudes of the longitudinal (L_f , L_r) and lateral (S) soil reactions. If L_f = 4.2 kN and L_r= 3.75kN, S = 4.9 kN and d = 2.15 m, then the amount of offset is

(A) 1.54 m
(B) 2.49 m
(C) 0.8 m
(D) 2.80 m

Ans (A)

$$e = \frac{dS}{L_f + L_r} = \frac{2.15 \times 4.9}{4.2 + 3.75} = 1.32$$

2.17 The power required to accelerate forage at a feed rate of 24 kg/s, at the cutter head of a combine at a peripheral velocity of 29.9 m/s is equal to

(A) 13.73 kW
(B) 12.48 kW
(C) 10.73 kW
(D) 11.55kW

Ans (C)

$$P = \frac{1}{2}mv^2 = \frac{1}{2} \times 24 \times 29.9^2 = 10.73kw$$

2.18 A six-cylinder engine has 130 mm stroke and 109.4 mm bore. The displacement of the engine at a compression ratio of 17:1 is equal to

(A) 8.27 litres
(B) 7.32 litres
(C) 6.96 litres
(D) 5.40 litres

Ans (B)

$$\text{Displacement} = \frac{\pi}{4}\times(0.1094)^2\times 0.13\times 6 = 7.32\ \textit{litres}$$

2.19 The amount of heat carried away from an engine and transferred from the water to the cooling air is 184520 J/s. If the frontal area of the radiator used is 56 m^2 and the heat transfer coefficient of the radiator is 100 units, then the differential temperature between the air and water is

(A) 32.95 ^{0}C
(B) 36.95 ^{0}C
(C) 40.95 ^{0}C
(D) 44.95 ^{0}C

Ans: (A)

Q = 184520 j/s or W, A = 56 m^2, h = 100 units = 100W/m^2.k

Q = hA ΔT $\Rightarrow$ ΔT = Q/hA = 184520/100 x 56 =32.95

2.20 There are 10 nozzles spaced 240 mm apart on a sprayer boom. The total discharge in one hour at an application rate of 300 litre/ha and at a forward speed of 10 km/h is

(A) 900 litres
(B) 860 litres
(C) 800 litres
(D) 720 litres

Ans: (D)

Width = 240 x 10 = 2400 mm = 2.4 m

$$\Rightarrow \text{Field capacity} = \frac{WS}{10} = \frac{2.4\times10}{10} = 2.4\, ha\,/\,hr$$

Rate of application = 300 lit/ ha

$\Rightarrow$ Discharge per hour = 300 x 2.4 =720 lit/hr

2.21 The inner and outer steering angles in a tractor are 9^0 and 9.8^0 respectively then for correct steering condition the value of the ratio of pivot axis spacing to track length is equal to

(A) 0.256

(B) 0.525
(C) 0.756
(D) 0.990
Ans: (B)

$$\frac{L}{b}=\cot\theta-\cot\phi=\cot 9-\cot 9.8=0.525$$

2.22 The average speed of an engine connected to a pneumatic governor is 1500 rpm. If the fluctuation in speed is ± 100 rpm, then the percent governor regulation is equal to
(A) 7.65
(B) 10.25
(C) 12.50
(D) 6.67
Ans: (C)

$$r=\frac{2(N_H-N_1)}{(N_H+N_1)}\times 100=\frac{2(1600-1400)}{(1600+1400)}\times 100=13.33\%$$

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Chapter **6**

Short Type Solution
(2003-2005)

2003

(1) Total swept volume of a 4-cylinder, 4-stroke cycle CI engine is $0.004 m^3$. If the clearance volume per cylinder is $62.5 \times 10^{-6} m^3$, the compression ratio of the engine is
(A) 14
(B) 15
(C) 16
(D) 17
Ans (D)

$$C.R. = \frac{V_s + V_c}{V_c} = 1 + \frac{V_s}{V_c} = 1 + \frac{(0.004/4)}{62.5 \times 10^{-6}} = 17$$

(2) A V-belt operates at $23.56 ms^{-1}$ peripheral speed. The mass of the belt per unit length is $0.9 kg.m^{-1}$. The volume of centrifugal tension in the belt is
(A) 21.20 N
(B) 249.80 N
(C) 499.60 N
(D) 4996.00 N
Ans (C)
$T_c = MV^2 = 0.9(23.56)^2 = 499.56$ N

(3) Firing frequency of a 4-cylinder, 4-stroke cycle engine operating at 1200 rpm is
(A) 40 cycle per second
(B) 80 cycle per second
(C) 120 cycle per second
(D) 300 cycle per second
Ans (A)

$$f = \frac{Nn}{120} = \frac{120 \times 4}{120} = 40 \text{ (for 4 Stroke)}$$

(4) In vibrating system , the centre frequency of one-third octave band over a frequency range of f_1 to f_2 is

(A) $\frac{(f_1 + f_{21})}{2}$

(B) $\sqrt{f_1 f_2}$

(C) $f_1 f_2/2$

(D) $2^{1/6} f_1$

Ans (B)

(5) With a mounted implement the upper link of the tractor is not subject to tension or compression when the line of pull passes

(A) Directly through the lower link hitch point

(B) Above the lower link hitch point

(C) Below the lower link hitch point

(D) Directly through the top link hitch point

Ans (D)

(6) When a differential lock is engaged in a two-wheel drive tractor operating under adverse soil conditions

(A) the axle torque must be equal

(B) the torque is higher in axle attached to the wheel with best traction

(C) the torque is higher in the axle attached to the wheel with poorest traction

(D) the power transmitted to both the axles must be the same

Ans (D)

(7) If VMD_1 and VMD_2 are droplet volume median diameters for a nozzle at pressure p_1 and p_2 respectively, the ratio of VMD_1 and VMD_2 is given by

(A) $\frac{VMD_1}{VMD_2} = (\frac{p_2}{p_1})^{1/3}$

(B) $\frac{VMD_2}{VMD_1} = (\frac{p_2}{p_1})^{1/3}$

(C) $\frac{VMD_1}{VMD_2} = (\frac{p_2}{p_1})^{2/3}$

(D) $\frac{VMD_1}{VMD_2} = (\frac{p_2}{p_1})^{2/3}$

Ans (A)

VMD $\propto \frac{1}{\sqrt[3]{P}}$, P < 690 kPa

(8) A farmer gets 60 kg of dung everyday from the herd of cattle he owns. The size of biogas plant he should construct utilizing this dung is

(A) 0.6 m^3
(B) 2.4 m^3
(C) 5.4 m^3
(D) 9 m^3

Ans (B)

60 x 0.04 = 2.4 m^3 (1 kg of dung produce 0.04 m^3)

(9) The mould board of a mould board plough is made of

(A) malleable iron
(B) forged steel
(C) soft-centre steel
(D) mild steel

Ans (C)

(10) Normal annual rainfall at metrological stations P, Q and R are 1606,1803 and 1653 mm respectively. In 1999 station Q was inoperative and stations P and R recorded annual rainfall of 1530 and 1451 mm respectively. Estimated value of rainfall at Q in 1999 is

(A) 1490.5 mm
(B) 1650.2 mm
(C) 1687.3 mm
(D) 1803.0 mm

Ans (B)

$$P_x = \frac{N_x}{2} = (\frac{P_1}{N_1} + \frac{P_3}{N_3}) = \frac{1803}{2}(\frac{1530}{1606} + \frac{1451}{1653}) = 1650.2mm$$

(11) Muskingum method of flood routing is used for

(A) hydraulic channel routing
(B) hydraulic reservoir routing
(C) hydrologic channel routing
(D) solving Saint- Venant equations

Ans: (C)

(12) A soil sample 75 mm in diameter and 150 mm in length is tested in a falling head permeameter, having 15 mm diameter standpipe. At the commencement of the test the initial head is 1300mm and it drops to 800 mm after one hour. The coefficient of permeability of soil is

(A) $1.88 \times 10^{-7} ms^{-1}$
(B) $8 \times 10^{-7} ms^{-1}$
(C) $8 \times 10^{-4} ms^{-1}$
(D) $9.25 \times 10^{-3} ms^{-1}$

Ans: (B)

$$K = \frac{aL}{At} In\frac{h_1}{h_2} = \frac{15^2 \times 0.15}{75^2 \times 3600}\ln(\frac{1300}{800}) = 8.09 \times 10^{-7} m/s$$

(13) For a submerged plane in a liquid, the resultant hydrostatic force P on side of the plane is related to area A, centroid depth. $\bar{y}$, depth of the center of pressure y_{ap} and depth of the bottom edge y_b as

(A) $P = \gamma A \bar{y}$
(B) $P = \gamma A\, y_{cp}$
(C) $P = \gamma A\, y_b$
(D) $P = \frac{A\bar{y}}{\gamma}$

Ans: (A)

(14) A Pipe and square section channel, whose side is equal to the diameter of the pipe, are running full with water. The ratio of hydraulic radius full with water. The ratio of hydraulic radius of the pipe to that of the channel is

(A) $\frac{1}{3}$
(B) $\frac{1}{2}$
(C) $\frac{3}{4}$
(D) 1

Ans:(C) $\left(\frac{\pi D^2}{\pi D}\right) \Big/ \left(\frac{D^2}{3D}\right) = 3/4$

(15) The energy of the rain drop causing erosion is expressed in

(A) $\dfrac{m-Mg}{ha-mm}$

(B) $\dfrac{m-Mg}{ha}$

(C) $\dfrac{m-t}{ha}$

(D) $\dfrac{t}{ha-m}$

Ans: (A)

(16) Chute spillway is used to control a drop of

(A) 0-3 m
(B) 1-4 m
(C) 2-4 m
(D) 3-6 m

Ans: (D)

(17) The wheat crop consumes 500 mm of water per hectare and gives yields a grain of 6 per hectare. Considering an application efficiency of 75%, the field water use efficiency, in kg ha^{-1} mm^{-1}, is

(A) 9
(B) 12
(C) 16
(D) 18

Ans: (A)

$$E_U = (Y/WR) = \frac{6000 kg/ha}{500/0.75} = 9\frac{kg}{ha-mm}$$

(18) The equation used to design a subsurface drainage system under steady state condition is

(A) Kraijenhoff equation

(B) Glover –dumm equation

(C) Kirkham equation

(D) Hamad equation

Ans: (C)

(19) Theis method of solution is used for

(A) steady state flow in a confined aquifer
(B) steady state flow in an unconfined aquifer

(C) unsteady state flow in an unconfined aquifer
(D) unsteady state flow in a confined aquifer
Ans: (D)

(20) Viscosity of tomato juice increases rapidly with increase in concentration of solid, therefore , the juice must be concentrated in a
(A) recirculating batch type rising film evaporator
(B) recirculating batch type falling film evaporator
(C) backward feed multiple effect evaporator
(D) forward feed multiple effect evaporator
Ans: (B)

(21) Air 200^0C dry bulb temperature, $60\,°C$ wet bulb temperature thermal conductivity 1.8×10^{-5} $Wm^{-1}\,°C^{-1}$ is introduced into a spray dryer. Water having drop size 50×10^{-6} m is introduced into the dryer. If the Nusselt number for heat transfer coefficient from air to drop surface will be
(A) 0.72 W $m^{-2}\,{}^0C^{-1}$
(B) 0.60 W $m^{-2}\,{}^0C^{-1}$
(C) 25.2×10^{-6} W $m^{-1}\,{}^0C^{-1}$
(D) 10.8×10^{-6} W $m^{-1}\,{}^0C$
Ans: (A)

$$N_u = \frac{hD}{K} \Rightarrow h = \frac{N_U K}{D} = \frac{2\times1.8\times10^{-5}}{50\times10^{-6}} = 0.72\frac{w}{m^2 - {}^0C}$$

(22) Size of dust particles separated in a cyclone separator will reduce when
(A) length of cyclone is increased
(B) outlet pipe diameter of cyclone is increased
(C) outlet pipe diameter and length of cyclone are increased
(D) outlet pipe diameter is decreased and length of cyclone is increased
Ans: (D)

$$D_L = \sqrt{\frac{18\,\mu Q}{V_t^{\,2}\Delta\rho\,2\pi L}}$$

(23) Tyler series sieves used for grading of food should have consecutive sieves having screen opening sizes D_1 and D_2 such that
(A) $D_1/D_2 = 2.0$
(B) $D_1/D_2 = (2)^{1/2}$

(C) $D_1/D_2 = (2)^{1/4}$
(D) $D_1/D_2 = (2)^{1/8}$
Ans: (B)

(24) A hot pressure cooker is kept inside a large room whose walls are cooler than the cooker. The total surface area, emissivity and temperature of the cooler are $A_1(m^2)$, ε_1 and $T_1(K)$ respectively, while the conducting values for the walls are $A_2(m^2)$, ε_2 and $T_2(k)$, the rate of heat loss from the cooker surface depends on
(A) A_1, A_2, T_1, T_2, ε_1 and ε_2
(B) A_1, T_1, T_2 and ε_2
(C) A_1, T_1, T_2 and ε_1
(D) A_1, A_2, T_1, T2 and ε_2
Ans: (C)

$$Q_{12} = \frac{A_1\sigma\,(T_1^{\,4} - T_2^{\,4})}{\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1}$$

(25) If Δx_i is the mass fraction of ground particles retained in sieve "i" having diameter 'd_i' then the average diameter 'd_{av}' of ground particles expressed by the equation $d_{av} = \dfrac{1}{\sum_{i=1}^{n} \dfrac{\Delta x_1}{d_1}}$ for "n" number of sieve is known as
(A) Volume mean diameter
(B) Sauter mean diameter
(C) Mass mean diameter
(D) Arithmetic mean diameter
Ans: (B)

(26) Compared to raw rice, milled rice obtained from parboiled paddy
(A) is whiter and contains more vitamin B_1
(B) requires less cooking time and contains more vitamin B_1
(C) gives higher head yield and contains more vitamin B_1
(D) has more oil in bran and contains less vitamin B_1
Ans: (C)

(27) In drying, free moisture content of grain is defined as the difference between
(A) initial moisture content and final moisture content
(B) initial moisture content and equilibrium moisture content

(C) initial moisture content and critical moisture content
(D) critical moisture content and equilibrium moisture content
Ans: (B)

(28) Relative humidity of air at 100^0C and one atmospheric pressure is 10%. If the ratio of molecular weights of water to air is 0.62, the absolute humidity of the air will be
(A) 0.0345 kg water per kg dry air
(B) 0.0752 kg water per kg dry air
(C) 0.0689 kg water per kg dry air
(D) 0.0445 kg water per kg dry air
Ans: (C)
$\Phi = P_v / P_s = 0.1 \Rightarrow P_v = 0.1 x 101.325 = 10.325$ kPa,
$$H=0.62 \frac{P_v}{P-P_v} = 0.62 \times \frac{10.325}{101.3-10.325}$$
= 0.069 kg water per kg dry air

(29) Air having density ρ ($kg\ m^{-3}$), viscosity μ (Pa s) and specific heat C_p($J\ kg\ {}^0C^{-1}$) is blown over a water surface at velocity v ($m\ s^{-1}$). If the length of water surface is L (m) and diffusivity of water vapour in air is D(m^2s^1), the rate of evaporation from the surface will depend on
(A) ρ, C_p, v, L and D
(B) ρ,μ, v,L and D
(C) ρ, C_p ,v,μ, and L
(D) μ, C_p , v,L and D
Ans: (B)

(30) A solid disc flywheel having 20 kg mass and 800 mm diameter rotates at 2400 rpm. The stored energy in the flywheel is
(A) 25.26 kJ
(B) 50.53 kJ
(C) 101.06 kJ
(D) 202.12 kJ
Ans: (C) KE = $\frac{1}{2} I\omega^2 = 1/2(mr^2)(2\pi N)^2$
$$=\frac{1}{2} \times 20 \times 0.4^2 \times (2\pi)^2 \times 40^2 = 101.06\,kJ$$

(31) An 8-row automatic transplanter operates at a forward speed of $0.25ms^{-1}$. If seedling spacing along the row is 0.25m and row to

row spacing is 0.75 m, the required feed rate of seedling into transplanter is

(A) 100 seedlings per minute
(B) 130 seedlings per minute
(C) 240 seedlings per minute
(D) 480 seedlings per minute

Ans: (D)

Area covered = nsv = 8x0.75 x 0.25 = 1.5 m^2/s = 90m^2/m

m^2/ seedling = 0.25x0.75 = 0.1875,

$\Rightarrow$seedling per minute = 90/0.1875 = 480

(32) A horizontal axis wind rotor of 5 m diameter is installed for water pumping in a farm. If the average wind velocity available in the farm is 14.4 kmh^{-1}, the theoretical power generated by wind rotor assuming an air density of 1.29 kgm^{-3} is

(A) 202.60 W
(B) 540.35 W
(C) 810.53 W
(D) 1621.06 W

Ans: (C)

$P=1/2\ \rho AV^3$

(33) A 4-row animal-drawn wheat seed drill with 300mm row-to-row spacing is operating at 1.5 km h^{-1}. If the time losses, based on observed total time in seeding 1 ha, are 15 percent in turning ,10 percent in seed filling and 20 percent in mechanical down time, the field efficiency of the machine is

(A) 32 percent
(B) 40 percent
(C) 65 percent
(D) 74 percent

Ans: (D)

$$FE=\frac{ideal}{actual}=\frac{idle}{idle+loss}=\frac{100}{100+(15+10+10)}=74.4\%$$

(34) A side-dressing fertilizer applicator is to place two bands per row on a crop with 1 m row spacing at an application rate of 600 Kg ha^{-1}. If the machine is calibrated by driving it forward over a distance of 50 m, the mass of material collected from each delivery tube is

(A) 0.75 Kg
(B) 1.25 Kg

(C) 1.50 Kg
(D) 3.00 Kg
Ans: (C)
600 Kg /ha, in an area of 50 x 1 = 50 m² the

In 50 m² the seed fall $= \frac{600}{10000} x50 = 3kg$

$\Rightarrow$ Seed in one delivery tube =3/2=1.5 kg

(35) A four-wheel tractor is travelling across a ground slope . If the rear wheel trade is 1400 mm and height of the centre of gravity of the tractor is 750 mm above the ground level, the critical angle of slope to prevent sideways overturning is
(A) 21.00 degree
(B) 28.20 degree
(C) 43.03 degree
(D) 68.96 degree
Ans: (C)

$$Z_{cg} W \sin\alpha = W \cos\alpha (T/2)$$

$$\Rightarrow \quad \tan\alpha = \frac{T/2}{Z_{cg}} = \frac{700}{750} \Rightarrow \alpha = 43.03^0$$

(36) If a 4-cylinder, 4-stroke cycle diesel engine operates at 2000 rpm and uses 20 litres of fuel per hour, the average volume of individual injection is
(A) 83.33 mm^3
(B) 166.66 mm^3
(C) 240.50 mm^3
(D) 333.33 mm^3
Ans: (A)

$$\frac{m^3}{\min} = LAn(\frac{N}{2})$$

$$\Rightarrow 20\frac{lit}{hr} = \frac{20\times10^{-3}}{60}\frac{m^3}{\min} = (LA)\times 4x\frac{2000}{2} \Rightarrow LA = 83.33m^3$$

(37) The absolute air pressure in the cylinder of a diesel engine is 100 kPa at the beginning of the compression stroke. The air is compressed to one-fourth of its volume, then the air pressure at the end of the stroke is
(A) 165.00kPa
(B) 400.00 kPa

(C) 606.28kPa
(D) 840.25kPa
Ans: (C)

$$\frac{T_2}{T_1} = (\frac{V_2}{V_1})^{1-k} = (\frac{P_2}{P_1})^{\frac{k-1}{k}}$$

$$\Rightarrow P_2 = P_1(\frac{V_2}{V_1})^{-k} = 100(\frac{V_1/4}{V_1})^{-1.3} = 606.28kPa$$

(38) A-2 stroke 4-cylinder engine with 75 mm bore and stroke consumes 12 kg of fuel per hour at 2000 rpm. If the air-fuel ratio is 13:1, then the volumetric efficiency of the engine, consuming the density of ambient air as 1.29 kg m^{-3}, is
(A) 75.50 percent
(B) 76.05 percent
(C) 77.21 percent
(D) 81.76 percent
Ans: (B)

$$\eta_v = \frac{(\frac{A}{F}) \times \frac{\dot{F}(\frac{kg}{\min})}{\rho_A \frac{kg}{m^3}}}{LAnN(\frac{m^3}{\min})} = \frac{(\frac{13}{1})\frac{\frac{12}{60}}{1.29}}{\frac{\pi}{4}(0.075)^3 \times 4 \times 200}$$

$= 0.76036 = 76.036\%$

(39) A hydraulic agitation system, having tank volume of 300 litres, is working at a pressure of 1.4 MPa. The recirculation rate of liquid in litres per minute is given by, Q = $1000Vp^{-0.4}$, where V is the tank volume in m^3 and P is the pressure at the agitation jet in kPa. If the pressure is increased to 1.6 MPa, the change in power requirement of agitator at the same rate of circulation will be
(A) 55 W
(B) 385 W
(C) 442 W
(D) 550W
Ans: (A)

$Power_1 = P_1 \times Q = (1.4 \times 10^6 \frac{N}{m^2}) \times [\ 1000 \times (300 \times 10^{-3}) \times$

$(1400)^{-0.4}x(10^{-3}/60)\frac{m^3}{s}$]= 386 W

Power$_2$ = P_2x Q = $(1.6 \times 10^6 \frac{N}{m^2})$ x[1000 x $(300x10^{-3})$ x

$(1400)^{-0.4}x(10^{-3}/60)\frac{m^3}{s}$]=441.19W

Change in power requirement = 441.19-386 = 55.19 W

(40) The parallel pipes P and Q of identical diameter and length are connected to reservoirs. If the friction factor of pipe P is 4 times that of Q, the ratio of discharge in P to that of in Q is
(A) 0.25
(B) 0.50
(C) 2.00
(D) 4.00
Ans: (B)

$$h_f = \frac{fLV^2}{2gD} = \frac{fLQ^2}{2gDA^2} \Rightarrow Q \propto \frac{1}{\sqrt{f}}, \frac{Q_1}{Q_2} = \sqrt{\frac{f_2}{f_1}} = \sqrt{\frac{1}{4}} = 0.5$$

(41) For a 50 m high homogenous earth dam , having 2m freeboard, a flownet was constructed with 24 potential drops and 4-flow channels. If the coefficient of permeability of the dam material is 0.003 cm s^{-1}, the discharge per metre length of the dam is
(A) $12X10^{-5}m^3s^{-1}$
(B) $24X10^{-5}m^3s^{-1}$
(C) $25X10^{-5}m^3s^{-1}$
(D) $864X10^{-5}m^3s^{-1}$
Ans: (B)

$$q = Kh\frac{N_f}{N_d} = K(H - f.b)\frac{N_f}{N_d} = \frac{0.003}{100}(50-2)\frac{4}{24}$$

$$= 24x10^{-5} \quad m^3/s$$

(42) A partially-saturated soil sample has moisture content : 10%, bulk density : 2g cm^{-3} and specific gravity : 2.7. The degree of saturation of soil sample is
(A) 11.1 percent
(B) 48.5 percent
(C) 55.6 percent
(D) 69.9 percent

Ans: (C)

Bulk density, $\gamma = \left(\frac{G + eS_r}{1+e}\right) Y_w$

$$\Rightarrow \gamma = \left(\frac{G + \omega G}{1 + \omega G / S_R}\right) y_W \quad \Rightarrow \quad 2x9.81 = \left(\frac{2.7 + 0.1x2.7}{1 + 0.1x2.7 / S_r}\right) 9.81$$

$$\Rightarrow S_r = 55.6\%$$

(43) A 6m-high retaining wall, with vertical earth face, supports cohesionless soil of unit weight $16kNm^{-3}$, angle of shearing resistance 35^0 and void ratio 0.68. The surface of the soil is horizontal and level with the top of the wall. Assuming the soil to be dry and wall friction to be negligible. The total thrust on the wall per metre length will be

(A) 26 kN
(B) 53 kN
(C) 78 kN
(D) 1067 kN

Ans: (D)

$$P_a = \frac{1}{2} K_p Y H^2 = \frac{1}{2}\left(\frac{1 + \sin 35}{1 - \sin 35}\right) \times 16 \times 6^2 = 1062 \text{ kN}$$

(44) In a rectangular channel, the flow is in critical state with a specific energy of 3.0m. The discharge per unit channel width is

(A) $2.00\ m^3s^{-1}m^{-1}$
(B) $3.13\ m^3s^{-1}m^{-1}$
(C) $5.75\ m^3s^{-1}m^{-1}$
(D) $8.86\ m^3s^{-1}m^{-1}$

Ans: (D)

$$\frac{2}{3} h_e = d_c = \sqrt[3]{\frac{Q^2}{b^2 g}}$$

$$\Rightarrow \frac{Q^2}{b^2} = q^2 = \left(\tfrac{2}{3} h_e\right)^3 \times g = \left(\tfrac{2}{3} \times 3\right)^3 \times 9.81 = 78.48$$

$$\Rightarrow \quad q = \sqrt{78.48} = 8.86\ m^3s^{-1}m^{-1}$$

(45) Bench terraces are constructed on a 10 % hill slope, If the vertical interval is 1.5m, the earthwork per hectare is

(A) $1875m^3$

(B) $3750 m^3$
(C) $7500 m^3$
(D) $18750 m^3$
Ans: (A)

$$\frac{S}{100} = \frac{VI}{HI} = \frac{D}{W}$$

$$\Rightarrow W = \frac{100D}{S} = \frac{100 \times 15}{10} = 15$$

$$\frac{L}{ha} = \frac{10000}{HI} = \frac{10000}{W} = \frac{10000}{15}$$

$$\text{Earthwork per hectare} = Ax\frac{L}{Ha} = \left[\frac{1}{8}WD\right] \times \frac{L}{Ha}$$

$$= \frac{1}{8} \times 15 \times 1.5 \times \frac{10000}{15} = 1875 m^3$$

(46) The effective root zone of a crop is 120 cm and evapotranspiration during the month of September is 270 mm. The field capacity and critical moisture content on volume basis are 16% and 6% respectively, and effective rainfall is 30 mm. The irrigation interval is
(A) 5 days
(B) 14 days
(C) 15 days
(D) 24 days

Ans: (C) $i = \frac{Loss\ to\ be}{Rate\ of\ Loss} = \frac{d + ER}{ET} = \left(\frac{\Delta M}{100}\right)\frac{D + ER}{ET}$

$$= \frac{(\frac{16-6}{100}) \times 120 + 3}{27/30} = \frac{15}{0.9} = 16.66 \quad \text{day s}$$

(47) The discharge of a sprinkler is 0.5 litres per second. Taking the coefficient of discharge as 0.9, the pressure head of a nozzle having $0.2 cm^2$ cross-sectional area is
(A) 0.39 m
(B) 2.50 m
(C) 27.78 m
(D) 39.33 m
Ans: (D)

q $= ac\sqrt{2gh}$, $0.5\times 10^{-3} = 0.2\times 10^{-4} \times \sqrt{2gh} \Rightarrow h = 39.327$ m

(48) The specific speed of a centrifugal pump rotating at 1440rpm is 160. At 30 m operating head the discharge of pump is
(A) 1.29 m^3s^{-1}
(B) 1.42 m^3s^{-1}
(C) 2.03 m^3s^{-1}
(D) 2.13 m^3s^{-1}
Ans: (C)

$$N_s = N\frac{Q^{1/2}}{H^{3/4}} \Rightarrow 160 = 1440\frac{Q^{1/2}}{H^{3/4}} \Rightarrow Q = 2.029\frac{m^3}{s}$$

(49) The drainage coefficient of a 1200-hectare watershed draining at a rate of $3m^3s^{-1}$ is
(A) 2 mm
(B) 20 mm
(C) 360 mm
(D) 480 mm
Ans: (B)

$$DC = \frac{Q}{A} = \frac{3\times 24\times 3600}{1200\times 10^4}\times 1000 = 21.6mm$$

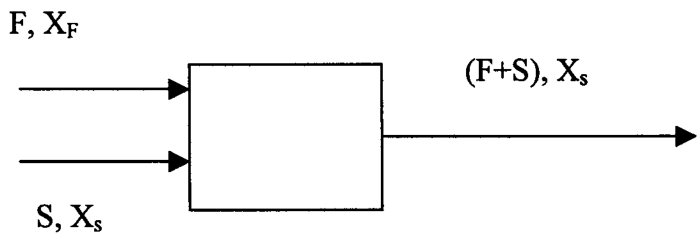
(50) One dimension transient heat conduction equation in a solid is expressed as : $\frac{\delta T}{\delta\theta} = \alpha\frac{\delta^2 T}{\delta x^2}$ Where "T" is temperature, 'θ' is time,"x" is distance and 'α' is thermal diffusivity. The relation between 'T' and 'x' within the solid at any time 'θ' under steady state heat conduction is
(A) $T = a+bx^2$
(B) $T = a+bx$
(C) $T = ae^{bx}$
(D) $T = ae^{-(b/x2)}$
Ans: (B)

Steady state $\frac{\partial T}{\partial\theta} = \theta \Rightarrow \propto \frac{\partial^2 T}{\partial x^2} = 0 \Rightarrow \frac{\partial T}{\partial x} = b \quad \Rightarrow T = a + bx$

(51) A bed of grain has height H (m), cross-sectional area A (m^2), porosity ε (fraction) and particle density ρ_p (kg m^{-3}). The grains to be dried by heated air at temperature T (^0C) under fluidization of the bed will depend on
(A) H,A,ε, ρ_p and T

(B) H, ρ_p and T
(C) H,A,ε and ρ_p
(D) H,ε,ρ_p and T
Ans: (D)

(52) A 40-kg syrup contains 20 wt % sucrose. Citric acid is added into the syrup such that its concentration in the resultant syrup is 3 wt%. The amount of citric acid added to the syrup is
(A) 0.96 kg
(B) 1.20 kg
(C) 1.24 kg
(D) 1.48kg
Ans: (C)



Taking only citric acid balance
$Sx1 = (40 + s) \times 0.03 \Rightarrow S = 1.237$ kg

(53) A silo 15.24m high and 1.83 m in diameter, is filled with grain having a bulk density of 635 kg m^{-3}. The pressure ratio and coefficient of friction between the grain and wall of the bin are 0.333 and 0.5 respectively. Vertical pressure developed at the base of the silo is
(A) 32.09 kPa
(B) 1.738 kPa
(C) 17.05 kPa
(D) 3.27 kPa
Ans: (C)

$$R=\frac{D}{4}=\frac{1.83}{4}=0.46, \quad h>D, \Rightarrow P_L=\frac{wR}{\mu}(1-e^{-\frac{\mu' kh}{R}})$$

$$\Rightarrow \quad P_L=\frac{635\ x0.46}{0.5}(1-e^{-\frac{0.5x0.333x15.24}{0.46}})=581 \quad kg/m^3$$

$$=581\times 9.81=5.7KPa$$

(54) Saturated steam at 120°C (enthalpy 2706.3 $kJkg^{-1}\,^0C^{-1}$) is injected into 10 kg water at 20 °C (specific heat 4.19$kJ^{-1}\,^0C^{-1}$) such that the water temperature reaches 60°C. The amount of steam required is

(A) 0.68 kg
(B) 0.62 kg
(C) 0.22 kg
(D) 0.15 kg

Ans: (B)

$$S = \frac{40 \times 4.19 \times 10}{2706.3} = 0.619 \text{ kg}$$

(55) A horizontal screw conveyor of length 2 m conveys wheat grain having bulk density of 680 kg/m³. The screw diameter, shaft diameter and pitch of the screw are 0.5 m, 0.3m and 0.45m respectively. If the screw is completely filled with the grain and rotates at 60 rpm, the capacity of the screw conveyor is

(A) 259 m^3h^{-1}
(B) 203.6 m^3h^{-1}
(C) 4.32 m^3h^{-1}
(D) 3.39 m^3h^{-1}

Ans: (B)

$$\overset{g}{m} = \rho Q$$

$$Q = AV = \left\{\frac{\Pi}{4}(0.5^2 - 0.3^2) \times 0.45 \times 60 \times 60\right\} \times 1 \times 1 \quad = 203.6\, m^3/hr$$

(56) An air-stream A (temperature 20°C, absolute humidity of 0.0152 kg water per kg dry air and flow rate of 10 kg dry air per hour) is mixed with stream B (temperature 40°C, absolute humidity of 0.0256 kg water per kg dry air and flow rate of 100 kg dry air per hour). If the heat capacity C_p of air and water vapour are 1.005 and 1.884 $KJkg^{-1}\,^0C^{-1}$ respectively, and latent heat of vaporization of water at 0 °C is 2500 $KJ.kg^{-1}$, the absolute humidity and temperature of the resultant stream are

(A) 0.0204 Kg water per kg dry air and 32.2 °C
(B) 0.0246 Kg water per kg dry air and 32.2 °C
(C) 0.0204 Kg water per kg dry air and 38.2 °C
(D) 0.0246 Kg water per kg dry air and 38.2 °C

Ans: (D)

Water content balance

$m_1H_1 + m_2H_2 = (m_1+m_2)H_3$

$\Rightarrow$ 10x0.0152+100x0.0256 = (10+100)xH_3

$\Rightarrow$ H_3 = 0.0246 kg/kg

$m_1H_1 \Delta T_1 + m_2H_2 \Delta T_2 = (m_1+m_2) H_3 \Delta T_3$

$\Rightarrow$ 10 x 0.0152 x 20 + 100 x 0.0256 = (10 +100) x 0.0246 x ΔT_3

$\Rightarrow$ ΔT_3 = 38.4°C

(57) A roller mill converts 100 kg.h^{-1} of wheat grits into flour. If the bonds energy constant for the wheat grits is 3.02 kWh.tonne^{-1} and mm$^{1/2}$, the power required to grind the grits from an average particle diameter of 3 mm to 0.1 mm is

(A) 0.92 kW
(B) 0.78 kW
(C) 0.30 kW
(D) 0.25 kW

Ans: (B)

$$E = \frac{\rho}{f} = K_b\left[\frac{1}{\sqrt{D_p}} - \frac{1}{\sqrt{D_f}}\right] = 3.02\left(\frac{1}{\sqrt{0.1}} - \frac{1}{\sqrt{3}}\right) = 0.78\text{kW}$$

(58) A semisolid food kept in a tin can is heated inside a retort using saturated steam. The relationship (with constants 'a' and 'b') between time of heating (θ) and difference between surface and centre temperature (ΔT) of the can will be

(A) ΔT = a$e^{-b\theta}$
(B) θ = a$e^{-b\Delta T}$
(C) ΔT = a (-bθ)
(D) ΔT = a ln(bθ)

Ans: (A)

(59) Air at pressure p_1 flows through a nozzle to a reduced pressure p_2. Mass flow rate of air through the nozzle will

(A) increase with increase in (p_1-p_2)
(B) increase with increase in (p_1/p_2)
(C) be maximum at a particular value of (p_1-p_2)
(D) be maximum at a particular value of (p_1/p_2)

Ans: (C)

(Q) A 2-wheel drive tractor is equipped with conventional differential. The differential has a crown gear with 39 teeth, driven by a bevel pinion with 8 teeth. Each side gear is connected to a rear axle through a final drive unit that provides a 5:1 speed reduction. The input torque to the bevel pinion is 1000 Nm at a pinion speed of 525 rpm. Take differential efficiency 0.98.

(60) When the tractor is moving straight ahead on uniform level ground, the power delivered to the right wheel is

(A) 26.94 kW
(B) 27.49 kW
(C) 28.05 kW
(D) 53.88 kW

Ans: (A)

$2\pi N_b T_b \times \eta_D = 2\pi N_c T_c \Rightarrow 525 \times 1000 = 107.69 \times T_c$

$\Rightarrow T_c = 4777.6$ N.m

$N_c t_c = N_b t_b \Rightarrow N_c \times 39 = 525 \times 8 \Rightarrow N_c = 107.69$ rpm ,

$N_{rear} = \dfrac{N_c}{5} = 21.53,$

$T_{rear} = \dfrac{T_c}{2} \times 5 = 11944$

$P_{Right} = \dfrac{2\pi N_c T_c}{2} = \dfrac{2\pi N_b T_b \eta_D}{2}$

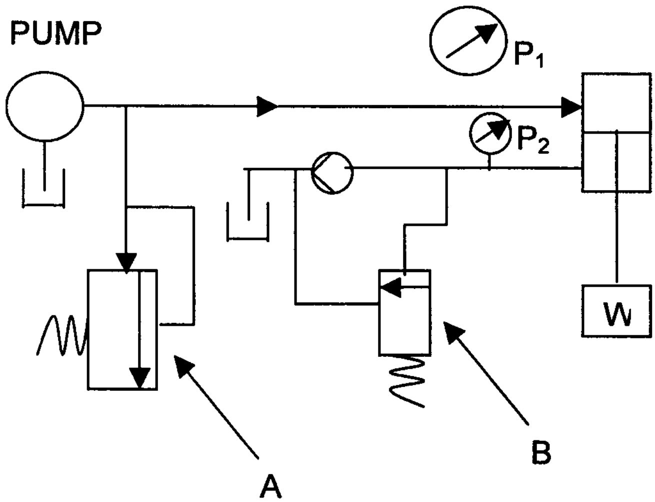
$= \pi \times \dfrac{525}{100} \times 1000 \times 0.98 = 26940 w = 26.94\ kW$

(61) If the left wheel encounters poorer traction such that the left axle torque drops 10% of its value under straight ahead position and left wheel begins turning 50% faster than right wheel, then power delivered to the right wheel is

(A) 12.13 kW
(B) 16.16 k
(C) 19.39 kW
(D) 29.09 kW

Ans: (B)

(Q) A simple tractor hydraulic system is shown in the figure. 'A' is a pressure relief valve and 'B' is counterbalance valve. The cylinder piston and the rod diameters are 50 mm and 25 mm respectively. The pressure relief valve is set at 0.75 MPa. The system pressure is indicated by P_1 and counterbalance pressure by P_2. The maximum suspended load W maintained at the given location is 1000 N.



(62) The pressure P_2 at the counterbalance valve is
(A) 0.32 Mpa
(B) 1.00 Mpa
(C) 1.07 Mpa
(D) 1.68 MPa
Ans: (A)

$F_1 + W = F_2 \Rightarrow P_1A_1 + W = P_2A_2$, $A_1 = \frac{\pi}{4}D^2$, $A_2 = \frac{\pi}{4}(D^2 - d^2)$

$$\Rightarrow \left[0.75\times10^6\times\frac{\pi}{4}(0.05)^2\right]+1000 = P_2\times\frac{\pi}{4}(0.05^2-0.025^2)$$

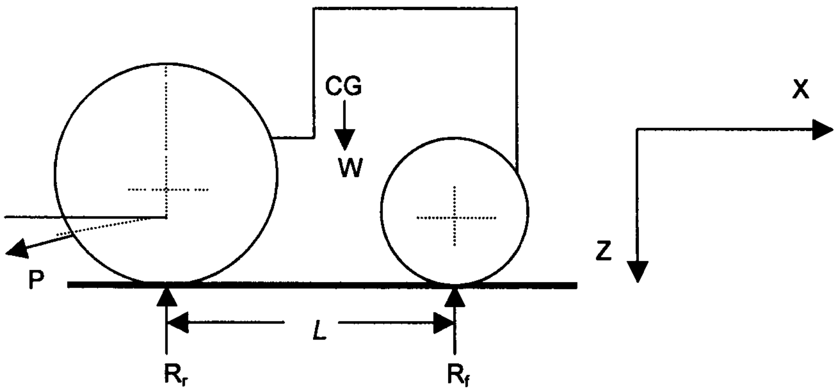
$\Rightarrow P_2 = 1.679 \times 10^{-6}\,N/m^2 = 1.679$ kPa

(63) If the downward velocity of piston is 50 mm s^{-1}, the flow rate through the counterbalance valve is
(A) 5.88 l/min
(B) 4.41 l/min
(C) 2.59 l/min
(D) 1.47 l/min
Ans: (B)

$$Qt = AL \Rightarrow Q = \frac{AL}{t} = AV = \frac{\pi}{4}(D^2-d^2)\times V$$

$$\Rightarrow Q = \frac{\pi}{4}(0.05^2 - 0.025^2\times50\times10^{-3}\times60\times10^3 = 4.41 \text{ lit/min}$$

(Q) A rear wheel drive tractor weighing 18 kN has the static weight divide in such a way that 12 kN is on the rear wheels and 6 kN on the front wheels. The tractor is pulling a plough at a forward speed of 5 km/hr. The plough exerts an inclined drawbar pull of 10 kN with the line of pull making an angle $\alpha = 15^0$ with the horizontal in the vertical plane. (See the figure below). The axle power required is 20 kW, the wheel base of the tractor L is 2100 mm and distance Y is 500 mm.



R_r - Soil reaction against rear wheel
R_f - Soil reaction against front wheel
W – Static weight of tractor

(64) The dynamic weight on the rear axle is
(A) 12.00 kN
(B) 12.62 kN
(C) 14.30 kN
(D) 16.89 kN
Ans: (D)
The dynamic weight of rear axle = static weight of rear wheel + weight of implement+ Weight transfer from front axle.

$$\Rightarrow 12 + P \sin \alpha + \frac{P \cos\alpha \times Y}{L}$$

$$= 12 + 10 \sin 15 + \frac{10 \cos 15\ (0.5)}{2.1} = 16.89\ kN$$

(65) The tractive efficiency of the tractor for this operation is
(A) 17.97 %
(B) 40.25 %
(C) 67.08 %

(D) 69.44 %
Ans: (C)

$$\text{T.E}=\frac{\textit{Drawbar power}}{\textit{Axle power}}=\frac{(P\cos\alpha)V}{20}$$

$$=\frac{(10\cos 15)(5/3.6)}{20}=0.6708=67.08\%$$

(Q) A flywheel type of chaff cutter has 2 cutting blades and flywheel rotates at 600 rpm. The width and the height of the throat are 300 mm and 100 mm respectively. The power from the flywheel to the feed rolls is transmitted by a worm and worm gear mechanism, which provides speed reduction of 25:1. The density of the forage in the throat is 100 kg/m^3. The desired theoretical length pf cut of the chaff is 10 mm.

(66) The diameter of the feed rolls required to get the desired length of cut is
(A) 191.00 mm
(B) 159.2 mm
(C) 114.6 mm
(D) 79.6 mm
Ans: (B)

$V_{\text{Fly wheel}} = V_{\text{feed roll}} \Rightarrow \text{NLn} = \pi D' N'$

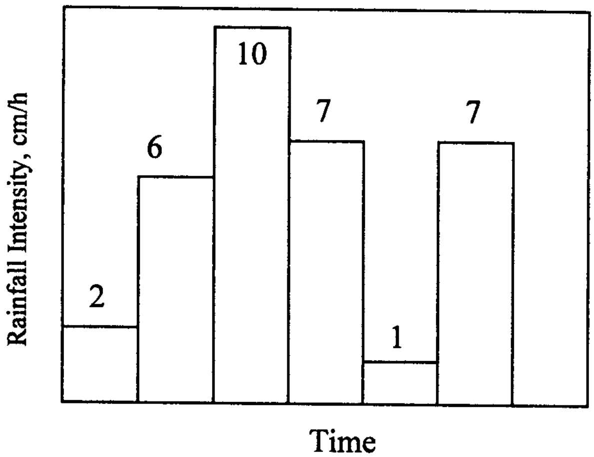
$$\Rightarrow 600 \text{ x } 10 \text{ x } 2 = \pi\times D\times(\frac{600}{25})$$

$\Rightarrow$ D=159.15 mm

(67) The theoretical capacity of the machine is
(A) 360 kg/h
(B) 1080 kg/h
(C) 2160 kg/h
(D) 3390 kg/h
Ans (C)

$\overset{g}{m} = \rho Q = \rho VA = \rho VA = \rho(\text{NLn})(\text{WH})$
$= 100 \text{ x } 600 \text{ x } 60 \text{ x } 10/1000 \text{ x } 2 \text{ x } 0.3 \text{ x } 0.1 = 2160\text{kg/hr}$

(Q) The following figures presents the rates of rainfalls for successive 10 minutes period of a 60 minute storm.



(68) A mass curve is plotted using the above hyetograph. The peak of the mass curve is
(A) 1.67 cm
(B) 3.00 cm
(C) 3.30 cm
(D) 5.50 cm

t (hr)	1/6	1/6	1/6	1/6	1/6	1/6
I (cm/hr)	2	6	10	7	1	7
P (cm)	1/3	1	10/6	7/6	1/6	7/6

Ans (D) Peak of mass curve = $\sum P = 5.5$ cm

(69) If the value of ϕ-index is 3 cm/hr. The runoff resulting due to the storm will be
(A) 2 cm
(B) 3 cm
(C) 4 cm
(D) 5 cm
Ans (B)

$$\phi = \frac{\sum P_e - R}{\sum t_e}$$

$$\Rightarrow 3 = \frac{(1+10/6+7/6+7/6)-R}{4/6} \Rightarrow R = 3 \text{ cm}$$

(Q) The following table presents ordinates of a 4-hour unit hydrograph. The average infiltration loss rate and constant base flow of the watershed are 0.5 cm/h and 20 m^3/s respectively.

Time (h)	0	4	8	12	16	20	24	28	32
UH ordinate (m^3/s)	0	180	560	540	260	120	35	8	0

(70) A rainfall event of 5 cm in 4 hours would result in peak outflow of
(A) 1620 m^3/s
(B) 1680 m^3/s
(C) 1700 m^3/s
(D) 2800 m^3/s
Ans: (C)

$$W_{index} = \frac{\sum P - R}{\sum t} \Rightarrow 0.5 = \frac{5-R}{4} \Rightarrow R = ER = 3\text{cm}$$

$$Q_P(UH) = \frac{Q_P(DRH)}{ER} = \frac{Q_P(SH) - Base\ flow}{ER}$$

$$\Rightarrow \quad 560 = \frac{Q_P(SH)-20}{3} \Rightarrow Q_P(SH) = 1700 \quad m^3/s$$

(71) The peak of a 12h unit hydrograph for the above watershed will be
(A) 426.67 m^3/s
(B) 453.33 m^3/s
(C) 1360.00 m^3/s
(D) 1680.00 m^3/s
Ans: (B)
Maximum out of all the 12 hr UH ordinates=

$$\frac{260+540+560}{3} = 453.33 \quad m^3/s$$

(Q) A fully penetrating well in a confined aquifer discharges at a rate of 30 Lps. The diameter of the well is 30 cm. the distance between the impervious bottom layer of the aquifer and pizeometric surface is 32 m. The transmissivity of the aquifer is 150 m^2d^{-1}. The distance of pizeometers from the well are 40 m and 60 m respectively. The head measured in the farther pizeometer is 22 m.

(72) The head in the nearer pizeometer is
(A) 18.26 m
(B) 19.28 m
(C) 20.89 m
(D) 22.48 m
Ans: (C)

$$Q= \frac{2\pi kbs}{ln(R/r_w)}=\frac{2\pi T(H-h_w)}{ln(R/r_w)}=\frac{2\pi T(h_1-h_2)}{ln(r_1/r_2)}$$

$$\Rightarrow 30x10^{-3}x3600x24=\frac{2\pi\times 150\times(h_1-22)}{ln(\frac{40}{60})} \Rightarrow h_1=20.89m$$

(73) The drawdown in the well is
(A) 24.57 m
(B) 25.98 m
(C) 26.47 m
(D) 27.64 m
Ans: (C)

$$Q=\frac{2\pi T(h_1-h_w)}{ln(\frac{r_1}{r_w})}$$

$$\Rightarrow 30x10^{-3}x3600x24=\frac{2\pi\times 150(20.89-h_w)}{ln(\frac{40}{0.15})}$$

$$\Rightarrow h_w=5.527m$$

$S = H-h_w = 32-5.27 = 26.47$

(Q) A drop inlet pipe spillway is designed for $3m^3/s$ peak flow and 4 m total head. The length of pipe is 10 m. The entrance and friction loss coefficients are 0.04 and 0.025 respectively.

(74) The cross-sectional area of pipe is
(A) 0.35 m^2
(B) 0.38 m^2
(C) 0.42 m^2
(D) 0.54 m^2
Ans: (B)

$$Q = AV = A\sqrt{\frac{2gh}{1+k_e+k_cL}}$$

$$\Rightarrow 3 = A\sqrt{\frac{2\times 9.81\times 4}{1+0.04+0.025\times 10}} = A\times 7.79$$

$$\Rightarrow A = 0.38m^2$$

(75) The normal slope is
(A) 0.077
(B) 0.097
(C) 0.125
(D) 0.156
Ans: (A)

$$S_n = \frac{H_f}{L} = K_c\times\frac{V^2}{2g} = 0.025\frac{(7.79)^2}{2\times 9.81} = 0.077$$

(Q) Cold water at 30^0C is heated to 70^0C in a plate heat exchanger using hot water at 90^0C. The flow of two fluids is overall counter-current in the heat exchanger and hot-water flow rate is twice the cold-water flow rate. The hot water makes 2 passes with 2 fluid passage per pass and the cold water makes 4 passes with 1 fluid passage per pass.

(76) Effectiveness of heat exchanger is
(A) 0.87
(B) 0.77
(C) 0.67
(D) 0.57
Ans: (C) $\varepsilon = \dfrac{C_h(T_{hi}-T_{ho})}{C_{min}(T_{hi}-T_{ci})} = \dfrac{70-30}{90-30} = 0.67$

(77) The number of co-current (CoC) and counter-current (CuC) flows within the heat exchanger is
(A) CoC = 3, CuC = 4
(B) CoC = 4, CuC = 3
(C) CoC = 3, CuC = 3
(D) CoC = 4, CuC = 4
Ans: (B)

(Q) A food contains 3 types of heat resistant micro-organisms P, Q and R with Z-values of 11, 9 and 14 ^{0}C respectively. For 6 log-cycle reduction of micro-organisms, the processing time (F_{121}) of a food at 121 ^{0}C is 1.0, 1.1 and 0.9 minutes respectively.

(78) The time required for 1 log-cycle reduction (D_{121}) of the micro-organisms is

(A) P > R > Q
(B) Q > P > R
(C) R > Q > P
(D) P > Q > R

Ans: (B)

$$F = D \log_{10}(\frac{N_0}{N}) \Rightarrow D_0 \propto F_0 \Rightarrow Q > P > R$$

(79) For a 6 log-cycle reduction of P, Q and R, the processing times (in seconds) of food at 130 ^{0}C are

(A) 6.6, 9.1, 12.3
(B) 9.1, 6.6, 12.3
(C) 12.3, 6.6, 9.1
(D) 12.3, 9.1, 6.6

Ans: (B)

(Q) In sieve analysis of corn grits with respect to any particular screen opening the mass fraction of desired particle size in feed, overflow and underflow stream are 0.47, 0.85 and 0.20 respectively. The feed rate of the material on the screen is 10 kg/hr.

(80) The mass flow rate for the overflow stream is

(A) 4.15 kg/hr
(B) 5.85 kg/hr
(C) 6.00 kg/hr
(D) 7.11 kg/hr

Ans: (A)

$F = P + R$

$\Rightarrow FX_F = P\, X_p + R\, X_R \Rightarrow 10 x 0.47 = P \times 0.85 + (10-P) \times 0.2$

$\Rightarrow P = 4.15 kg/hr$

(81) The overall effectiveness of the screen is

(A) 0.462
(B) 0.562
(C) 0.662
(D) 0.762

Ans (C)

$$E = \frac{PR}{F^2}\left[\frac{X_p(1-X_r)}{X_F(1-X_F}\right] = \frac{4.15 \times 5.85}{10^2} \times \frac{0.85(1-0.2)}{0.47(1-0.47)} = 0.662$$

Latent heat of vaporization of water at 0 ^{0}C : 2500 kJ/kg
Latent heat of liquification of ice at 0 ^{0}C : 330 kJ/kg
Specific heat of water vapour : 1.88 kJ/kg ^{0}C
Specific heat of water : 4.19 kJ/kg ^{0}C
Specific heat of ice : 2.00 kJ/kg ^{0}C

(82) Amount of heat required to vaporize water at 80 ^{0}C is
(A) 2650.4 kJ/kg
(B) 2420.0 kJ/kg
(C) 2315.2 kJ/kg
(D) 2164.8 kJ/kg
Ans: (C)
Water (80^{0}C) $\Rightarrow$ water (0^{0}C) $\Rightarrow$ vapor (0^{0}C) $\Rightarrow$ vapor (80^{0}C)
$\therefore$ Q=(-80X4.19)+2500+1.88x80=2650.4-335=2315 $\frac{kJ}{kg}$

(83) Amount of heat required to sublime ice at -20 ^{0}C is
(A) 2832.4 kJ/kg
(B) 2830.0 kJ/kg
(C) 2460.0 kJ/kg
(D) 2170.0 kJ/kg
Ans: (A)
Ice(-20^{0}C) $\Rightarrow$ ice(0^{0}C) $\Rightarrow$ water(0^{0}C) $\Rightarrow$ vapor(0^{0}C)
$\Rightarrow$ Vapor(-20^{0}C)
$\therefore$ Q = 20 x 2 + 2830 - 20 x 1.88 = 2832.4 kJ kg^{-1}

Choose the correct answer from among the alternatives A, B, C and D
(84)

Group 1	Group 2
P Rear tyre inflation pressure	1 300 to 400 kPa gauge
Q Fuel injection pressure	2 80 to 100 kPa absolute
R Forced feed lubrication pressure	3 49 to 50 kPa gauge
S Engine intake manifold pressure	4 13 to 14 MPa gauge
	5 200 to 210 kPa gauge
	6 80 to 120 kPa gauge

(A)	(B)	(C)	(D)
P-5	P-6	P-6	P-5
Q-3	Q-4	Q-4	Q-2
R-2	R-1	R-5	R-1
S-6	S-2	S-3	S-6

Ans (B)

(85)

Group 1	Group 2
P Tractor-drawn seed drill	1 Shear pin
Q Tractor-drawn mower	2 Jump clutch
R Hydrostatic transmission	3 Single plate clutch
S Vertical Conveyor reaper	4 Pitman shaft
	5 Pressure relief valve
	6 Vacuum spring

(A)	(B)	(C)	(D)
P-2	P-2	P-6	P-3
Q-4	Q-6	Q-2	Q-4
R-5	R-4	R-5	R-5
S-1	S-1	S-1	S-2

Ans (D)

(86)

Group 1	Group 2
P Tropical cyclone	1 High pressure region with clockwise winds in northern hemisphere
Q Front	2 Interface between two distinct air masses
R Anti-cyclone	3 Local phenomena due to heating and formation of circulation cell
S Convective precipation	4 Precipitation as a result of mechanical lifting of warm moist air in the mountainous region
	5 Strong depression with anti-clockwise winds in northern hemisphere
	6 Localised phenomena of centripetal winds of extremely high and destructive velocity

(A)	(B)	(C)	(D)
P-5	P-3	P-6	P-1
Q-2	Q-5	Q-2	Q-4
R-1	R-6	R-3	R-5
S-3	S-4	S-4	S-6

Ans (A)

(87)

Group 1	Group 2
P Sprinkler method	1 Rice crop
Q Check basin method	2 Undulated topography
R Border method	3 High yield
S Drip method	4 Saline water
	5 Ground water
	6 Wheat crop

(A)	(B)	(C)	(D)
P-2	P-2	P-6	P-3
Q-4	Q-1	Q-2	Q-4
R-5	R-6	R-5	R-5
S-1	S-4	S-1	S-2

Ans (B)

(88)

Group 1	Group 2
P Convective mass transfer	1 Prandtl number
Q Radiation heat transfer	2 Sherwood number
R Fluid flow in pipe	3 Nusselt number
S Conduction heat transfer	4 Biot number
	5 View factor
	6 Reynolds number

(A)	(B)	(C)	(D)
P-5	P-1	P-3	P-2
Q-3	Q-2	Q-5	Q-5
R-6	R-6	R-6	R-6
S-4	S-3	S-2	S-4

Ans (D)

(89)

Group 1	Group 2
P Particle size distribution in a mixture of comminuted solid	1 Fick's law
	2 Hagen-Poiseulli equation
Q Molecular diffusion in solid	3 Q_{10}
R Thermal sterilization of food	4 Fineness modulus
S Moisture sorption isotherm	5 Plank's equation
	6 Henderson's equation

(A)	(B)	(C)	(D)
P-4	P-5	P-4	P-4
Q-1	Q-1	Q-5	Q-1
R-3	R-4	R-3	R-3
S-2	S-6	S-6	S-6

Ans (D)

2004

(1) The starting aid provided in diesel power tillers of 10-15 hp engine size is
(A) glow plug
(B) thermostat
(C) spark plug
(D) decompression lever
Ans (D)

(2) In modern cooling system used in I.C. engines, the boiling point of water can be raised to 125°C, if radiator water pressure above atmospheric pressure level is maintained at
(A) 50 kPa
(B) 100 kPa
(C) 150 kPa
(D) 200 kPa
Ans (C)

(3) A towed wheel with rolling radius of 0.35 m and normal load of 500 N requires a horizontal force of 50 N to move it forward. The vertical soil reaction against the wheel can be considered to act ahead of vertical line passing through the wheel axis at a distance of
(A) 3.18×10^{-1}m
(B) 3.50×10^{-1}m
(C) 3.18×10^{-2}m
(D) 3.50×10^{-2}m
Ans (D)

$$\frac{TF}{W} \times r = \frac{50}{500} \times 0.35 = 3.5 \times 10^{-2} m$$

(4) The solar declination angle on March 31 in a leap year is
(A) 3.62°

(B) 4.02°
(C) 8.10°
(D) 23.10°
Ans: (A)

(5) A tractor with a mass of 1600 kg develops a maximum tractive effort of 3000 N in top gear on a concrete surface. The total rolling resistance is 160 N. If the gradient angle is defined as the angle that the inclined plane makes with the horizontal, the maximum gradient that can be negotiated by the tractor is
(A) 10.44°
(B) 11.63°
(C) 29.40°
(D) 34.29°
Ans (A)
mg sinθ =T-R
$\Rightarrow$ 1600 x 9.81 x Sin θ = 3000-160
$$\Rightarrow \theta = \sin^{-1}\left(\frac{2840}{1600 \times 9.81}\right) = 10.42^{o}$$

(6) A tillage tool under vibratory mode, compared to a non-vibratory mode, requires
(A) more draft and less power
(B) more draft and more power
(C) less draft and more power
(D) less draft and same power
Ans: (C)

(7) Rice is sown with a drum seeder at the rate of 20 seeds per 30 cm length of row. If row-to-row spacing is 20 cm and the mass of 1000 seeds is 23 grams, the seed rate would be
(A) 23.00 kg ha^{-1}
(B) 76.67 kg ha^{-1}
(C) 153.33 kg ha^{-1}
(D) 172.50 kg ha^{-1}
Ans (B)
$$\text{Seed rate} = \frac{20}{600} \times 10^4 \times 10^4 \times \frac{23}{1000} \times \frac{1}{1000} = 76.67 \quad \text{kg ha}^{-1}$$

(8) A prony brake dynamometer required a balancing force of 42 N at an arm length of 76 cm during testing of an engine, which runs at 1800 rev min^{-1}. The power output of the engine is
(A) 0.62 kW

(B) 1.92 kW
(C) 3.01 kW
(D) 6.02 kW
Ans (D)

$$\text{Power} = 2\pi NT = 2\pi FrN = 2x3.141x42x0.76x\frac{1800}{60}\times\frac{1}{1000}$$

= 6.02 kW

(9) A capillary tube of 0.04 mm diameter, immersed in water shows zero degree contact angle between the capillary tube and the water meniscus. The density of water is 1000 kg m^{-3} and its surface tension is 72 $x10^{-3}$ N m^{-1} at 20°C. The rise of water in the capillary tube is

(A) 1.0×10^{-4} m
(B) 7.0×10^{-4}m
(C) 1.4×10^{-3}m
(D) 73.4×10^{-2} m
Ans (D)

$$h = \frac{2T\cos\theta}{r\rho g} = \frac{2\times 72\times 10^{-3}\times 1}{0.02/_{1000}\times 1000\times 9.81} = 73.4\times 10^{-2}m$$

(10) A tensiometer, attached with a mercury manometer, is installed at 0.4m below the soil surface. The height of mercury in the cup is 0.2 m for saturated soil. The density of mercury is 13600 kgm^{-3}. The rise of mercury in the manometer at 0.6 atmosphere tension is

(A) 45.60×10^{-4}m
(B) 50.01×10^{-2}m
(C) 60.00×10^{-2}m
(D) 105.60×10^{2}m
Ans (B)

$$h = \frac{0.6\times 1.013\times 10^{5}}{13600\times 9.81} = 45.60 \text{ x } 10^{-2}\text{ m}$$

(11) Casagrande apparatus is used for determination of

(A) Liquid limit
(B) Plastic limit
(C) Plasticity index
(D) Shrinkage limit
Ans (A)

(12) The bulk density and moisture content of the saturated soil are 1700 kg m^{-3} and 45 percent (dry weight basis), respectively. The soil moisture content becomes 25 percent at 1 m soil water tension. The density of water is 1000 kg m^{-3}. The drainable porosity of the soil at 1 m soil water tension is

(A) 1.00
(B) 0.76
(C) 0.42
(D) 0.34

Ans (D)

At 45% moisture content, volume= 1700 x 0.45 =765gm = 765cc
At 25% moisture content volume = 1700 x 0.25 = 425gm = 425cc
Drainable porosity = (765-425)/1000=0.34

(13) The area of a watershed is 130 km^2. The distance and elevation difference between the outlet and the farthest point in the watershed are 20 km and 740 m, respectively. The total length of channels of all orders is 650 km. The drainage density of the watershed is

(A) 10.00 km km^{-2}
(B) 5.00 km km^{-2}
(C) 0.15 km km^{-2}
(D) 0.01 km km^{-2}

Ans (B)

$$\text{Drainage density} = \frac{Total\ channel\quad length}{Total\ Area}$$

$$= \frac{650}{130} = 5\ \text{km}/\text{km}^2$$

(14) Furrows of 100 m length and spaced 1 m apart are applied with 0.12 m depth of water in 50 minutes. The required size of the irrigation stream is

(A) $4 \times 10^{-3} m^3 s^{-1}$ (B) $24 \times 10^{-3} m^3 s^{-1}$
(C) $120 \times 10^{-3} m^3 s^{-1}$ (D) $240 \times 10^{-3} m^3 s^{-1}$

Ans (A)

$$\frac{dWL}{t} = q \Rightarrow \frac{100 \times 1 \times 0.12}{50 \times 60} = 4 \times 10^{-3}\, m^3/s$$

(15) A tubewell (WI) of 0.3 m diameter, drilled into a confined aquifer of thickness 30 m, hydraulic conductivity 0.05 m s^{-1} and radius of influence 100 m, shows a drawdown of 5 m against a given discharge. Another tubewell (W2) of 0.6 m diameter is drilled into

the same aquifer with the aforesaid aquifer parameters. The discharge of W2 will be
(A) same as that of W1
(B) reduced by 11 percent of W1
(C) increased by 11 percent of W1
(D) increased by 20 percent of W1
Ans(C)

$$Q = \frac{2\pi T S_w}{\ln(R / r_w)}$$

(16) In a multi-size drip lateral system, the sequence of layout of laterals of different diameters from sub-main is
(A) small, medium and large
(B) medium, large and small
(C) small, large and medium
(D) large, medium and small
Ans (D)

(17) If the atmospheric air is heated
(A) its relative humidity would decrease
(B) its relative humidity would increase
(C) its absolute humidity would increase
(D) its absolute humidity would decrease
Ans (A)

(18) Energy required to grind a material is expressed by
(A) Fick's law
(B) Kick's law
(C) Newton's law
(D) Stoke's law
Ans (B)

(19) Milling of paddy is done in the moisture (wet basis) range of
(A) 8-10 percent
(B) 10-12 percent
(C) 12-14 percent
(D) 14-16 percent
Ans (C)

(20) Soyabean is mostly used in India for production of
(A) edible oil
(B) pulses
(C) milk substitutes
(D) processed foods

Ans (A)

(21) If 10 W/m^2 heat flux is conducted across a wall of 2 cm thickness experiencing a temperature gradient of 2°C, the thermal conductivity of the wall is

(A) 1×10^{-3} W $m^{-1}K^{-1}$
(B) 1×10^{-2} W $m^{-1}K^{-1}$
(C) 1×10^{-1} W $m^{-1}K^{-1}$
(D) 1×10^{-0} W $m^{-1}K^{-1}$

Ans (C)

$$\frac{q}{A} = \frac{k}{x}\Delta t \quad \Rightarrow 10 = \frac{k}{0.02}\times 2 \quad \Rightarrow k = 1\times 10^{-1} Wm^{-1}K^{-1}$$

(22) A countercurrent heat exchanger carrying the same flow rate of the same liquid as hot and cold streams has an NTU (number of transfer unit) of 3. The effectiveness of the heat exchanger is

(A) 0.60
(B) 0.65
(C) 0.70
(D) 0.75

Ans (D)

$$\text{Effectiveness} = \frac{NTU}{1+NTU} = \frac{3}{1+3} = \frac{3}{4} = 0.75$$

(23) Orange juice has 16 percent total solid initially. If the concentration of total solid of the juice is to be increased to 40 percent, the fraction of initial water to be removed from the juice is

(A) 0.42
(B) 0.63
(C) 0.71
(D) 0.84

Ans (C)

$$\text{Fx16=40xL} \Rightarrow \text{L} = \frac{16}{40}\times 100 = 40,$$

Initial water = 84%,

$$\text{Final water content} = \frac{40\times 60}{100} = 24\%,$$

$$\text{Fraction} = \frac{84-24}{84} = 0.71$$

(24) Milk stored for 18 hours at 20° C results in 200 times increase in bacterial count. Storing the same milk at the same temperature for only 6 hours will cause the bacterial count to increase by

(A) 1.34 times
(B) 5.85 times
(C) 14.14 times
(D) 66.67 times

Ans (B)

$\ln\left(\frac{N_0}{N}\right) = Kt$

$\Rightarrow \ln(1/200) = k \times 18$

$\Rightarrow k = -0.2943$

$\Rightarrow \frac{N}{N_0} = e^{0.2943 \times 6} = 5.85$

(25) The critical speed of turning for tractors to avoid overturn during high speed can be increased by

P decreasing the height of centre of gravity of the tractor
Q decreasing the turning radius
R increasing the rear tread width
S increasing the wheel ballasting

(A) P,Q
(B) Q, R
(C) Q, S
(D) P, R

Ans (D)

(26) The seed rate in a tractor-drawn wheat seed drill equipped with fluted roller type seed metering mechanism can be increased by

P decreasing the peripheral speed of the fluted roller for a given forward speed of the ground wheel
Q increasing the peripheral speed of the fluted roller for a given forward speed of the ground wheel
R increasing the exposed area of the fluted roller
S increasing the forward speed of the tractor

(A) P, R
(B) Q, R
(C) Q, S
(D) P, S

Ans (B)

(27) The rate of water flow through soil-plant–atmosphere system (where, ψ and r are the water potential and resistance of the system at various sites, respectively) is

P $(\psi_{leaf} - \psi_{air})/(r_{leaf} + r_{air})$

Q $(\psi_{xylem}-\psi_{leaf})/(r_{xylem} + r_{leaf})$

R $(r_{leaf}-r_{air})/(\psi_{leaf} + \psi_{air})$

S $(r_{xylem}-r_{leaf})/ \psi_{xylem} + \psi_{leaf})$

(A) P, Q
(B) P, R
(C) Q, R
(D) R, S
Ans (A)

(28) The structures used to protect the stream banks of meandering nature are

P stone terracing
Q wooden jacks
R spurs
S gabions

(A) P, Q
(B) P, R
(C) Q, R
(D) R, S
Ans (C)

(29) The internal moisture movement mechanisms during drying in food grains cannot be due to

P capillary flow
Q gravitational flow
R liquid water diffusion
S water vapour diffusion

(A) P, Q
(B) Q, R
(C) R, S
(D) P, S
Ans(C)

(30) The fat can be separated from whole milk by application of

P the principle of Stoke's law
Q centrifugal force difference
R buoyancy-gravity force difference
S hydrostatic pressure

(A) P, Q

(B) Q, R
(C) R, S
(D) P, S
Ans (B)

(31) The volume inside a tractor tyre is 0.5 m^3. The universal gas constant is 8314 m^3 Pa (kg mole)$^{-1}$ K^{-1} and equivalent molecular mass of air is 29 kg (kg mole)$^{-1}$. If the air temperature in the tyre is 27°C and the gauge pressure is 200 kPa, the mass of air in the tyre is
(A) 1.16 kg
(B) 1.75 kg
(C) 12.92 kg
(D) 19.46 kg
Ans (A)

$$PV=\frac{m}{M}RT \Rightarrow m=\frac{200x10^3x0.5x29}{8341x300}=1.16\,kg$$

(32) The kinetic energy available from a tractor engine flywheel rotating at 2000 rev min^{-1} is 100 kJ. If the radius of gyrations is 0.27 m, the weight of the flywheel is
(A) 62.54 N
(B) 165.51 N
(C) 306.46 N
(D) 612.93 N
Ans (D)

$$K.E = \frac{1}{2}I\omega^2 \quad = \frac{1}{2}mK^2 \times (\frac{2\pi N}{60})^2$$

$$\Rightarrow m = 62.56\,kg \Rightarrow weight = mg = 62.56\times 9.8 = 612.93N$$

(33) If the draft requirement of a tillage tool at a forward speed of 1m s^{-1} is 1600 N and at a forward speed of 2 m s^{-1} is 1900 N, then the draft requirement at 1.5 m s^{-1} would be
(A) 1689 N
(B) 1725 N
(C) 1750 N
(D) 1763 N
Ans (B)

$D_s=D_0+KS^2$

$\Rightarrow$ 1600=D_0+ K and 1900=D_0+4K

$\Rightarrow$ K=100 and D_0=1500

$\Rightarrow D_s$=1500+$(1.5)^2$x 100 =1725 N

(34) A two-wheel drive tractor pulls an implement which requires a draft of 12.5 kN. The motion resistance of the tractor is 4.5 kN and the slip of the drive wheels is 20 percent. The transmission efficiency is 0.8. The percentage of power lost in converting engine power into drawbar power is
(A) 26.47
(B) 36.00
(C) 41.18
(D) 52.94
Ans (D)

$$\text{Available Power} = \frac{12.5+4.5}{0.8\times0.2} = 26.562$$

$$\text{Percentage loss} = \frac{26.562-12.52}{26.562} = 52.94\%$$

(35) A horizontal axis windmill with 5 m diameter rotor is used for pumping water at a head of 5 m with average wind velocity of 3 m s^{-1}. If the power coefficient of the rotor is 0.35 and the conversion efficiency of the rotor power into hydraulic power is 45 percent, the average output of the windmill, assuming air density of 1.29 kg m^{-3} is
(A) 0.37 x 10^{-3} m^3 s^{-1}
(B) 1.10 x 10^{-3} m^3 s^{-1}
(C) 2.20 x 10^{-3} m^3 s^{-1}
(D) 3.14 x 10^{-3} m^3 s^{-1}
Ans (B)

$$\text{Power of wind} = \frac{1}{2}\rho AV^3C_p = 0.5\times\frac{\pi\times5^2}{4}\times1.29\times3^3\times0.35$$

Water power= $\rho_w gHQ$

$$\text{Hydraulic power efficiency} = \frac{\textit{water power}}{\textit{wind power}}$$

$\Rightarrow$ Q=1.1x10^{-3} m^3/ sec

(36) An edge cell type plate planter, with 40 cells on the metering plate, is used for sowing pea. If the seed to seed spacing is 10 cm and the ground wheel diameter is 48 cm, the ratio of the velocity of the ground wheel to that of the metering plate is
(A) 0.12

(B) 0.38
(C) 2.65
(D) 8.3
Ans (C)

$$\frac{\pi DN}{10} = 40 \Rightarrow \quad N = 2.65$$

(37) A single disk of a disk harrow, maintained at a disk angle of 19°, is tested in a soil bin. The disk experiences a soil reaction force, which has a thrust component of 166 N, acting perpendicular to the plane of the disk, a horizontal component of 89 N, acting parallel to the plane of the disk, and a vertical component of 250 N. The draft force required to operate the disk is
(A) 138.29 N
(B) 157.84 N
(C) 185.93 N
(D) 255.00 N
Ans (A)
L=166 sin 19 + 8.9 cos 19 = 138.20 N

(38) A bicycle ergometer requires an average torque of 21 N m at a particular load. The machine is operated by pedalling it at a speed of 40 rev min^{-1}. The physiological energy expenditure rate at the work efficiency of 24 percent would be
(A) 87.96 W
(B) 116.67 W
(C) 183.26 W
(D) 366.52 W
Ans (D)

$$P = \frac{2\pi NT}{60\eta} \Rightarrow P = 366.52 W$$

(39) A diesel tractor is rated at 24 kW and develops a maximum torque of 115 N m. The largest diameter of a single plate clutch, with both sides effective, that may be fitted to the tractor is 0.25 m. The pressure being applied axially by means of springs is limited to 1.5 x 10^{-5} N m^{-2}. If the coefficient of friction between the lining material and the contact surface is 0.25, the inner diameter of the clutch plate, assuming uniform pressure, is
(A) 2.14 x 10^{-1} m
(B) 1.57 x 10^{-1} m
(C) 2.33 x 10^{-1}m

(D) 2.42×10^{-1}m
Ans (A)
$T = \mu F r_m N$

$$\Rightarrow T = \mu \times P \times \frac{\pi}{4}(D^2 - d^2) \times \frac{1}{3} \times (\frac{D^3 - d^3}{D^2 - d^2}) \times N$$

$$\Rightarrow d = 2.14 \times 10^{-1} m$$

(40) In a V-belt drive, the angle of wrap on the large pulley is 220° and on the small pulley is 145°. Initial tension on the belt is 40 N. Coefficient of friction between pulley material and the belt is 0.3. Angle of V-groove of the pulleys is 40°. The tension on the tight side of the belt during operation is
(A) 53.57 N
(B) 59.60 N
(C) 72.16 N
(D) 72.34 N
Ans (C)

$$\frac{T_1}{T_2} = e^{r\theta \operatorname{cosec}\alpha} \Rightarrow \frac{T_1}{T_2} = 9.20 \quad and\ T_1 + T_2 = 2T_0\ ,$$

$$\Rightarrow \frac{T_1}{80 - T_1} = 9.2 \Rightarrow T_1 = 72.16\text{N}$$

(41) A two-wheel drive tractor is equipped with a diesel engine, which develops a maximum torque of 120 N m. The maximum engine power is produced at 2200 rev min^{-1}, which gives a maximum road speed of 30kmh^{1}. The transmission efficiency in top gear (gear ratio 1) is 80 percent and the rolling radius of the rear wheels is 0.6m. If the maximum pulling force required is 18 kN and the total motion resistance of the tractor is 2 kN, the desired bottom gear ratio of the tractor is
(A) 6.78
(B) 7.53
(C) 12.56
(D) 15.06
Ans (C)

(42) A four-cylinder two-stroke cycle engine, with a swept volume of 750 cm^3 per cylinder, gives a specific fuel consumption of 0.25 kg kW^{-1} h^{-1} when developing a brake mean effective pressure of 650 kPa at 1500 rev min^{-1}. If the calorific value of the fuel is 40 MJ kg^{-1}, the brake thermal efficiency of the engine is

(A) 9.00 percent
(B) 18.00 percent
(C) 32.00 percent
(D) 36.00 percent
Ans (D)

(43) The relationship between the Chezy's roughness coefficient C and the Darcy Weisbach roughness coefficient (f) is given by
(A) $C = (8g/f)^{1/2}$
(B) $C = (8f/g)^{1/2}$
(C) $C = (8g)^{1/2}/f$
(D) $C = 8\ (f/g)^{1/2}$
Ans (A)

(44) The physical parameters of two soils are given below

Soil	Soil volume (m^3)	Moisture content (percent)	Degree of saturation	Specific gravity	Density of water (kg m^{-3})
X	1	40	1	2.75	1000
Y	1	25	1	2.50	1000

The ratio of soil water content in soil X to soil Y is
(A) 0.57
(B) 0.63
(C) 1.10
(D) 1.76
Ans (D)

$$\text{Ratio} = \frac{0.4 \times 2.75}{0.25 \times 2.5} = 1.76$$

(45) A stratified soil contains four distinct horizontal layers of equal thickness. The coefficient of permeability of both the first and the third layers is 10^{-5} m s^{-1}. The coefficient of permeability of both the second and the fourth layers is 10^{-4} m s^{-1}. The average coefficient of horizontal permeability is
(A) 2.0×10^{-5} m s^{-1}
(B) 5.5×10^{-5} m s^{-1}
(C) 2.0×10^{-4} m s^{-1}
(D) 2.2×10^{-4} m s^{-1}
Ans (B)

$$K = \frac{K_1 Z_1 + K_2 Z_2 + K_3 Z_3 + K_4 Z_4}{Z_1 + Z_2 + Z_3 + Z_4}$$

$$=\frac{(2\times10^{-5}+2\times10^{-4})Z}{4Z}=5.5\times10^{-5}ms^{-1}$$

(46) The internal angle of friction of soil particles is 30°. The ratio of the coefficient of passive to active earth pressure is

(A) 9.00
(B) 0.58
(C) 0.33
(D) 0.11

Ans (A)

$$K_a=\frac{1-\sin\phi}{1+\sin\phi}, K_p=\frac{1+\sin\phi}{1-\sin\phi}$$

$$\Rightarrow\frac{K_p}{K_a}=\left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2=\left(\frac{1+0.5}{1-0.5}\right)^2=3^2=9$$

(47) The pressures at the opposite ends of a sprinkler lateral are 290 kPa and 270 kPa. The diameter and coefficient of discharge for both the sprinklers are the same. If the sprinkler discharge corresponding to 290 kPa pressure is 8 x 10^{-4} m^3 s^{-1}, the discharge corresponding to 270 kPa pressure is

(A) 6.2 x 10^{-4} m^3 s^{-1}
(B) 7.7 x 10^{-4} m^3 s^{-1}
(C) 8.3 x 10^{-4} m^3 s^{-1}
(D) 1.2 x 10^{-3} m^3 s^{-1}

Ans (B)

$$\frac{Q_1}{Q_2}=\sqrt{\frac{P_1}{P_2}}$$

$$\Rightarrow Q_2=Q_1\sqrt{\frac{P_2}{P_1}}=8\times10^{-4}\sqrt{\frac{270}{290}}=7.7\times10^{-4}\quad m^3s^{-1}$$

(48) The depth and velocity of flow in a rectangular channel, after the hydraulic jump, are 1.30 m and .20 ms^{-1}, respectively. The depth of flow in the rectangular channel before the occurrence of hydraulic jump is

(A) 0.25m
(B) 0.49 m
(C) 0.62m
(D) 0.70 m

Ans (A)

(49) The area within the contour elevations of 45, 46, 47 and 48 m are 0.06, 0.18, 0.36 and 0.86 ha, respectively. Using the trapezoidal rule, the volume of water storage is

(A) 5000 m^3
(B) 7500 m^3
(C) 10000 m^3
(D) 15000 m^3

Ans (C)

$$V_w = \frac{1}{2}\{(0.06 + 0.86) + 2(0.18 + 0.36)\}1 = 1.01 \text{ ha-m}$$

(50) A centrifugal pump with double-suction radial impeller discharges 0.08 $m^3\ s^{-1}$ at an operating head of 18 m. The pump is connected with a motor operating at 1560 rev min^{-1}. The specific speed of the centrifugal pump is

(A) 0.59 $m^{0.75}s^{-1.5}$
(B) 0.83 $m^{0.75}s^{-1.5}$
(C) 35.70 $m^{0.75}s^{-1.5}$
(D) 49.98 $m^{0.75}s^{-1.5}$

Ans (B)

$$n_s = \frac{Nq^{1/2}}{n^{3/4}} = \frac{1560}{60} \times \frac{(0.08)^{1/2} m^{1.5} s^{-0.5}}{18^{3/4}\ m^{0.75}} = 0.83\, m^{0.75} s^{-1.5}$$

(51) The discharge and velocity of flow in a 5 m-wide rectangular channel are 10 $m^3\ s^{-1}$ and 1.5 m s^{-1}, respectively. The specific energy of the flowing water is

(A) 0.18 m
(B) 1.45 m
(C) 9.31 m
(D) 10.05 m

Ans (B)

$$\text{Flow depth, h} = \frac{10}{1.5 \times 5} = 1.33$$

$$\text{Specific energy} = \text{h} + \frac{V^2}{2g} \Rightarrow 1.33 + \frac{(1.5)^2}{2 \times 9.81} = 1.45m$$

(52) A 90°V – notch delivers 70m^3 of water in 24 hours. The coefficient of discharge of the V-notch is 0.6.The head over the crest of 90°V – notch is

(A) 1.33 m
(B) 5.00 x 10^{-2}m

(C) 3.92×10^{-2} m
(D) 1.90×10^{-2} m
Ans (B)

$$Q = \frac{70}{24 \times 3600} = 8.1 \times 10^{-4}\ m^3/s \text{ and } Q = \frac{8}{15} C_d \sqrt{2g} \tan\theta\ H^{5/2}$$

$\Rightarrow$ H= 5×10^{-2} m

(53) The height of a shelterbelt is 16m. The threshold and actual wind velocity at 15 m height above the ground surface are 9 m s^{-1} and 18 m s^{-1}, respectively. The angle of deviation of prevailing wind direction from the perpendicular to the shelterbelt is 10 degree. The spacing between the shelterbelt is
(A) 23 m
(B) 92 m
(C) 134 m
(D) 533 m
Ans (C)

$$d = 17\,h\,(\frac{V_w}{V} \cos\theta) = 17 \times 16 \times 9/18 \times \cos 10 = 134 \text{ m}$$

(54) The air at 10°C with an absolute humidity of 0.007 kg H_2O (kg dry air)$^{-1}$ is mixed with another stream of air at 43.5°C with absolute humidity of 0.028 kg $H_2{}^{O}$ (kg dry air)$^{-1}$ under adiabatic condition. The absolute humidity of the air mixture is found to be 0.021 kg H_2O) (kg dry air)$^{-1}$.The temperature of the air mixture is
(A) 26.75°C
(B) 32.33°C
(C) 53.50°C
(D) 61.33°C
Ans (B)

$$T_3 = \frac{T_1H_2 - T_2H_1 + H_3(T_2 - T_1)}{(H_2 - H_1)}$$

$$= \frac{10 \times 0.028 - 43.5 \times 0.007 + 0.021 \times 33.5}{(0.028 - 0.007)} = 32.33\ ^{\circ}C$$

(55) 1 tonne of dried grain at 12 percent moisture content (wet basis) is obtained from steamed parboiled paddy grain of 30 percent moisture content (wet basis). The weight of steamed parboiled paddy is
(A) 1137 kg

(B) 1180 kg
(C) 1257 kg
(D) 1300 kg
Ans (C)
Water content = 1000x0.12= 120, Dry matter = 1000-120=880 kg,

$$M.C = 0.3 = \frac{w_w}{w_w + 880} \Rightarrow w_w = 377.14 \text{ kg}$$

$$\therefore \text{Total weight} = 377.14 + 880 = 1257.14\text{kg}$$

(56) 1000 kg of milk (C_p = 3.9 kJ kg^{-1} K^{-1}) at 80° C is to be heated to 135°C in a sterilizer by injecting steam at 500 kPa (152°C, λ= 2109 kJ kg^{-1}, C_{pw} = 4.18 kJ kg^{-1} K^{-1}). If heat loss to the surroundings is 5 percent, the amount of steam to be injected is
(A) 98.4 kg
(B) 101.7 kg
(C) 103.3 kg
(D) 106.8kg
Ans (D)

$$\text{Amount of steam} = \frac{1000 \times 3.9 \times 55 \times \frac{105}{100}}{2109} = 106.8 \quad kg$$

(57) One tonne of grain stored in a bin is cooled by aeration with ambient air at 20°C (density 1.15 kg m^{-3}) at a flow rate of 0.1 m^3 min^{-1} $tonne^{-1}$. The heat capacities of the grain and the air are 1.67 kJ kg^{-1} K^{-1} and 1.00 kJ kg^{-1} K^{-1}, respectively. The time required for cooling the grain in the bin is
(A) 104 h
(B) 110 h
(C) 214 h
(D) 220 h
Ans (D)

(58) Heat is flowing across the layers of air, concrete and air. The convective heat transfer coefficients for two layers of air are 100 Wm^{-2} K^{-1} and 10 W m^{-2} K^{-1}. Overall heat transfer coefficient for the composite layers is 8 W m^{-2} K^{-1}. The thickness of concrete (thermal conductivity = 0.76 W m^{-1} K^{-1}) layer is
(A) 1.14 cm
(B) 4.04 cm
(C) 17.86 cm
(D) 30.92 cm

Ans (A)

$$U = \frac{1}{\frac{1}{h_0} + \frac{1}{h_i} + \frac{x}{KA}} \Rightarrow 8 = \frac{1}{0.1 + 0.01 + (\frac{x}{0.76})} \Rightarrow x = 1.14cm$$

(59) Fresh carrot cubes weighing 10 kg-f at an initial moisture content of 82 percent (wet basis) is dried during constant rate drying period to 60 percent (wet basis) moisture content. If the exposed surface area of carrot cubes is 3 m^2 and the constant drying rate is 2.53 kg H_2O $m^{-2}h^{-1}$, the time taken for drying is

(A) 5 s
(B) 3 min
(C) 17 min
(D) 43 min

Ans (D)

$$t = \frac{L_s}{AR_c}(X_1 - X_2) = \frac{1.8(4.55 - 1.5)}{3 \times 2.83} = 43.17 \min$$

(60) Pineapple fibres are settling in its juice due to gravity. The fiber particles are of 100 μm diameter having a mass density of 1065 kg m^{-3}. The density and viscosity of juice are 1020 kg m^{-3} and 0.5 cP, respectively. The terminal velocity of the fibre is

(A) 4.91 x 10^{-4} mm s^{-1}
(B) 4.91 x 10^{-1} mm s^{-1}
(C) 4.91 mm s^{-1}
(D) 49.1 mm s^{-1}

Ans (B)

$$V_T = \frac{1}{18} \times 9.81 \times \frac{D_P^2(\rho_p - \rho_a)}{\mu}$$

$$= \frac{9.81 \times (100 \times 10^{-6})^2 (1065 - 1020)}{18 \times (0.5 \times 10^{-3})} = 4.91 \times 10^{-1} \quad mm/s$$

(61) Fish fillet has 85 percent moisture and it is to be frozen using air blast freezer maintaining a temperature of –30°C. The initial temperature of the fillet is at freezing point of 0°C. Mass density of unfrozen fish is 1057 kg m^{-3}. Convective heat transfer coefficient of air is 25 W m^{-2} K^{-1} and thermal conductivity of frozen fish is 1.0 W m^{-1} K^{-1}. If latent heat of crystallization is 335 kJ kg^{-1}, the freezing time for a 20 min-thick large block of fillet is

(A) 0.50 h
(B) 0.75h
(C) 1.00 h
(D) 1.25 h
Ans (D)

$$t=\frac{\lambda\rho}{T_f-T_t}\left(\frac{a}{2h}-\frac{a^2}{8K}\right)=\frac{335\times0.85\times1057}{30}\left(\frac{0.02}{50}-\frac{0.02^2}{8}\right)=1.25\text{h}$$

(62) The fineness modulus (F.M.) of the ground maize feed is 3.7. The average size of the particles is
(A) 4.9 μm
(B) 53.3 μm
(C) 125.6 μm
(D) 1353 μm
Ans (D)
$D_p = 0.104\,(2)^{F.M} = 0.104x\; 2^{3.7} = 1.351$ mm = 1351 μm

(63) Pathogenic organism Listeria monocytogen in milk has a Z value of 6.1°C at 71°C standard pasteurization temperature. Universal gas constant is 8.314 kJ kg mole^{-1} K^{-1} and the decimal reduction time of Listeria monocytogen at 71°C is 5 s. The decimal reduction time of the same organism at 62°C is
(A) 149.40 s
(B) 94.42 s
(C) 49.45 s
(D) 0.03 s
Ans (A)

$$\Rightarrow \frac{D_T}{D_0}=10^{\left(\frac{T_0-T}{Z}\right)} \Rightarrow D_T = 149.41\text{ s}$$

(64) A mower with a reciprocating type cutter bar uses an offset slider crank mechanism to drive the cutter bar in the horizontal plane. The crank rotates at 900 rev minute^{-1} in a vertical plane. The length of the pitman is 40 cm, offset distance is 6 cm and crank radius is 3.8 cm.The crank angle positions, measured from the horizontal at which the knife bar reaches ends of the stroke are
(A) –7.87° and 170.46°
(B) -8.63° and 171.37°
(C) –9.54° and 172.13°
(D) –14.18° and 176.85°

Ans (B)

(Q) A tractor-mounted field sprayer has 11 nozzles fixed on a boom and is operated at a forward speed of 6.5 kmh^{-1}. The nozzles have 70° spray angle. The boom is operated at a height of 50 cm above a crop canopy, which gives 30 percent overlap for uniform coverage. Each nozzle gives a discharge of 350 ml min^{-1}. The average diameter of spray droplet coming out of the nozzles is 250 μm.

(65) The spray application rate is
(A) $65.92 \times 10^{-3}\ m^3\ ha^{-1}$
(B) $94.17 \times 10^{-3}\ m^3\ ha^{-19}$
(C) $129.33 \times 10^{-3}\ m^3\ ha^{-1}$
(D) $134.53 \times 10^{-3}\ m^3\ ha^{-1}$
Ans (A)
x = tan 35 x 50 = 35cm
Actual width $= 2x - 2x \times 0.30 \quad = 49cm$
Total width = 49x11 = 539cm = 5.39m
Field capacity = 5.39x6.5/10 = 3.5 ha/hr
$\Rightarrow$ 0.28 hr/ha = 17min/ha
Discharge = 350x17x11 = 65450ml /ha = 65.45 $\times 10^{-3} m^3\ ha^{-1}$

(66) Number of droplets per cm^2 of land area would be
(A) 45
(B) 57
(C) 81
(D) 16
Ans (C)

(67) In an open loop hydrostatic transmission, a pump running at 1440 rev min^{-1} is used to supply fluid to drive a motor. The motor displacement is $0.5 \times 10^{-3}\ m^{-3}\ rev^{-1}$ and it is to run at 65 rev min^{-1}. The pressure drop across the motor is 132 bar and the pressure drop between the pump and the motor is 5 bar. The torque and the volumetric efficiencies of both the pump and the motor are 95 percent and 90 percent, respectively. The torque required at the motor is
(A) 988 Nm
(B) 945 Nm
(C) 998 Nm
(D) 1228 Nm
Ans (D)

$$\text{Power} = 0.5 \times 10^{-3} \frac{65}{60} \times 132 \times 10^{5} \times \frac{100}{90} = 7944.48 = 2\pi NT$$

$\Rightarrow$ T=1228 Nm

(Q) A four-wheel-drive tractor with a total weight of 135 kN is pulling a level drawbar load of 55 kN on a concrete track. The actual travel speed is 10 km/hr.Owing to unequal tyre pressures and uneven wear of tyres, the theoretical speed of the front tyres is maintained 6 percent higher than that of the rear tyres. The axle power to the front tyres is 110 kW and to the rear tyres is 90 kW.

(68) If the travel reduction of the front tyres is 15 percent, the travel reduction of the rear tyres is

(A) 9.90 percent
(B) 15.00 percent
(C) 20.00 percent
(D) 30.00 percent

Ans (A)

$$S_f = 1 - \frac{10}{x} \Rightarrow 0.15 = 1 - \frac{10}{x} \Rightarrow x = \frac{10}{0.85} = 11.76$$

$V_a = 11.76(1-0.06) = 11.097$

$S_r = 1-(10/11.097) = 9.88\%$

(69) The tractive efficiency of the tractor for this operation is

(A) 40.74 percent
(B) 61.11 percent
(C) 76.39 percent
(D) 84.87 percent

Ans (C)

$$TE = \frac{55 \times 10 \times 5/18}{110 + 90} = 76.39\%$$

(Q) The drip irrigation system is installed for 1 ha area of guava plantation with a spacing of 4m x 4m. The percentage wetted area and crop coefficient are 40 percent and 0.7, respectively. The maximum pan evaporation during summer months and pan coefficient are 8 mm $d^{-1}$and 0.7, respectively. The pump, used to irrigate the plantation, has a discharge of 2.18 x 10^{-3} m^3 s^{-1}. The total dynamic head required to operate the pump is 20 m. The pump efficiency is 60 percent.

(70) Total daily water requirement of guava plantation is

(A) 15.68 m^3
(B) 22.40 m^3

(C) 32.00 m^3
(D) 39.20 m^3
Ans (B)
Daily water requirement = 8 x10^{-3} x 0.7x 10^4 x 40/100 = 22.4 m^3

(71) The horse-power requirement of the pump is
(A) 0.50
(B) 1.00
(C) 1.25
(D) 2.50
Ans (B)

$$HP = \frac{2.18 \times 20}{75 \times 0.6} = 0.968 \quad hp$$

(Q) Conservation practice factors of a watershed having 18 ha contour farming and 12 ha strip cropping are 0.6 and 0.3, respectively. The slope steepness factor is 1.2. The soil erodibility factor is 0.04 Mg ha h ha^{-1} MJ^{-1} mm^{-1}. The rainfall and runoff erosivity index for geographic location is 5000 MJ mm ha^{-1} h^{-1}.The slope length is 100 mother dimensionless exponent in slope length factor is 0.5. The cover management factor is 0.2. The average land slope of the watershed is 10 percent.

(72) The average annual soil loss from the watershed is
(A) 10.80 x 10^3 kg ha^{-1}
(B) 49.07 x 10^3 kg ha^{-1}
(C) 91.01 x 10^3 kg ha^{-1}
(D) 23.04 x 10^5 kg ha^{-1}
Ans (B)
A= RKLSCP

$$\Rightarrow A = \frac{18 \times 0.6 \times 1.2 \times \times 0.04 \times 5000 \times (\frac{100}{22})^{0.5} \times 0.2 + 12 \times 0.3 \times 1.2 \times 0.04 \times 5000 \times (\frac{100}{22})^{5} \times 0.2}{30}$$

$$= 49.12x10^3 \; kg / ha$$

(Q) An irrigation stream size of 1 x 10^{-3} m^3 s^{-1} per metre width is supplied for 5 hours to a vegetated border strip of 250 m long and 5 m wide. The average longitudinal slope of the border is 0.2 percent. The Manning's roughness coefficient is 0.1.The volume of water collected as runoff loss at the end of the border strip is 36 m^3. Assume negligible evaporation loss.

(73) The normal depth of flow is
(A) 3.84 x 10^{-5} m
(B) 6.45 x 10^{-3} m

(C) 2.57×10^{-2} m
(D) 2.57×10^{-1} m

Ans (C) $n = \dfrac{d^{5/3} s^{1/2}}{q}$

$$\Rightarrow d^{5/3} = \frac{0.1 \times 1 \times 10^{-3}}{(0.002)^{0.6}} = 2.57 \times 10^{-2} \text{ m}$$

(Q) Solid particles of size 0.2 mm and density 1100 kg m^{-3} are to be fluidized using air at 202.65 kPa pressure and at 25°C. The void fraction at minimum fluidizing condition is 0.43. The cross-sectional area of the empty bed is 0.12 m^2 and the bed contains 125 kg of solid. Density of air at 25°C is 1.2 kg m^{-3}.

(74) The minimum height of the fluidized bed is
(A) 0.60 m
(B) 1.66 m
(C) 1.85 m
(D) 1.21 m
Ans: (B)

$$L = \frac{125/1100}{0.12} = 0.946$$

$$\Rightarrow \frac{0.946}{L_{mf}} = \frac{1-0.43}{1}$$

$$\Rightarrow L_{mf} = 0.946/0.57 = 1.66 \text{ m}$$

(75) If the bed height of the particles is 3 m and the porosity is 0.6 in fluidized state, the pressure drop across the bed is
(A) 12.94 kPa
(B) 19.40 kPa
(C) 53.90 kPa
(D) 80.84 kPa
Ans (A)

$$\Delta p = L_{mf}(1-\varepsilon_{mf})(\rho_p - \rho)g$$

=3(1-0.6)x (1100-1.2)x 9.8 =12.92 kPa.

(Q) Atmospheric air at 30°C and 0.02 kg H_2O (kg dry air)$^{-1}$ is heated to 60° C in an indirect heat exchanger using flue gases from husk fired furnace. The hot air enters the grain dryer of 1 tonne h^{-1} capacity at the rate of 0.8 m^3 s^{-1}. The exhaust air from the dryer has a temperature of 40°C and an absolute humidity of 0.04 kg H_2O (kg dry air)$^{-1}$. The humid volume of air at 40°C is 0.945 m^3 (kg dry air)$^{-1}$. The specific heat of air is 1.006 kJ kg^{-1} K^{-1}. The calorific value of husk is 12546 kJ kg^{-1} and the combines efficiency of the furnace and the heat exchange system is 30 percent.

(76) The rate of moisture removal from the grain during drying is

(A) 0.907 kg min^{-1}

(B) 1.016 kg min^{-1}

(C) 1.814 kg min^{-1}

(D) 2.032 kg min^{-1}

Ans (B)

$$R = G\,(H_2 - H_1) = \frac{0.8\,\frac{m^3}{\sec}}{0.945\,\frac{m^3}{kg}}(0.04-0.02) \text{ x } 60 = 1.0158 \text{ kg/min}$$

(77) The husk consumption rate for the furnace is

(A) 2.2 kg h^{-1}

(B) 4.9 kg h^{-1}

(C) 24.5 kg h^{-1}

(D) 48.9 kg h^{-1}

Ans (C)

Husk consumption rate

$$= \frac{mC_p\Delta T}{12546} = \frac{0.8\times3600\times1.006\times30}{0.945\times12546} = 24.5 kg/h$$

(Q) Fruit juice having specific heat of 3.5 kJ k^{-1} K^{-1} is flowing in a double tube, concentric, countercurrent heat exchanger at the rate of 2000 kg h^{-1}. The juice is to be cooled from 90° C to 60°C using cold water entering at 30°C with a flow rate of 3500 kg h^{-1}. Specific heat of water is 4.2 kJ kg^{-1} K^{-1} and there is 10 percent heat loss from the hot juice to the surrounding. Overall heat transfer coefficient is 558 W m^{-2} K^{-1} and the area of the heat exchanger is 2.48 m^2.

(78) The outlet temperature of the cooling water is

(A) 60.00°C

(B) 44.29°C

(C) 42.86°C

(D) 35.37°C

Ans (C)

$m_hC_h\Delta T_h = m_cC_c\Delta T_c$

$$\Rightarrow \Delta T_c = \frac{2000 \times 3.5 \times 30 \times 0.90}{3500 \times 4.2} = 12.86$$

$\Rightarrow T = 30 + 12.86 = 42.86$

(79) The number of transfer unit (NTU) for the heat exchanger is

(A) 0.34

(B) 0.71

(C) 1.41

(D) 2.95

Ans (B)

$$NTU = \frac{UA}{C_{\min}} = \frac{558 \times 2.48}{2000/3600 \times 3.5 \times 1000} = 0.7116$$

(Q) A polyethylene film of 200 mm thickness is to be used for wrapping banana at 30° C temperature. The partial pressure of oxygen outside and inside the wrapper are 21.30 kPa and 1.01 kPa respectively. The partial pressures of nitrogen outside and inside the wrapper are 78.02 kPa and 1.01 kPa respectively. Permeability of oxygen and nitrogen at 30°C temperature through polyethylene are 4.12 x 10^{-16} m^3 solute at STP m^{-1} s^{-1} kPa^{-1} and 1.50 x 10^{-14} m^3 solute at STP m^{-1} s^{-1} kPa^{-1}, respectively.

(80) The flux of oxygen through polyethylene at steady state is

(A) 1.86 x 10^{-12} kg mole m^{-2} s^{-1}

(B) 2.78 x 10^{-13} kg mole m^{-2} s^{-1}

(C) 4.18 x 10^{-14} kg mole m^{-2} s^{-1}

(D) 1.86 x 10^{-10} kg mole m^{-2} s^{-1}

Ans (A)

$$N_A = \frac{P_m(P_{A1} - P_{A2})}{22.4(Z_2 - Z_1)}$$

$$\Rightarrow \frac{4.12 \times 10^{-16}(21.30 - 1.013)}{22.4 \times 200 \times 10^{-6}} = 1.86 \times 10^{-12}\ Kg\ mole\ m^{-2}s^{-1}$$

(81) The flux of nitrogen through polyethylene at steady state is

(A) 2.58 x 10^{-13} kg mole m^{-2} s^{-1}

(B) 5.78 x 10^{-12} kg mole m^{-2} s^{-1}

(C) 1.44 x 10^{-11} kg mole m^{-2} s^{-1}

(D) 2.58 x 10^{-10} kg mole m^{-2} s^{-1}

Ans (D)

$$N_A = \frac{P_m (P_{A1} - P_{A2})}{22.4(Z_2 - Z_1)}$$

$$\Rightarrow \frac{1.5 \times 10^{-14}(78.02 - 1.02)}{22.4 \times 200 \times 10^{-6}} = 2.58 \times 10^{-10} kg\ mole\ m^{-2} s^{-1}$$

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(1) the function tan 2x is discontinuous when x equals

(A) π

(B) $\frac{\pi}{2}$

(C) $\frac{\pi}{3}$

(D) $\frac{\pi}{4}$

Ans (D)

(2) If x = a (θ - sin θ), and y = a (1 - cos θ), $\frac{dy}{dx}$ is

(A) tan θ

(B) cot θ

(C) $\tan\frac{\theta}{2}$

(D) $\cot\frac{\theta}{2}$

Ans (D)

y = a (1 - cos θ)

$$\frac{dy}{d\theta} = a\sin\theta \quad \frac{dx}{d\theta} = a - a\cos\theta$$

$$\frac{dy}{dx} = \frac{a\sin\theta}{a - a\cos\theta} = \cot\frac{\theta}{2}$$

(3) Matrix A = $\begin{pmatrix} 1 & 2 & 4 & 3 \\ 0 & 5 & 1 & 3 \\ 0 & 0 & 2 & 9 \\ 0 & 0 & 0 & 5 \end{pmatrix}$ is characterized as

(A) an upper triangular matrix
(B) a scalar matrix
(C) a null matrix
(D) a lower triangular matrix
Ans (A)

(4) The method of "false position" (Regula Falsi) is a numerical method used for
(A) computing real root(s) of an algebraic equation with one unknown.
(B) solving simultaneous algebraic equations with several unknowns.
(C) solving a differential equation.
(D) solving a partial differential equation.
Ans (C)

(5) Variable Θ is a function of independent variables x and t. In terms of conical forms, the partial differential equation is given by $\alpha \frac{\partial^2 \theta}{\partial x^2} - \frac{\partial \theta}{\partial t} = 0$ $\{\alpha = \text{constant}\}$
(A) elliptic
(B) hyperbolic
(C) parabolic
(D) ultra hyperbolic
Ans (A)

(6) The value of $\lim_{x \to 0} \frac{\sin 4x}{x}$ is
(A) 0
(B) ¼
(C) 4
(D) ∞ (infinity)
Ans (C)

$$\lim_{x \to 0} \frac{\sin 4x}{4x} \times 4 = 4 \times 1 = 4$$

(7) One property of the normal distribution is
(A) $\int_{-\infty}^{+\infty} p(x)dx = -1$
(B) $\int_{-\infty}^{+\infty} p(x)dx = 0$
(C) $\int_{-\infty}^{+\infty} p(x)dx = 1$

(D) $\int_{-\infty}^{+\infty} p(x)dx \geq 1$

Ans (C)

(8) In case of linear regression, the standard error of estimate is given by

(A) $S_{y,x} = [1/(n-2)\sum(y - y_{est})^2]^{\frac{1}{2}}$

(B) $S_{y,x} = [1/(n-1)\sum(y - y_{est})^2]^{\frac{1}{2}}$

(C) $S_{y,x} = [1/n\sum(y - y_{est})]^{\frac{1}{2}}$

(D) $S_{y,x} = [1/(n+1)\sum(y - y_{est})]^{\frac{1}{2}}$

Ans (A)

(9) The compression ratio of CI engine is 16 and n = 1.3. During the compression stroke, the lowest theoretical ambient temperature at which the engine would start on diesel with self-ignition temperature of 387^0 C is

(A) -8.65^0C
(B) 10.53^0C
(C) 14.28^0C
(D) 17.96^0C

Ans (C)

$$\left(\frac{V_1}{V_2}\right)^{r-1} = \frac{T_2}{T_1}$$

$$\Rightarrow 16^{-3} = \frac{660}{T_1} \Rightarrow T_1 = \frac{660}{16^{0.3}} = 287.28k = 14.28^0 C$$

(10) A self-propelled combine harvester has a purchase price of Rs. 8,00,000, an expected economic life of 10 years and an expected salvage value of 10% of new cost. At the time of purchase the prevailing annual interest rate is 7%. The annual interest on investment following straight line method would be

(A) Rs.5,600
(B) Rs.25,200
(C) Rs.30,800
(D) Rs.56,000

Ans (C)

$$\text{Annual interest} = \frac{C+S}{2} \times i$$

$$= \frac{8{,}00{,}000 + 80{,}000}{2} \times 0.07 = \text{Rs. } 30{,}800$$

(11) The brakes are applied to a tractor with a mass of 2200 Kg while it is descending on a surface inclined at an angle of 10^0 with the horizontal. If the coefficient of adhesion between the tyres and the surface is 0.54, the maximum possible deceleration will be

(A) 3.51 m/s^2

(B) 5.22 m/s^2

(C) 6.92 m/s^2

(D) 7.96 m/s^2

Ans (A)

$f/g = \mu \cos\theta - \sin\theta$

$$\Rightarrow f = [0.54\cos 10 - \sin 10]9.81 = 3.51 m/s^2$$

(12) The apparent specific gravity of soil is 1.70 and specific gravity of solids is 2.55. For a perfectly dry soil the void ratio is

(A) 0.25

(B) 0.35

(C) 0.50

(D) 0.65

Ans (C)

$$G_{app} = \frac{\gamma_d}{\gamma_\omega} \Rightarrow 1.7 = \frac{\gamma_d}{9.81} \Rightarrow \gamma_d = 16.677$$

$$e = \frac{G\gamma_\omega}{\gamma_d} - 1$$

$$\Rightarrow e = \frac{2.55 \times 9.81}{16.6777} - 1 = 0.5$$

(13) The intensity of active earth pressure at a depth of 12 m in dry cohesionless soil with angle of internal friction of 30 degree, unit dry weight of 2 Mg/m^3 and saturated weight of 2.4 Mg/m^3 will be

(A) 8.00 Mg/m^2

(B) 9.60 Mg/m^2

(C) 72.0 Mg/m^2

(D) 86.4 Mg/m^2

Ans (A)

$$k_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30}{1+\sin 30} = 0.33$$

Intensity, P = kaγh= 0.33 × 2 × 12 = 8.00 Mg/m^2

(14) Kinetic energy of a rainfall with intensity of 100 mm/hr will be

(A) 71.8 m t $ha^{-1}mm^{-1}$
(B) 121.3 m t $ha^{-1}mm^{-1}$
(C) 299.3 m t $ha^{-1}mm^{-1}$
(D) 388.3 m t $ha^{-1}mm^{-1}$

Ans (C)

K.E. = 12.1 + 8.9 logi = 12.1 + 8.9 × log (100)
= 29.93 m t $ha^{-1}mm^{-1}$ = 299.3 m t $ha^{-1}cm^{-1}$

(15) The root zone depth of crop is 90 cm and its available water-holding capacity is 15 cm/metre. Irrigation is to be applied when 40% of available water in the root zone is depleted. If daily consumptive use of crop is 3 mm, the irrigation period is

(A) 20 days
(B) 18 days
(C) 15 days
(D) 22 days

Ans (B)

Water holding capacity = 15 cm, d =90 cm
Water depth = 15 × 0.9 13.5 cm
IR = 0.4 × 13.5 = 5.4 cm
Irrigation period = (54 mm/3 mm) = 18 days.

(16) A cropped field needs sub-surface drainage to control salinity. The electrical conductivity of irrigation water is 1.2 mmho cm^{-1} and depth of irrigation water applied is 5 cm. If the equivalent depth of leachate is 2 cm, the electrical conductivity of leachate is

(A) 0.05 mmho cm^{-1}
(B) 1.65 mmho cm^{-1}
(C) 2.25 mmho cm^{-1}
(D) 3.12 mmho cm^{-1}

Ans (D)

$$\frac{EC_i}{EC_d} = \frac{d_e}{d_i} \Rightarrow \frac{1.25}{EC_d} = \frac{2}{5} \Rightarrow EC_d = 3.12 \text{ mmoh/cm}$$

(17) A centrifugal pump is more efficient if its

(A) impeller has backward curved vanes
(B) impeller has forward curved vanes
(C) delivery had constitutes a small fraction of total head

(D) casing is of large size

Ans: (A)

(18) Oil content (whole mass basis) in rice bran ranges between

(A) 8 – 10 %

(B) 11 – 16 %

(C) 17 – 22 %

(D) 23 – 35 %

Ans (A)

(19) The paddy dehusking (Sheller) machine has two rubber rolls that rotate with

(A) identical speed in same direction

(B) identical speed in opposite direction

(C) differential speed in same direction

(D) differential speed in opposite direction

Ans: (D)

(20) Animal starch is

(A) dextrin

(B) amylose

(C) amylopectin

(D) glycogen

Ans: (D)

(21) In Tyler standard screen series the ratio of area of the opening in any one screen to that of the opening of the next smaller screen is

(A) $\sqrt{2}$

(B) 2

(C) $\sqrt{3}$

(D) 4

Ans: (A)

(22) The differential equation $y = \frac{dy}{dx} + \frac{c}{\frac{dy}{dx}}$ [c = constant] has the following order and degree.

P = first order Q = single degree (linear) R = second order

S = second degree (non linear)

(A) P,Q

(B) R,S

(C) P,S

(D) Q,R

Ans(C)

$$y = \frac{dy}{dx} + \frac{C}{\frac{dy}{dx}} \Rightarrow y \times \frac{dy}{dx} = \left(\frac{dy}{dx}\right)^2 + C$$

order = 1, degree = 2

(23) The longitudinal stability of a rear wheel driven tractor moving up a slope in hilly areas for haulage work can be improved by
P = adding ballast on the front axle
Q = increasing the hitch height of the tractor
R = decreasing the hitch height of the tractor
S = decreasing the air inflation pressure of the trailer tyres.
(A) P,R
(B) Q,S
(C) P,Q
(D) P,S
Ans (A)

(24) Variable Z is a function of independent variables A and S and is given by
$Z = 40\ A^{1/4}S^{1/2}\text{-}1200\text{-}A\text{-}S$
A and S are independent of each other. Z will have a maximum value when A and S take the values
(A) $A = 4 \times 10^4, S = 8 \times 10^4$
(B) $A = 8 \times 10^4, S = 4 \times 10^4$
(C) $A = 2 \times 10^4, S = 5 \times 10^4$
(D) $A = 5 \times 10^4, S = 2 \times 10^4$
Ans (A)
$Z = 40 \times (4 \times 10^4)^{1/4} (8 \times 10^4)^{1/4} - 4 \times 10^4 - 8 \times 10^4 = 38{,}800$
So, $A = 4 \times 10^4$, $S = 8 \times 10^4$

(25) The probability of fewer than 5 occurrences of 20 year storm in a 100 year period using Poisson distribution is
(A) 0.2405
(B) 0.4405
(C) 0.5405
(D) 0.6405
Ans (A)
P=1/100=0.01
$m = rp = 20 \times 0.01 = 0.2$

(26) Matrix $A = [x\ 3 \times 10^4\text{-}x]$ and Matrix, $R = \begin{pmatrix} 0.09 \\ 0.11 \end{pmatrix}$

Given that the matrix product, AR = 3060, the value of x is

(A) 12000
(B) -18000
(C) 31800
(D) -12000

Ans (A)

$$[X \; 3 \times 10^4 - X] \begin{bmatrix} 0.04 \\ \hline 0.11 \end{bmatrix} = 3060$$

$\Rightarrow 0.09X + (0.11 \times 3 \times 10^4) - 0.11X = 3600$

$\Rightarrow X = 12,000$

(27) $x = m \cos kt + n \sin kt$ (m and n are arbitrary constant)

The above equation is the general solution of the differential equation.

(A) $\dfrac{d^2x}{dt^2} + kx = 0$

(B) $\dfrac{d^2x}{dt^2} + k^2x = 0$

(C) $\dfrac{d^2x}{dt^2} + kx^2 = 0$

(D) $\dfrac{d^2x}{dt^2} + k^2x^2 = 0$

Ans (B)

$X = m \cos kt + n\sin kt$

$$\frac{dx}{dt} = -mk \sin kt + nk \cos kt$$

$$\frac{d^2x}{dt^2} = -mk^2 \cos kt + (-nk^2) \sin kt$$

$= -k^2 [m \cos kt + n \sin kt] = -k^2x$

$$\Rightarrow \frac{d^2x}{dt^2} + k^2x = 0$$

(28) Using the binomial distribution the probability that a storm with a return period of 20 years will occur once in 10 years is

(A) 0.255
(B) 0.285
(C) 0.300

(D) 0.315
Ans (D)
P = 1/T = 1/20 = 0.05

$$P_{10,1} = \frac{101}{91} \times 0.05 \times 0.95^9 = 0.315$$

(29) The velocity of a boat relative to the flowing water of the river is represented by the vector 3i+4j, and the velocity of the flowing water relative to the riverbank by i-3j. If I and j represent velocities of 1 Km h^{-1} East and North respectively, velocity of the boat relative to the bank in Km h^{-1} is
(A) $\sqrt{65}$
(B) $\sqrt{53}$
(C) $\sqrt{17}$
(D) $\sqrt{11}$
Ans (B)

$$R = \sqrt{(3i + 4j)^2 + (i - 3j)^2}$$
$$= \sqrt{9i^2 + 16j^2 + 24ij + i^2 + 9j^2 - 6ij}$$
$$= \sqrt{9 + 16 + 24 + 1 + 9 - 6} = \sqrt{53}$$

(30) For a bullock-drawn mould board plough, the horizontal component of soil forces is inclined to an angle of 20 degree from the direction of travel while the line of pull is along the direction of travel. If the horizontal component of pull is inclined at an angle of 10 degree from the direction of travel rather than being straight ahead, the percent increase in draft of the plough bottom will be
(A) 7.26
(B) 8.93
(C) 15.40
(D) 46.00
Ans (A)

$R_x = P_x \cos 20 \Rightarrow P_x = R_x / \cos 20 = 1.0641 R_x$
$R_x = P_h \cos 30 \Rightarrow P_h = R_x / \cos 30$

$$\text{New draft} = P_h \cos 10 = \frac{R_x}{\cos 30} \cos 10 = 1.0381\ R_X$$

Percentage increase $= \dfrac{1.1381 - 1.0641}{1.0641} \times 100 = 7.3\%$

(31) A leather belt 100 mm wide and 10 mm thick with a safe permissible stress of 1.5 MPa is used for transmitting a maximum power of 15 kW. If the density of the belt material is 1.0 g/cm^3, the velocity of the belt for maximum power transmission will be

(A) 7.14 m s^{-1}

(B) 22.36 m s^{-1}

(C) 38.73 m s^{-1}

(D) 70.71 m s^{-1}

Ans (B)

T = 1.5 x 10^6 x 0.1 x 0.01= 1500N

M = 1/1000 x 10 x 1 Kg/cm = 1 Kg/cm

$$V = \frac{\sqrt{T}}{\sqrt{3M}} = \sqrt{\frac{1500}{3 \times 1}} = 22.36 \text{ m/s}$$

(32) A tractor-drawn single acting disk harrow is moving at a forward speed of 4.5 km h^{-1}. Each gang of the disk harrow has 7 disks of 450 mm diameter each with a disk spacing of 200 mm. The field capacity of the disk harrow will be

(A) 1.03 ha h^{-1}

(B) 1.09 ha h^{-1}

(C) 1.14 ha h^{-1}

(D) 1.26 ha h^{-1}

Ans (D)

Width of cut = 7 x 0.2 = 1.4 m

Field Capacity = 4.5/3.6 x 1.4 = 1.75 m2/s = 0.63 ha/hr

Total Field Capacity = 0.63 x 2= 1.26 ha/hr

(33) A 50 kW tractor engine is provided with a pressurized water cooling system. The heat transfer rate from water to air is 25 kW. The air velocity maintained by the cooling fan is 6 m/s. The expected temperature rise as air moves through the radiator is 20^0 C. If density of air is 1.29 kg m^{-3} and specific heat of air is 1 kJ kg^{-1} ^{0}C^{-1}, the required frontal area of the radiator will be

(A) 0.16 m^2

(B) 0.19 m^2

(C) 0.21 m^2

(D) 0.97 m^2

Ans (A)

$Q = MC_p \Delta t$

$\Rightarrow \dfrac{25\times10^3}{A} = 1.29 \times 6 \times10^3 \times 20$

$\Rightarrow$ A = 0.16m^2

(34) An accelerometer mounted to the waist of an operator sitting on the tractor seat records a vibration acceleration level of 3.5 dB at 8Hz. The amplitude of vibration is

(A) 0.59 mm
(B) 0.84 mm
(C) 1.96 mm
(D) 3.36 mm

Ans (B)

$W = 2\pi f = 2\pi \times 8 = 50.265$

$V = \dfrac{1}{\sqrt{2}}(W^2A) = \dfrac{1}{\sqrt{2}}(50.265)^2 \times A$

VAL = 20 log V/1

$\Rightarrow 3.5 = 20 \log [\dfrac{1}{\sqrt{2}} W^2 A]$

$\Rightarrow$ A = 0.84 mm

(35) A 4 × 100 cm maize planter is to be operated at a forward speed of 3.6 Km h^{-1}. The diameter of the ground wheel is 50 cm. A cup type metering mechanism with 10 cells on its periphery is used for dropping one seed in a hill. Power is transmitted from the ground wheel shaft to the metering shaft with the help of chain and sprocket arrangement. If the desired plant population is 6000 per hectare and average emergence percentage of maize is 75, the speed ratio between ground wheel shaft and metering shaft will be

(A) 1.97
(B) 2.68
(C) 7.96
(D) 10.64

Ans (A)

π DN/60 = V = 3.6/3.6

$\Rightarrow$ N = 60/ π x 0.5 = 38.147 rpm

Total number of seed fall = 6000/0.75 = 8000/ha

Distance covered per ha. = 10^4/4 = 2500m

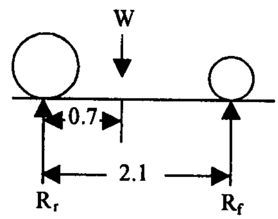
Time taken = 2500/1 = 2500 sec. = 2500/60 = 41.66 min

Speed of metering devices = 800/41.66 = 19.2 rpm

Ratio = 38.197/19.2 =1.97

(36) A two-wheeled drive tractor weighing 21 kN has a wheel base of 2.1m. The centre of gravity is located 0.70 m ahead of rear axle centre in horizontal plane. During haulage work, the tractor pulls a 2-wheel trailer with a gross load of 2 tons. The hitch height of the tractor is 500 mm above the ground. The transfer of weight by the trailer on to the tractor hitch is 15 percent of the trailer gross load. If the resulting coefficient of traction is 0.4, the pull exerted by the trailer on the tractor is

(A) 5.600 kN
(B) 6.187 kN
(C) 6.776 kN
(D) 7.490 kN



Ans (C)

$R_f \times 2.1 = 21 \times 0.7$

$\Rightarrow R_f = 7$ KN

Weight transfer = 0.15 x 19.62 = 2.943 KN

Dynamic load on rear wheel = 14 + 2.943 = 16.943 KN

$\mu = P/16.943$

$\Rightarrow P = 0.4 \times 16.943 = 6.776$ KN

(37) A cylindrical tank of 2 m diameter is filled with water to a height of 1.0 m and emptied through an orifice of 2 mm diameter fitted at the bottom. If the coefficient of discharge is 0.60, the time taken to empty it to level of 0.50 m is

(A) 6.9 h
(B) 30.5 h
(C) 52.0 h
(D) 61.2 h

Ans (D)

$a = \pi/4\ d^2 = \pi/4\ (0.002)^2 = 3.14\times10^{-6}$

$A = \pi/4\ D^2 = \pi/4 \times 2^2 = 3.141\ m^2$

$$T = \frac{2A\left(\sqrt{H_1} - \sqrt{H_2}\right)}{C_d a\sqrt{2g}}$$

$$= \frac{2\times3.141\left(\sqrt{1} - \sqrt{0.5}\right)}{0.6\times3.14\times10-6\times\sqrt{2\times9.81\times4}} = 220526 \text{ sec} = 61.2 \text{ hr}$$

(38) A hydraulically-efficient trapezoidal channel section is built on a side slope of 1:1 and depth of 1.0 m. If the velocity of flow in the channel is 54.69 cm s^{-1}, the discharge is

(A) 0.5 $m^3\ s^{-1}$

(B) 1.0 $m^3 s^{-1}$
(C) 1.5 $m^3 s^{-1}$
(D) 2.0 $m^3 s^{-1}$
Ans (B)
$\tan \theta = 1, \theta = 45^0$
$b = 2d \tan \theta/2 = 2 \times 1 \tan 45/ 2 = 0.828$
$A = bd + zd^2 = 0.824 \times 1 + 1 \times 1^2 = 1.824\ m^2$
$Q = AV = 1.824 \times 0.5469 = 1\ m^3/ s$

(39) In a falling head permeability test, a tube of 3 cm^2 cross-section and 30 cm length is fitted over the permeameter of 75 cm^2 cross-section and 20 cm height. The permeameter is filled with the test soil sample and water up to the top of the tube. If the permeability of the soil is 0.008 mm min^{-1}, the time taken for the water level to fall by 10 cm is
(A) 42 min
(B) 97 min
(C) 112 min
(D) 223 min
Ans (D)
$a = 3\ cm^2, A = 75\ cm^2, L = 20\ cm = 0.2\ m$
$h_1 = 30 + 20 = 50\ cm, h_2 = 50 - 10 = 40\ cm$
$$k = \frac{aL}{At} \ln(h_1/h_2)$$
$\Rightarrow t = 3 \times 0.2 / 75 \times 0.008 \times 10^{-3} \ln 30/40$
$\Rightarrow t = 223$ min

(40) At the foot of chute spillway water flows with a velocity of 7 m/s and a depth of 0.12 m. Hydraulic jump is created for energy dissipation in a rectangular channel. The sequent depth after the jump should be
(A) 1.04 m
(B) 1.24 m
(C) 1.54 m
(D) 2.04 m
Ans (A)
$$F = \frac{v}{\sqrt{gD}} = 6.45$$
$$\frac{d_1}{d_2} = \frac{1}{2}\left[-1 + \sqrt{1 + 8F^2}\right] = \frac{1}{2}\left[-1 + \sqrt{1 + 8 \times 6.45^2}\right] = 1.04\ m$$

(41) If the width of a bench terrace is W, drop D and existing land slope S, then for 1:1 riser slope the drop D is equal to
(A) WS/(200-S)
(B) WS/(100-S)
(C) 2WS/(100-S)
(D) 2WS/(200-S)
Ans (B)

$$D = \frac{WS}{100 - S}$$

(42) Pumping was done at a constant rate of 1500 L min^{-1} from a well drilled in a confined aquifer. One piezometer installed at a distance of 2 m from the centre of the well showed a drawdown of 4.5 m. If the transmissibility of the aquifer is 0.192 m^2 min^{-1}, a drawdown of 2 m would be observed at a distance of
(A) 12.52 m
(B) 14.92 m
(C) 22.65 m
(D) 25.42 m
Ans (B)
Q = 1500 L/min = 1.5 m^3/min

$$1.5 = \frac{2\pi T(h_2 - h_1)}{\ln {}^{r_2}\!/_{r_1}}$$

$$\Rightarrow 1.5 = \frac{2\pi 0.192(4.5 - 2)}{\ln {}^{r_2}\!/_{r_1}}$$

$\Rightarrow r_2/2 = 7.46 \Rightarrow r_2 = 14.92$ m

(43) The specific speed of a centrifugal pump with an operating speed of 1450 rpm and discharge of 25 lps is 18. If it is operated at 1600 rpm, the operating head will be
(A) 2.453 m
(B) 6.018 m
(C) 16.545 m
(D) 36.216 m
Ans (A)

$$N = \frac{N_s H^{3/4}}{Q^{1/2}}$$

$$\Rightarrow 1600 = \frac{1450 \times H^{3/4}}{25^{1/2}}$$

$\Rightarrow$ H = 2.453 m

(44) Due to overuse of ground water the water-table in a 10-ha catchment is observed to drop by 4 m. If the porosity is 30% and specific retention is 10%, the change in ground water storage will be

(A) 4×10^4 m^3
(B) 8×10^4 m^3
(C) 16×10^4 m^3
(D) 20×10^4 m^3

Ans (B)

n = 30 %

$10 \times 10^4 \times 4 = 4 \times 10^5$ m^3

$n = S_r + S_y$

$\Rightarrow 0.3 \times 4 \times 10^5 = S_y + 0.1 \times 4 \times 10^5$

$\Rightarrow S_y = 8 \times 10^4$

(45) The storage (S) and outflow (Q) of an emergency spillway are related as S = 8000 Q, where S is in m^3 and Q is in m^3 s^{-1}. The inflow, outflow and storage at the beginning are assumed to be zero. The outflow rate from the reservoir at the end of one hour when the inflow rate is 400 m^3 s^{-1} will be

(A) 16.13 m^3 s^{-1}
(B) 73.47 m^3 s^{-1}
(C) 116.13 m^3 s^{-1}
(D) 124.14 m^3 s^{-1}

Ans (D)

S = 8000 Q

S + Q = inflow

Or 8000 Q + 3600 Q = 400 x 3600

$\Rightarrow$ Q (8000 + 3600) = 400 x 3600

$\Rightarrow$ Q = 124.14 m^3/sec

(46) A wheat field needs to be irrigated with a depth of irrigation of 50 cm, the duration of the crop season is 125 days. A stream size of 15 lps flowing for 15 hours a day can irrigate an area of

(A) 5.25 ha

(B) 10.25 ha
(C) 20.25 ha
(D) 25.25 ha
Ans (C)
d = 50 cm, t = 125 days.
For 15 hrs = 15 x 10^{-3} x 15 x 3600 x 125= 101250 m^3
Area = 101250/0.5 = 20.2500 m^2 = 20.25 ha.

(47) Malthus law on microbial growth is given by the differential equation, $\frac{dx}{dt} = \mu x$ where x is microbial density (mass of cells per unit volume of batch culture), μ is specific growth rate of culture (constant for the batch), and t is time. The time required for microbial density to double will be

(A) $\frac{\ln 2}{\mu}$
(B) $\frac{\mu}{\ln 2}$
(C) $\mu.\ln 2$
(D) $\mu.(\ln 2)^2$

Ans (A)

$$\frac{dx}{dt} = \mu x \Rightarrow \int\frac{dx}{x} = \int \mu dt \Rightarrow \ln x = \mu t$$

when microbial density become double
$k(2x) = kt_1 \Rightarrow \ln 2 + \ln x = \mu t_1$
$\mu (t_1 - t) = \ln 2$
$\Rightarrow t_1 - t = \ln 2/\mu$

(48) A batch type horizontal abrasive polisher was used to polish brown rice. Based on the mass of brown rice fed, a relationship between percent head yield (Y) and percent bran removed (X) was established as follows: Y = 98 – 1.5X [5≤ X≤ 20]. If degree of polish (percent bran removed) is 9 percent. Broken rice percentage is

(A) 5.2
(B) 6.5
(C) 7.1
(D) 8.6

Ans (B)

Y = 98 -1.5x= 98 – (1.5 x 9) = 84.5

broken rice percentage = 100 – 84.5 – 9 = 6.5

(49) A spherical fish ball with a radius of 25.4 mm is at an uniform temperature of 15^{0}C. It is suddenly brought to a cold chamber whose temperature is held constant at -30^{0}C having convective heat transfer coefficient of 10 W m^{-2} ^{0}C^{-1}. The average thermo physical properties of fish are, thermal conductivity = 0.5 W m^{-1} ^{0}C^{-1}, density = 970 kg/m^3, and specific heat = 2.45 kJ kg^{-1} ^{0}C^{-1}. The temperature of the fish ball after keeping for one hour in the cold chamber will be

(A) 14.58 ^{0}C
(B) 19.72 ^{0}C
(C) -10.86 ^{0}C
(D) -28.60 ^{0}C

Ans (A)

For sphere V/A = r/3 = 25.4/3 = 8.46 mm

$$\frac{t - t_w}{t_0 - t_w} = e^{\left(-\frac{hA}{\rho CpV}\right)\times\tau}$$

$$\Rightarrow \frac{t-(-30)}{15-(-30)} = e^{\left(-\frac{10}{970\times2.45\times1000\times0.00846}\right)\times1}$$

$\Rightarrow$ t = 14.58^0 C

(50) A ball mill of 1.5 m diameter is charged with balls each having diameter of 5 cm, the rotational speed of ball mill is kept at 70% of the critical speed. The operating speed of rotation in rpm is

(A) 17.4
(B) 24.6
(C) 35.1
(D) 50.2

Ans (B)

$$N_s = \frac{1}{2\pi}\sqrt{g/_{R-r}} = \frac{1}{2\pi}\sqrt{\frac{9.81}{0.75-0.025}} = 35.1$$

Operating speed = 0.7 x 35.1= 24.6

(51) 100 kg of fish is cooled from 30 to -20^{0}C. The specific heat of fish above and below freezing are 3.18 and 1.72 kJ kg^{-1} K^{-1} respectively. The initial freezing point of fish is -2.5 ^{0}C and the latent heat of freezing is 250 kJ kg^{-1}. The total heat load to cool the fish in kJ is

(A) 33,575
(B) 35,165
(C) 36,025
(D) 38,345
Ans (D)
Total heat load =100 x 3.18 x (30 + 2.5) + (100 x 250) + 100 x 1.72 x (20 – 2.5) = 38,345 KJ

(52) From the heat and mass transfer analogy,

$\frac{h}{C_p \rho v}\left(N_{pr}\right)^{2/3} = K_c\left(N_{Sc}\right)^{2/3}$, where , v is velocity; N_{pr} and N_{Sc} are Prandtl and Schmidt Number respectively. If mass transfer coefficient, Kc = 0.5 m s^{-1}; density, ρ = 0.915 kg m^{-1}; specific heat,C_p = 1.08 kJ kg^{-1} K^{-1}; heat transfer coefficient, h = 400 W m^{-2} K^{-1} and thermal conductivity, k = 0.028 W $m^{-1}K^{-1}$, the mass diffusivity will be
(A) 3.14 x10^{-5} m^2 s^{-1}
(B) 3.26 x10^{-5} m^2 s^{-1}
(C) 3.61 x10^{-5} m^2 s^{-1}
(D) 3.89 x10^{-5} m^2 s^{-1}
Ans (D)
$N_{pr} = \mu C_p/k$ $\qquad$ $N_{SC} = \mu/\rho D_{AB}$

$$\frac{h}{\rho C_p}\left(\frac{\mu C_p}{k}\right)^{2/3} = kc\left(\frac{\mu}{\rho D_{AB}}\right)^{2/3}$$

$$\Rightarrow \frac{400}{0.915\times 1.08\times 10^3}\times\left(\frac{1.08\times 10^3}{0.028}\right)^{2/3} = 0.5\left(\frac{1}{0.915\times D_{AB}}\right)^{2/3}$$

$\Rightarrow D_{AB} = 3.89 \times 10^{-5}\ m^2/s$

(53) A single solid grain particle is let fall freely under gravity through a stagnant fluid medium. At an instant, the buoyant force encountered by the grain particle is 31 percent and drag force 43 percent of the weight of the grain. If the acceleration due to gravity is 'g', the acceleration of the particle at that instant is
(A) 14 percent of g
(B) 26 percent of g
(C) 68 percent of g
(D) 88 percent of g
Ans (B)
43% + 31% = 74%

Acceleration = 100 – 79= 26%

(54) A gas with a mass of 3.06 x 10^{-3} kg has a volume of 3.5 x 10^{-3} m^3 at 500 mm mercury (density = 13595.1 kg m^{-3}) pressure and 21^0 C temperature. Using the ideal gas law (Universal gas constant = 8314.41J kg-mol^{-1} K^{-1}), the molar mass of the gas is

(A) 2.0

(B) 4.0

(C) 28.0

(D) 32.0

Ans (D)

$$\rho V = \frac{W}{\mu} RT \Rightarrow \mu = 32$$

(55) A cold storage is made of composite wall consisting of 25 mm concrete, 100 mm brick, 100 mm thermocole, and 5 mm plywood having thermal conductivities of 0.76, 0.69, 0.024, and 0.2 W m^{-1} K^{-1} respectively. The rate of heat-gain in W m^{-2} by the cold storage is

(A) 7.78

(B) 9.31

(C) 12.66

(D) 5.62

Ans (A)

$$Q = kA\frac{dT}{dx} \Rightarrow \frac{Q}{A} = \frac{dT}{(dx/k)} = \frac{36-2}{\frac{0.025}{0.75} + \frac{-1}{0.69} + \frac{0.005}{0.2}} = 7.78$$

(56) A single stage evaporator is to concentrate mango juice from 10 percent to 60 percent solids (whole mass basis) under steady state condition. If the feed rate is 60 kg h^{-1} the rate of production of concentrated mango juice will be

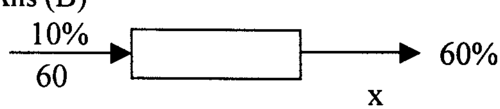
(A) 9 kg h^{-1}

(B) 10 kg h^{-1}

(C) 11 kg h^{-1}

(D) 15 kg h^{-1}

Ans (B)



$$x = \frac{60 \times 10}{60} = 10 \text{ kg/hr}$$

(57) A liquid food (specific heat = 3540 J kg^{-1} K^{-1}) is fed to a counter-current heat exchanger at 283 K at a rate of 0.5 kg s^{-1} where it is heated by hot water (specific heat = 4.12 kJ kg^{-1} K^{-1}) entering at 370 K at a rate of 3 kg s^{-1}. The overall heat transfer coefficient is 250 W m^{-2} K^{-1} and the heat transfer area available is 20 m^2. The number of transfer unit (NTU) is

(A) 0.02
(B) 0.14
(C) 2.82
(D) 45.76

Ans (C)

$$NTU = \frac{UA}{C_{\min}} = \frac{250 \times 20}{3540 \times 0.5} = 2.82$$

(58) Whole milk having density of 1030 kg m^{-3} and kinematics viscosity of 2.06 x 10^{-6} m^{-2} s^{-1} flows with an average velocity of 20 mm s^{-1} through a circular tube of length 10 m having an inside diameter of 25.4 mm. The pressure drop along the tube-length is

(A) 5.52 Pa
(B) 21.04 Pa
(C) 82.27 Pa
(D) 100.58 Pa

Ans (B)

$\rho = 1030 \text{ kg/m}^3$, $v = 2.06 \times 10^{-6}$, V = 20 mm/sec

$$V_{av} = \frac{\Delta\rho A^2}{32\mu l}$$

$$\Rightarrow \frac{20}{1000} = \frac{A\rho \times (0.0254)^2}{32 \times 2.06 \times 10^{-6} \times 10 \times 1030}$$

$$\Rightarrow A\rho = 21.04 \text{ Pa}$$

(59) At ambient temperature of 30^0C, if the vapour pressure of water is 4.242 kPa, the partial pressure of water vapour in the atmosphere is 2.52 kPa and atmospheric pressure is 101.325 kPa, the percentage relative humidity is

(A) 41.8
(B) 59.4

(C) 68.6
(D) 74.2
Ans (B)

$$\%RH = \frac{2.52}{4.242} = 59.4$$

(60) Air at 400 K is flowing at an average velocity of 0.5 m s^{-1} through a thin walled tube of 25.4 mm diameter having a thermal conductivity of 16.4 W m^{-1} K^{-1}. The flow is laminar and thermal conductivity of air is 0.03 Wm^{-1} K^{-1}. For a Number of 3.66, the heat transfer coefficient in W m^{-2} k^{-1} will be
(A) 0.05
(B) 3.09
(C) 4.32
(D) 76.15
Ans (C)

$$N_{NU} = \frac{hx}{k} \Rightarrow 3.66 = \frac{h \times 0.0254}{0.03} \Rightarrow h = 4.32$$

(61) A fat particle of 10 μm diameter having density of 930 kg m^{-3} is being separated from milk having density of 1030 kg m^{-3} and viscosity of 1.8 x10^{-3} Pa s. The rate at which the fat particle would rise is
(A) 0.03 mm h^{-1}
(B) 6.58 mm h^{-1}
(C) 10.89 mm h^{-1}
(D) 102.62 mm h^{-1}
Ans (C)

$$V_t = \frac{gD_p^{\,2}(\rho_P - \rho)}{18\mu} = \frac{9.81(10\times10^{-6})^2 \times (1030-930)}{18\times1.8\times10^{-3}}$$

= 10.89mm/hr

(Q) A sprinkler irrigation system has two laterals and twelve sprinklers on each lateral. The spacing between the laterals is 15 m and the spacing between the sprinklers is 10 m. The discharge of each sprinkler is 0.5 l s^{-1}. A water-cooled diesel pump-set is used to operate the system and 5 percent of the pump discharge is utilized for cooling the engine.

(62) The rate of application of irrigation water is
(A) 0.6 cm h^{-1}

(B) 1.2 cm h^{-1}
(C) 2.4 cm h^{-1}
(D) 12.0 cm h^{-1}
Ans (B)
Total number of sprinklers = 12 × 2 = 24
Area covered by each sprinkler = 15 × 10 = 150 m^2

Rate of application = $\dfrac{0.5 \times 10^3}{150}$ = 3.33 × 10^{-6} m/s = 1.2 cm/hr

(63) The required capacity of the pump is
(A) 27.27 m^3 h^{-1}
(B) 45.47 m^3 h^{-1}
(C) 54.15 m^3 h^{-1}
(D) 81.25 m^3 h^{-1}
Ans (B)
Total discharge of pump = 0.5 × 24 = 12 lit/sec= 43.2 m^3/hr
Due to cooling required capacity = 43.2 × 1.05 = 45.47 m^3/hr

(Q) In a drop inlet spillway, water flows through a 750 mm diameter RCC pipe (Manning's n = 0.025) of 20 m length with a square-edged entrance. Elevation of the inlet invert is 55 m and the elevation of the outlet invert is 54.75 m. Head water elevation is 56.60 m and the tail water elevation is 53.90 m. Entrance loss coefficient (K_e) and the friction loss coefficient (K_c) are 0.5 and 0.12 respectively.

(64) For pipe flow condition, the discharge is
(A) 0.87 m^3/s
(B) 1.17 m^3/s
(C) 1.37 m^3/s
(D) 1.57 m^3/s
Ans (B)

$$H = 56.6 - (54.75 + 0.6 \times 0.75) = 1.4m$$

$$V = \frac{\sqrt{2gH}}{\sqrt{1 + k_e + k_c L}} = \frac{\sqrt{2 \times 9.8 \times 1.4}}{\sqrt{1 + 0.5 \times 0.12 \times 20}} = 2.65$$

$$Q = AV = 2.65 \times \frac{\pi}{4} \times 0.75^2 = 1.17 m^3 / \sec$$

(65) The neutral slope of the spillway in percent is
(A) 2.28
(B) 3.38
(C) 4.38

(D) 4.88

Ans (C)

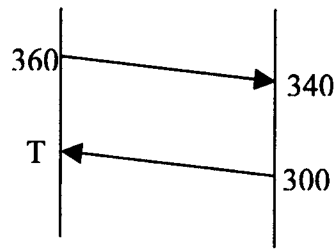
$$S = \frac{k_C V^2}{2g} = \frac{0.12 \times 2.65^2}{2 \times 9.81} = 4.3$$

(Q) A counter-current concentric tube heat exchanger is required to cool 20 kg per second of water from 360 K to 340 K by means of 25 kg/sec of water entering at 300 K. The overall heat transfer coefficient and specific heat of water remain constant at 2 $kWm^{-2}K^{-1}$ and 418 $kJkg^{-1}K^{-1}$ respectively

(66) The logarithmic mean temperature difference is

(A) 41.9 K (B) 39.2 K

(C) 17.9 K (D) 15.2 K



Ans (A)

20 × Cp × (360 - 340)

= 25 × Cp × (T - 300)

⇒ T = 316 K

$$LMTD = \frac{(360-316)-(340-300)}{\ln\left(\frac{360-316}{340-300}\right)} = 41.96$$

(67) The heat transfer surface area required is

(A) 55.0 m^2

(B) 46.7 m^2

(C) 21.3 m^2

(D) 19.9 m^2

Ans (D)

Q = UA × (Δt)m = 20 × 4.18 × (360 - 340) = 2 × A × 41.96

$\Rightarrow A = 19.92\ m^2$

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