DIGITAL EDUCATION
MARTCOST

CHEMICAL ENGINEERING

Process Calculation

Hand Notes For GATE, IES, PSUs & Competitive Exam

Hand Notes

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Process Calculation

↳ Unit operation – physical

↳ Unit process – Chem

Raw — [System] — Final.

Units & Dimensions :–

Dimensions :–

eg :– length, mass, temp, volume, velocity.

Physical varaibles required to define the nature & characteristic of the ~~nature~~ System or object.

↳ Primary – (fundamental) → Independent dimensions & measurable. time, length, mass temp etc.

↳ Secondary – (Derived) → Combination of fundamental dimension. volume, speed, density.

Units :–

To characterize (define) the dimensions.

time → sec, hrs, min, yrs, days

Mass → Kg, g, lb

temp → K, R°, °C, F

Unique units are associated with unique dimensions.

System of Units	mass	time	temp.	length
↳ MKS System (metric System)	kg	Sec	°C	m
↳ FPS system	lb	Sec	°F	ft
↳ CGS System	g	Sec	°C	cm
↳ SI System (System International)	Kg	Sec	K	m
Dimension	M	T	θ or K	L

Desired Units

*P

force

$$F = ma$$

$$F = kg\, m/s^2 = [MLT^{-2}]$$

Unit — Dimension.

1N

Force required to displace the 1 kg of mass wid accl. of 1 m/sec²

$$\underbrace{1N}_{SI} = \underbrace{1kg \cdot 1\, m/s^2}_{MKS}$$

C.g.s

$$1\, kg\, m/s^2 = 1kg \cdot \frac{m}{s^2}\left(\frac{10^3 g}{1kg}\right) \times \left(\frac{100\, cm}{1m}\right)$$

$$1N = 1\, kg\, m/s^2 = 10^5 g \cdot cm/s^2$$

In C.G.S System, $1\, dyne = 1 g \cdot cm/s^2$

$$\boxed{1\, N = 10^5\, dyne}$$

1 lb = 0.4536 kg
1 ft = 0.3048 m
1 ft = 12 inch.
1 inch = 2.54 cm

$$1\, kg \cdot m/s^2 = lb \cdot ft/s^2$$

mass → kg. lbm

weigh → mass × g $= kg \times \frac{m}{s^2} = N = lbf$

*W

⊟ = 80 kg

$$W_{earth} = 80_{kg} \times 9.81\, m/s^2$$

$$W_{moon} = 80 kg \times \frac{1}{6} \times 9.81\, m/s^2$$

* Pressure

$$P = \frac{F_N}{A} = N/m^2$$

$$\boxed{1 Pa = 1 N/m^2}$$

$$P = \rho h g$$

$$P = \frac{Kg}{m^3} \times m \times \frac{m}{s^2} = \frac{1\ \frac{kgm}{s^2}}{m^2} = 1\ N/m^2$$

wid

$1\ atm = 101325\ Pa$ or $(N/m^2) = 1.01325\ bar$

$1\ bar = 10^5$ Pascal

$1\ atm = 760\ mm\ Hg = 760$ tor

$1\ mm\ Hg = (1\ torr)$

$1\ atm = 101.325\ KPa = 101.325\ KN/m^2$

$= 101.325$

$= 101325\ KPa = 101325\ N/m^2$

$= 101325\ (Kg\ m/s^2)/m^2$

$= 101325\ \left(\frac{lbm\ ft/s^2}{ft^2}\right)$

$g = 9.81\ m/sec^2 = ft/s^2$

$\underbrace{\frac{lbf}{ft^2}}_{psi} = \frac{lbf}{in^2}$

$= 101325\ lbf/in^2$

$\boxed{1\ atm = 14.7\ psi}$ pound per sq. inch.

* Work

$W = F \times d$

$\boxed{1 J = 1 N \times m} = \frac{kg \cdot m}{s^2} \times m$

$1 J = Kgm^2/s^2 \quad [ML^2T^{-2}]$

$1 J = 1 \cdot Nm = 1\ kgm^2/s^2 = \frac{10^3 g \times (10^2 cm)^2}{s^2}$

$= 10^7 \, g\,cm^2/s^2$

$1 \, erg = 1 \, g\,cm^2/s^2$

$$\boxed{1 J = 10^7 erg}$$

* Power

$1 hp = 745.7 W$

$P = W/t$

$\boxed{1 W = 1 J/sec} = 1 \cdot Nm/sec$

$$\frac{\left(\frac{kg\,m}{s^2}\right) m}{s} = \frac{kg\,m^2}{s^3} = [ML^2T^{-3}]$$

* Energy

Heat, PE, KE

$PE = mgh = kg \cdot \frac{m}{s^2} \cdot m = kg\,m^2/s^2 = N/m = \text{Joule}.$

$KE = \frac{1}{2} mv^2 = kg (m/s)^2 = kg\,m^2/s^2 = N/m = \text{Joule}.$

Heat → Joule (mech. unit)
 ↳ Cal (actual)

$$\boxed{1 Cal = 4.1858 J}$$

- 10^1 → deca (da)
- 10^{-1} → deci (d)
- 10^{-2} → Centi (c)
- 10^{-3} → mili (m)
- 10^2 → hecto (h)
- 10^3 → kilo (k)
- 10^{-6} → micro (μ)
- 10^{-9} → nano (n)
- 10^{-12} → Pico (p)
- 10^6 → mega (M)
- 10^9 → Giga (G)
- 10^{12} → terra (T)

Q.> The flow rate of water through a pipe is reported as 15 ft^3/min. The density of water is 1 g/cm^3. Calculate the mass flow rate kg/s ?

$$\dot{m} = 15 \frac{ft^3}{min} \times 1\ g/cm^3$$

$$= 15 \frac{ft^3}{min} \times \frac{g}{cm^3} \times \frac{1\ min}{60\ sec} \times \frac{1\ kg}{1000g} \times \frac{0.3048\ m^3}{1\ ft^3} \times \frac{1\ cm}{(10^{-2}m)}$$

$= 7.079$ kg/sec.

Q.> In SI system, thermal conductivity has the unit of W/k. For a solid material thermal conductivity is given by $K = x \cdot Q / A\Delta T$ where Q = rate of heat transfer, x thickness of material, A = cross-sectional area, ΔT - tem diff. For an experiment the values are found to be Q = 10000 KJ/h, A = 1 m^2, x = 100 mm, ΔT = 800 k. Calculate

i.> K in W/mk

ii.> K in Kcal/mhr°C

$g = 9.80658\ m/sec^2$

i.>

$$K = \frac{100\ mm \times 10000\ kJ/h}{1m^2 \times 800K}$$

$$= \frac{10^6}{800} \frac{mm \times kJ}{h \times m^2 \times k} \times \frac{10^{-3}m}{1mm} \times \frac{1hr}{3600\ sec} \times \frac{1000J}{1kJ}$$

$= 0.347$ W/mk.

2.> $0.347\ J/msK \times \left(\frac{1\ Cal}{4.1818\ J}\right) \times \left(\frac{3600\ sec}{1\ hr}\right)\left(\frac{1K}{°C}\right)$

298.628 Cal/mh°C

0.29862 Kcal/mh°C

Δdiff
ΔT = K
∴ ΔT = °C