UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF FOOD TECHNOLOGY
NATIONAL DIPLOMA

MODULE	**FOOD PROCESS ENGINEERING 1** **FTN2AE1**
CAMPUS	**DFC**
EXAM	**07 July 2018**

DATE: **SESSION** **14:00**

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DURATION **3 HOURS** **MARKS** **100**

NUMBER OF PAGES: **5 PAGES**
ANNEXURES: **4 PAGES**

INSTRUCTIONS: **ANSWER ALL THE QUESTIONS.**

QUESTION 1

Water in a tank flows through an outlet 25 m below the water level into a 0.15 m diameter horizontal pipe 30 m long, with a 90° elbow at the end leading to a vertical pipe of the same diameter 15 m long. This is connected to a second 90° elbow which leads to a horizontal pipe of the same diameter, 60 m long, containing a fully open globe valve and discharging to atmosphere 10m below the level of the water in the tank. Taking e/d = 0.01 and the viscosity of water as 1 mN s/m^2, what is the initial rate of discharge?

(20)

QUESTION 2

The dimensionless Grashof number (Gr) arises in the study of natural convection heat flow. If the number is given as

$$\frac{D^3 \rho^2 \beta g \Delta T}{\mu^2}$$

Verify the dimensions of β the coefficient of expansion of the fluid.

(17)

QUESTION 3

Orange juice concentrate is made by concentrating single-strength juice to 65% solids followed by dilution of the concentrate to 45% solids using single-strength juice.

Draw a diagram for the system and set up mass balances for the whole system and for as many subsystems as possible.

Consider a hypothetical proportionator that separates the original juice (S) to that which is fed to the evaporator (F) and that (A) which is used to dilute the 65% concentrate. Also, introduce a blender to indicate that part of the process where the 65% concentrate (C_{65}) and the single-strength juice are mixed to produce the 45% concentrate (C_{45}).

(19)

QUESTION 4

Calculate the specific heat of a formulated food product that contains 15% protein, 20% starch, 1% fiber, 0.5% ash, 20% fat, and 43.5% water at 25∘C.

Protein: $C_{pp} = 2008.2 + 1208.9 \times 10^{-3}\,T - 1312.9 \times 10^{-6}\,T^2$
Fat: $C_{pf} = 1984.2 + 1473.3 \times 10^{-3}\,T - 4800.8 \times 10^{-6}\,T^2$
Carbohydrate: $C_{pc} = 1548.8 + 1962.5 \times 10^{-3}\,T - 5939.9 \times 10^{-6}\,T^2$
Fiber: $C_{pfi} = 1845.9 + 1930.6 \times 10^{-3}\,T - 4650.9 \times 10^{-6}\,T^2$
Ash: $C_{pa} = 1092.6 + 1889.6 \times 10^{-3}\,T - 3681.7 \times 10^{-6}\,T^2$
Water above freezing: $C_{waf} = 4176.2 - 9.0864 \times 10^{-5}\,T + 5473.1 \times 10^{-6}\,T^2$

(12)

QUESTION 5

Calculate the pressure drop along 170 m of 5 cm diameter horizontal steel pipe through which olive oil at 20°C is flowing at the rate of 0.1 $m^3\ min^{-1}$.

(20)

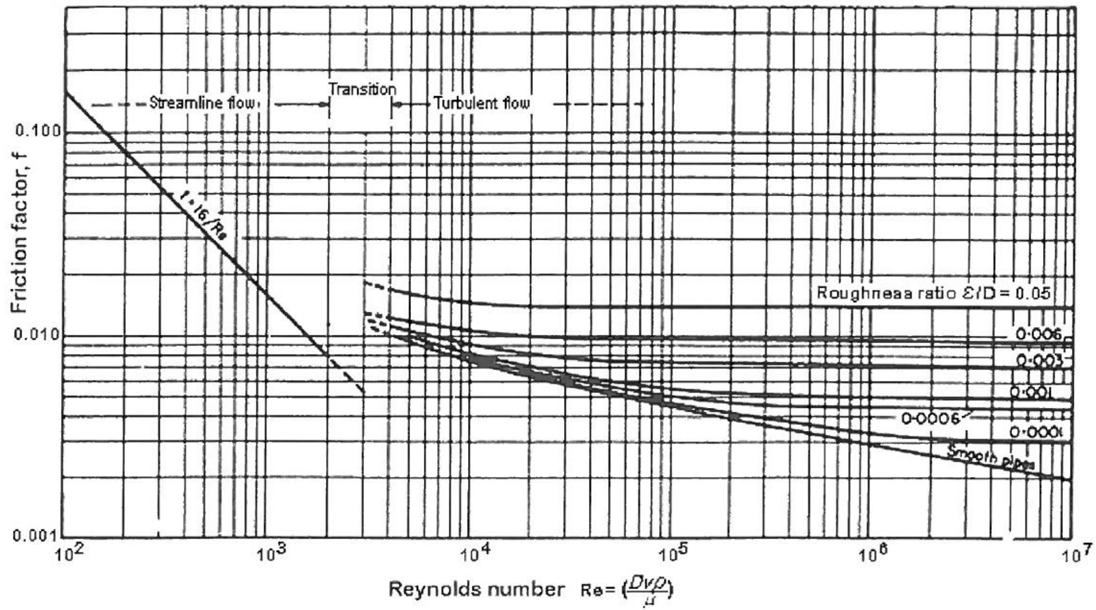
QUESTION 6

The wall of a bakery oven is built of insulating brick 10 cm thick and thermal conductivity 0.22 $J\ m^{-1}\ s^{-1}\ °C^{-1}$. Steel reinforcing members penetrate the brick, and their total area of cross-section represents 1% of the inside wall area of the oven. If the thermal conductivity of the steel is 45 $J\ m^{-1}\ s^{-1}\ °C^{-1}$.
Calculate:

6.1 The relative proportions of the total heat transferred through the wall by the brick and by the steel and **(7)**

6.2 The heat loss for each m^2 of oven wall if the inner side of the wall is at 230°C and the outer side is at 25°C. **(5)**

TOTAL 100

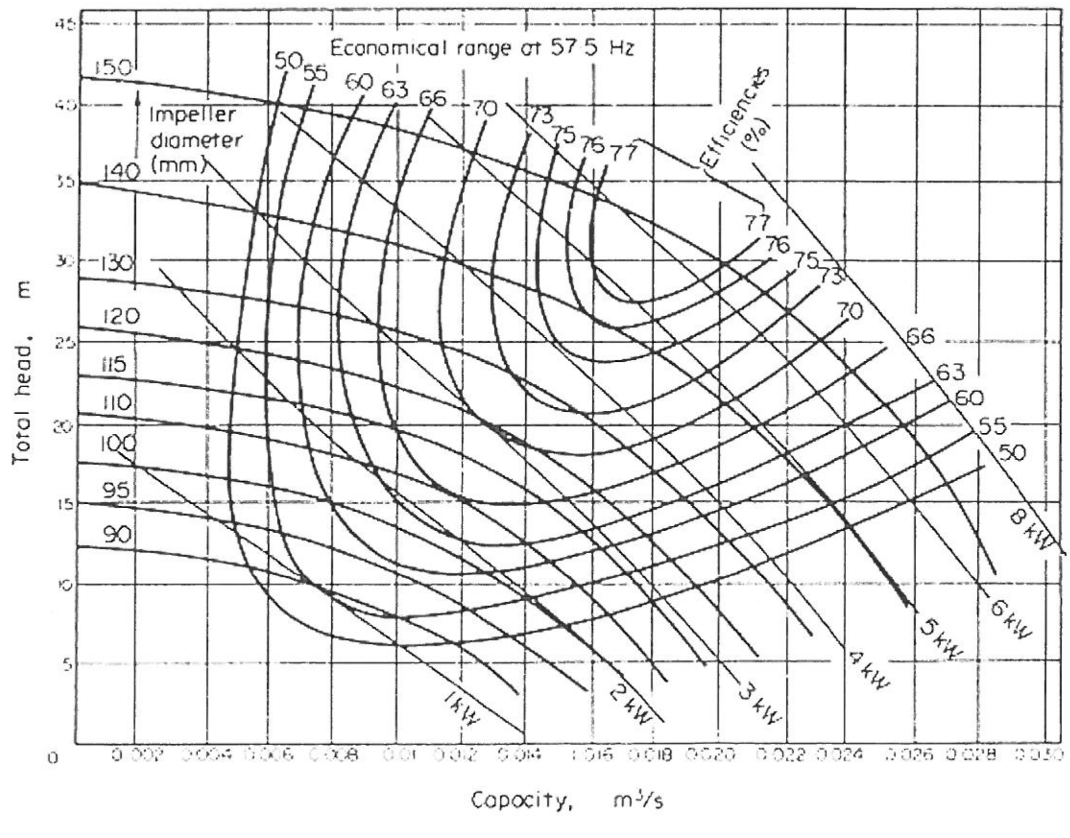


RELATIVE ROUGHNESS FACTORS FOR PIPES

Material	Roughness factor (ε)	Material	Roughness factor (ε)
Riveted steel	0.001- 0.01	Galvanized iron	0.0002
Concrete	0.0003 - 0.003	Asphalted cast iron	0.001
Wood staves	0.0002 - 0.003	Commercial steel	0.00005
Cast iron	0.0003	Drawn tubing	Smooth

FRICTION LOSS FACTORS IN FITTINGS

	k
Valves, fully open:	
gate	0.13
globe	6.0
angle	3.0
Elbows:	
90° standard	0.74
medium sweep	0.5
long radius	0.25
square	1.5
Tee, used as elbow	1.5
Tee, straight through	0.5
Entrance, large tank to pipe:	
sharp	0.5



APPENDIX 1

SYMBOLS, UNITS AND DIMENSIONS

a	acceleration m s^{-2}; [L] $[t]^{-2}$ thickness m; [L]
a_w	water activity; dimensionless
A	area m^2; $[L]^2$
b	height of liquid in a centrifuge m; [L]
(Bi)	Biot number $h_sL/k; h_sD/k$; dimensionless
c	specific heat J kg^{-1} $°C^{-1}$; [F] [L] $[M]^{-1}$ $[T]^{-1}$, c_p specific heat at constant pressure, c_s humid heat
C	heat conductance J m^{-2} s^{-1} $°C^{-1}$; [F] $[L]^{-1}$ $[t]^{-1}$ $[T]^{-1}$ coefficients - discharge, drag, geometric; constant; dimensionless
d	diameter m; [L]
D	diameter m; [L] diffusivity m^2 s^{-1}; $[L]^2$ $[t]^{-1}$
e	small temperature difference °C; [T] roughness factor m; [L]
E	energy J; [F] [L] E_c pump energy, E_f friction energy, E_h heat energy, E_i work index in grinding, E_k kinetic energy, E_p potential energy, E_r pressure energy
f	friction factor; dimensionless
f_c	crushing strength kg m^{-1} s^{-2}; [M] $[L]^{-1}$ $[t]^{-2}$
F	force N, kg m s^{-2}; [F], $[M][L][T]^{-2}$ F_c centrifugal force, F_d drag force, F_c external force, F_f friction force, F_g gravitational force; ratio of liquid to solid in thickener feed; dimensionless time to sterilize at 121°C min; [t]
(Fo)	Fourier number ($kt/c\rho L^2$); dimensionless
(Fr)	Froude number (DN^2/g); dimensionless
$F(D)$	Cumulative particle size distribution, $F'(D)$ particle size distribution; dimensionless
g	acceleration due to gravity m s^{-2}; [L] $[t]^{-2}$
G	mass rate of flow kg m^{-2} s^{-1}; [M] $[L]^{-2}$ $[t]^{-1}$
(Gr)	Grashof number ($D^3\rho^2\beta g\Delta t/\mu^2$); dimensionless
h	heat transfer coefficient J m^{-2} $s^{-1}$$°C^{-1}$; [F] $[L]^{-1}$ $[t]^{-1}[T]^{-1}$ h_c convection, h_h condensing vapours on horizontal surfaces, h_r radiation, h_s surface, h_v condensing vapours on vertical surface
H	enthalpy J; [F] [L] Henry's Law constant atm mole $fraction^{-1}$ kPa mole $fraction^{-1}$; [F] $[L]^{-2}$
k	constant constant of proportionality friction loss factor; dimensionless thermal conductivity J m^{-1} s^{-1} $°C^{-1}$; [F] $[t]^{-1}$ $[T]^{-1}$ mass-transfer coefficient

	k_g gas mass-transfer coefficient, k'_g mass-transfer coefficient based on humidity difference, k_l liquid mass transfer coefficient ; units and dimensions depend on context
K	constant, K', K'', etc.
	mass-transfer coefficient kg m^{-2} h^{-1}; [M] $[L]^{-2}$ $[t]^{-1}$
	K_x crystal interface
K_K	Kick's constant m^3 kg^{-1} ; $[L]^3$ $[M]^{-1}$
K_R	Rittinger's constant m^4 kg^{-1}; $[L]^4$ $[M]^{-1}$
K_s	rate constant for crystal surface reactions m s^{-1}; [L] $[t]^{-1}$
K_d	rate constant for crystal surface reactions m s^{-1}; [L] $[t]^{-1}$
L	flow rate of heavy phase kg h^{-1} ; [M] $[t]^{-1}$
	half thickness of slab for Fourier and Biot numbers m; [L]
	length m; [L]
	ratio of liquid to solid in thickener underflow;
L_c	dimensionless thickness of filter cake m; [L]
(Le)	Lewis number $(h_c/k'_g c_p)$or $(h_c/k_g c_s)$; dimensionless
m	mass kg; [M]
	number, general
(M)	mixing index, dimensionless
M	molecular weight; dimensionless
	molal concentration (kg) moles m^{-3} ; [M] $[L]^{-3}$
n	number, general
N	number of particles in sample;
	rotational frequency, revolutions/minute or s ; $[t]^{-1}$
(Nu)	Nusselt number ($h_c D/k$); dimensionless
p	partial pressure Pa; [F] $[L]^{-2}$
	p_a partial pressure of vapour in air, p_s saturation partial pressure
	ratio in mixing and grinding; dimensionless
P	constant in freezing formula; dimensionless; power N ms^{-1}; [F] [L] $[t]^{-1}$
	pressure Pa; [F] $[L]^{-2}$
P_a	pressure on surface Pa; [F] $[L]^{-2}$
(Po)	Power number ($P/D^5N^3\rho$); dimensionless
(Pr)	Prandtl number ($c_p\mu/k$); dimensionless
q	heat flow rate J s^{-1}; [F] [L] $[t]^{-1}$
	fluid flow rate m^3 s^{-1}; $[L]^3$ $[t]^{-1}$
	factor in particle geometry in grinding and mixing; dimensionless

Q	quantity of heat J; [F] [L]
r	radius m; [L]
	r_n neutral radius in centrifuge
	specific resistance of filter cake kg m^{-1}; r' specific resistance of filter cake under 1 Atm pressure [M] $[L]^{-1}$
R	constant in freezing formulae; dimensionless
	Universal gas constant 8.314 kJ $mole^{-1}$ K^{-1}; $[L]^2 [t]^{-2} [T]^{-1}$; 0.08206 m^3 atm $mole^{-1}$ K^{-1}
(Re)	Reynolds number ($Dv\rho/\mu$.) and ($D^2N\rho/\mu$); dimensionless
s	compressibility of filter cake; dimensionless
	distance m ; [L]
	standard deviation of sample compositions from the mean in mixing; dimensionless
s_o , s_r	initial and random values of s in mixing; dimensionless
(Sc)	Schmidt number ($\mu/\rho D$); dimensionless
(Sh)	Sherwood number ($K'd/D$); dimensionless
SG	specific gravity; dimensionless
t	time s, h, min; [t]
	t_f , freezing time h
T	temperature °C or ***T*** K; [T]
	T_{av} mean temperature, T_a air, T_s surface, T_c centre
	T_m mean temperature in radiation
U	overall heat-transfer coefficient J m^{-2} s^{-1} $°C^{-1}$; [F] $[L]^{-1}$ $[t]^{-1}$ $[T]^{-1}$
v	velocity m s^{-1} ; [L] $[t]^{-1}$
V	flow rate of light phase kg h^{-1}; [M] $[t]^{-1}$
	volume m^3; $[L]^3$
	volumetric flow rate m^3 s^{-1}; $[L]^3$ $[t]^{-1}$
w	solid content per unit volume kg m^{-3}; [M] $[L]^{-3}$
	weight kg; [F]
W	work Nm; [F] [L]
x	concentration in heavy phase kg m^{-3}; [M] $[L]^{-3}$
	distance m; [L]
	fraction, mole or weight, dimensionless
$\bar{x}$	mean
X	moisture content; dimensionless
	X_c critical moisture content, X_f final moisture content, X_o initial moisture content;
	thickness of slab m ; [L]
y	concentration in light phase kg m^{-3}; [M] $[L]^{-3}$

fraction, mole or weight, dimensionless

Y humidity, absolute; humidity difference; dimensionless

z height m; [L]

temperature difference for 10-fold change in thermal death time °C, [T]

Z depth, height of fluid m; [L]

α absorbtivity; dimensionless

β coefficient of thermal expansion m m^{-1} °C^{-1}; $[T]^{-1}$

β_1, β_2 length ratios in freezing formula; dimensionless

δ thickness of layer for diffusion m; [L]

Δ difference

Δt_m logarithmic mean temperature difference °C; [T]

ε emissivity; dimensionless

roughness factor; dimensionless

η efficiency of coupling of freezing medium to frozen foodstuff

λ latent heat J kg^{-1}; [F] $[M]^{-1}$

shape factor for particles; dimensionless

μ viscosity kg s^{-1} m^{-1}; Pa s ; [M] $[t]^{-1}$ $[L]^{-1}$; [F][t]$[L]^{-2}$

π ratio of circumference to diameter of circle , 3.1416

Π total pressure Pa; [M] $[L]^{-1}[t]^{-2}$

osmotic pressure kPa; [F] $[L]^{-2}$

ρ density kg m^{-3}; [M] $[L]^{-3}$

σ Stefan-Boltzman constant, 5,73 x10^{-8} kg $m^{-2}s^{-1}$°C^{-4} ; [M] $[t]^{-3}$ $[T]^{-4}$ or [F] $[L]^{-1}$ $[t]^{-1}$ $[T]^{-4}$

τ shear stress in a fluid Pa; [F] $[L]^{-2}$

ϕ fin efficiency; dimensionless

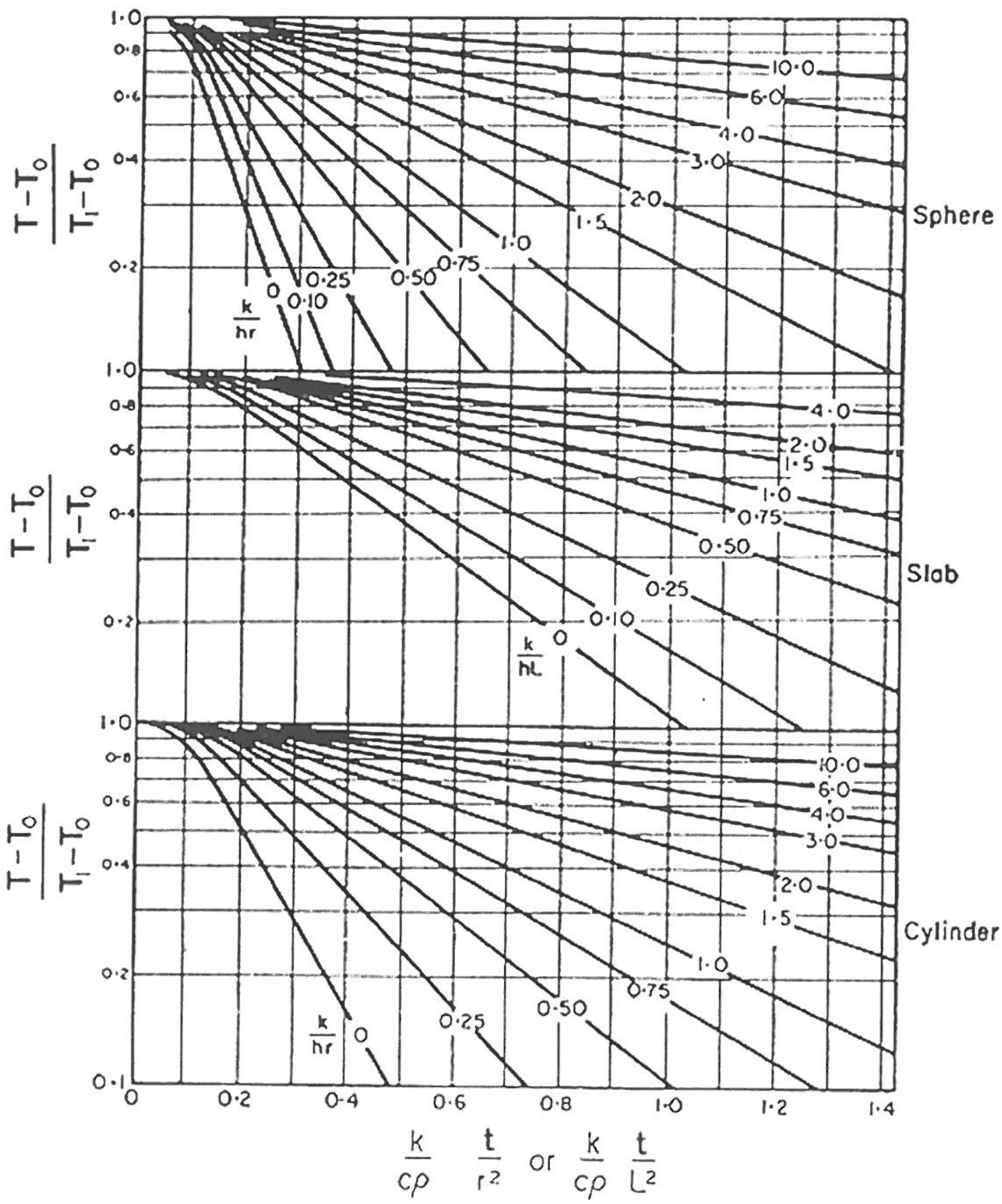
ω angular velocity radians s $^{-1}$, $[t]^{-1}$

APPENDIX 2

UNITS AND CONVERSION FACTORS

Length	1 inch	= 0.0254 m
	1 ft	= 0.3048 m
Area	1 ft^2	= 0.0929m^2
Volume	1 ft^3	= 0.0283 m^3
	1 gal Imp	= 0.004546 m^3
	1 gal US	= 0.003785 $m^{3 = 3.79\ l}$
	1 litre	= 0.001 m^3
Mass	1 lb	= 0.4536 kg
	1 mole	molecular weight in kg
Density	1 lb/ft^3	= 16.01 kg m^{-3}
Velocity	1 ft/sec	= 0.3048 m s^{-1}
Pressure	1 lb/m^2	= 6894 Pa
	1 torr	= 133.3 Pa
	1 atm	= 1.013 x 10^5 Pa
		= 760 mm Hg
Force	1 Newton	= 1 kg m s^{-2}
Viscosity	1 cP	= 0.001 N s m^{-2} = 0.001 Pa s
	1 lb/ft sec	= 1.49 N s m^{-2} = 1.49 kg m-1 s-2
Energy	1 Btu	= 1055 J
	1 cal	= 4.186 J
Power	1 kW	= 1 kJ s^{-1}
	1 horsepower	= 745.7 W = 745.7 J s^{-1}
	1 ton refrigeration	= 3.519 kW
Heat-transfer coefficient	1 Btu ft^{-2} h^{-1} $°F^{-1}$	= 5.678 J m^{-2} s^{-1} °C
Thermal conductivity	1 Btu ft^{-1} h^{-1} $°F^{-1}$	= 1.731 J m^{-1} s^{-1} $°C^{-1}$
Constants	π	3.1416
	σ	5.73 x 10^{-8} J $m^{-2s-1}K^{-4}$
	e	2.7183
	R	8.314 kJ $mole^{-1}$ K^{-1} or 0.08206 $m^{3\ atm}$ $mole^{-1\ K-1}$

(M) Mega = 10^6,
(k) kilo = 10^3,
(m) milli = 10^{-3},
(μ) micro = 10^{-6}
Temperature unit (°F) = 5/9 (°C) = 5/9 (K)



Transient heat conduction

Temperatures at the centre of sphere,slab,and cylinder: adapted from Henderson and Perry, *Agricultural Process Engineering, 1955*