

iemisc: Calculating the Friction Loss Examples

Irucka Embry, E.I.T. (EcoC²S)

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Replicate the R code

Note: If you wish to replicate the R code below, then you will need to copy and paste the following commands in R first (to make sure you have all the packages and their dependencies):

```
install.packages(c("install.load", "iemisc", "data.table", "units", "pander", "pracma"))  
# install the packages and their dependencies
```

```
# load the required packages  
install.load::load_package("iemisc", "data.table", "units", "pander")  
# load needed packages using the load_package function from the install.load  
# package (it is assumed that you have already installed these packages)
```

```
import::from(pracma, newtonRaphson)  
# import newtonRaphson from the pracma package
```

Example 1 Set

```
# Please note that the f2, f3, f4, f5, f6, f7, f8, and the relerror functions
# are found within the iemisc R package created by Irucka Embry

# Example 1 -- Example 17.2 (Lindeburg Manual Reference)

Re <- 4e+05

eps <- 0.004

D <- 1

eps/D

## [1] 0.004
# Answers from the Lindeburg Manual Reference text: 0.028 - Moody diagram
# 0.0287 - Appendix 17.B 'Darcy Friction Factors (turbulent flow)' 0.0288 -
# Swamee-Jain approximation 0.0287 - Colebrook equation

f2 <- f2(eps = eps, D = D, Re = Re)
f2

## [1] 0.02944312
f3 <- f3(eps = eps, D = D, Re = Re)
f3

## [1] 0.0286854
f4 <- f4(eps = eps, D = D, Re = Re)
f4

## [1] 0.02867517
f5 <- f5(eps = eps, D = D, Re = Re)
f5

## [1] 0.02869798
f6 <- f6(eps = eps, D = D, Re = Re)
f6

## [1] 0.02881149
f7 <- f7(eps = eps, D = D, Re = Re)
f7

## [1] 0.02869798
f8 <- f8(eps = eps, D = D, Re = Re)
f8

## [1] 0.02867606
# determine the relative error
acc <- 0.0287

relerror(acc, f2)
```

```
## [1] 2.589255
relerror(acc, f3)

## [1] 0.05086994
relerror(acc, f4)

## [1] 0.08652119
relerror(acc, f5)

## [1] 0.00704152
relerror(acc, f6)

## [1] 0.3884771
relerror(acc, f7)

## [1] 0.007044366
relerror(acc, f8)

## [1] 0.08341057
```

Example 2 Set

```
# Please note that the f2, f3, f4, f5, f6, f7, and the f8 functions are found
# within the iemisc R package created by Irucka Embry

# Example 2 (EngineerExcel Reference)

eps <- 5e-05

D <- 0.0254

Re <- 6000

# f equal to 0.0375 from Microsoft Excel Goal Seek

f2(eps = eps, D = D, Re = Re)

## [1] 0.0379846
f3(eps = eps, D = D, Re = Re)

## [1] 0.03555518
f4(eps = eps, D = D, Re = Re)

## [1] 0.03549632
f5(eps = eps, D = D, Re = Re)

## [1] 0.03781183
```

```
f6(eps = eps, D = D, Re = Re)
## [1] 0.03843287
f7(eps = eps, D = D, Re = Re)
## [1] 0.03549702
f8(eps = eps, D = D, Re = Re)
## [1] 0.03781382
```

Problem 1 Statement

Example 1 [Kudela]

“Oil, with $\rho = 900 \text{ kg/m}^3$ and kinematic coefficient of viscosity $\nu = 0,00001 \text{ m}^2/\text{s}$, flows at $q_v = 0,2 \text{ m}^3/\text{s}$ through 500 m of 200-mm diameter cast-iron pipe. Determine the head loss.”

“Absolute roughness for iron-cast pipe is $\epsilon = 0.26 \text{ mm}$.”

Solution 1

```
# Please note that the Re2, f2, f3, f4, f5, f6, f7, f8, and the colebrook
# functions are found within the iemisc R package created by Irucka Embry

# oil iron-cast pipe find the friction loss -- the head loss is 117 meters

# given the water flow of 0.2 m^3/s create a numeric vector with the units of
# cubic meters per second for the volumetric flow rate
Vdot <- set_units(0.2, m^3/s)
Vdot

## 0.2 [m^3/s]

# given length of 500 m create a numeric vector with the units of meters
L_SI <- set_units(500, m)
L_SI

## 500 [m]

g_SI <- set_units(9.80665, m/s^2)
g_SI

## 9.80665 [m/s^2]
```

```

# given saturated liquid density of oil (SI units)
rho_SI <- set_units(900, kg/m^3)
rho_SI

## 900 [kg/m^3]

# given kinematic viscosity of oil (SI units)
nu_SI <- set_units(1e-05, m^2/s)
nu_SI

## 1e-05 [m^2/s]

# create a numeric vector with the units of millimeters for the given specific
# roughness
epsilon <- set_units(0.26, mm)
epsilon

## 0.26 [mm]

# create a numeric vector with the units of meters for the given specific
# roughness
epsilon <- epsilon

units(epsilon) <- make_units(m)
epsilon

## 0.00026 [m]

# create a numeric vector with the units of millimeters for the given internal
# pipe diameter
Di <- set_units(200, mm)
Di

## 200 [mm]

# create a numeric vector with the units of meters for the given internal pipe
# diameter
units(Di) <- make_units(m)
Di

## 0.2 [m]

# relative roughness (dimensionless) of the cast iron pipe
rel_roughness <- epsilon/Di
rel_roughness

## 0.0013 [1]

# internal area of the cast iron pipe
Ai <- Di^2 * pi/4
Ai

## 0.03141593 [m^2]

# average velocity of the flowing water
V <- Vdot/Ai
V

## 6.366198 [m/s]

```

```

# Reynolds number using the kinematic viscosity
Re_SI <- Re2(D = drop_units(Di), V = drop_units(V), nu = drop_units(nu_SI))
Re_SI

## [1] 127324

# Darcy friction factor (f) for cast iron pipe Moody equation
fr2_SI <- f2(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI)

# Romeo, et. al. equation
fr3_SI <- f3(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI)

# Žarko Čojbašića and Dejan Brkić equation
fr4_SI <- f4(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI)

# Colebrook-White equation
fr5_SI <- f5(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI)

# Colebrook-White equation from Didier Clamond
colebrook_SI <- colebrook(Re_SI, K = drop_units(rel_roughness))

# Swamee-Jaine equation
fr6_SI <- f6(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI)

# Zigrang-Sylvester equation
fr7_SI <- f7(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI)

# Vatankhah equation
fr8_SI <- f8(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI)

# friction loss for cast iron pipe
hf_SI1 <- (f2(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI) * drop_units(L_SI) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_SI))

hf_SI2 <- (f3(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI) * drop_units(L_SI) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_SI))

hf_SI3 <- (f4(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI) * drop_units(L_SI) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_SI))

hf_SI4 <- (f5(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI) * drop_units(L_SI) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_SI))

hf_SI5 <- (colebrook(Re_SI, K = drop_units(rel_roughness)) * drop_units(L_SI) * drop_units(V)^2)/(2 *
  drop_units(Di) * drop_units(g_SI))

hf_SI6 <- (f6(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI) * drop_units(L_SI) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_SI))

hf_SI7 <- (f7(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI) * drop_units(L_SI) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_SI))

hf_SI8 <- (f8(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_SI) * drop_units(L_SI) *

```

```

drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_SI))

# result table
result_table_SI <- data.table(V1 = c("Moody equation", "Romeo, et. al. equation",
  "Žarko Čojbašića and Dejan Brkić equation", "Colebrook-White equation",
  "Colebrook-White equation from Didier Clamond", "Swamee-Jaine equation", "Zigrang-Sylvester equation",
  "Vatankhah equation"), V2 = c(fr2_SI, fr3_SI, fr4_SI, fr5_SI, colebrook_SI, fr6_SI,
  fr7_SI, fr8_SI), V3 = c(hf_SI1, hf_SI2, hf_SI3, hf_SI4, hf_SI5, hf_SI6, hf_SI7,
  hf_SI8))

setnames(result_table_SI, c("Darcy friction factor equation", "Darcy friction factor (f) for cast iron pipe",
  "Friction loss for cast iron pipe over total length"))

pander(result_table_SI)

```

Darcy friction factor equation	Darcy friction factor (f) for cast iron pipe
Moody equation	0.02329
Romeo, et. al. equation	0.01745
Žarko Čojbašića and Dejan Brkić equation	0.01743
Colebrook-White equation	0.02272
Colebrook-White equation from Didier Clamond	0.01711
Swamee-Jaine equation	0.02291
Zigrang-Sylvester equation	0.01742
Vatankhah equation	0.02271

Friction loss for cast iron pipe over total length
120.3
90.14
90.05
117.4
88.41
118.4
89.98
117.3

Henryk Kudela calculated 117 meters for the head loss.

Problem 2 Statement

Example 1 [Subramanian]

Find the head loss due to the flow of 1,500 gpm of oil ($\nu = 1.15 \times 10^{-4} \text{ ft}^2/\text{s}$) through 1,600 feet of 8" diameter cast iron pipe. The density of the oil $\rho = 1.75 \text{ slug/ft}^3$.

"For cast iron, $\epsilon = 8.5 \times 10^{-4} \text{ ft}$."

Solution 2

```
# Please note that the Re2, f2, f3, f4, f5, f6, f7, f8, and the colebrook
# functions are found within the iemisc R package created by Irucka Embry

# oil cast iron pipe find the head loss -- the head loss is 83.7 feet

# given the water flow of 1500 gpm (gal / min) create a numeric vector with the
# units of gallons per minute for the volumetric flow rate
Vdot <- set_units(1500, gallon/min)
Vdot

## 1500 [gallon/min]

# create a numeric vector with the units of cubic feet per second for the
# volumetric flow rate
units(Vdot) <- make_units(ft^3/sec)
Vdot

## 3.342014 [ft^3/s]

# given length of 1600 ft create a numeric vector with the units of feet
L_Eng <- set_units(1600, ft)
L_Eng

## 1600 [ft]

# create a numeric vector for gravity (US Customary units)
g_Eng <- set_units(9.80665 * (3937/1200), ft/sec^2)
g_Eng

## 32.17398 [ft/s^2]

# given saturated liquid density of oil (US Customary units)
rho_Eng <- set_units(1.75, slug/ft^3)
rho_Eng

## 1.75 [slug/ft^3]

# given kinematic viscosity of oil (US Customary units)
nu_Eng <- set_units(0.000115, ft^2/sec)
nu_Eng

## 0.000115 [ft^2/s]

# create a numeric vector with the units of feet for the given specific
# roughness
epsilon <- set_units(0.00085, ft)
epsilon
```



```

## 0.00085 [ft]
# create a numeric vector with the units of inch for the given internal pipe
# diameter
Di <- set_units(8, inch)
Di

## 8 [inch]
# create a numeric vector with the units of feet for the given internal pipe
# diameter
units(Di) <- make_units(ft)
Di

## 0.6666667 [ft]
# relative roughness (dimensionless) of the cast iron pipe
rel_roughness <- epsilon/Di
rel_roughness

## 0.001275 [1]
# internal area of the cast iron pipe
Ai <- Di^2 * pi/4
Ai

## 0.3490659 [ft^2]
# average velocity of the flowing water
V <- Vdot/Ai
V

## 9.574165 [ft/s]
# Reynolds number using the kinematic viscosity
Re_Eng <- Re2(D = drop_units(Di), V = drop_units(V), nu = drop_units(nu_Eng))
Re_Eng

## [1] 55502.41
# Darcy friction factor (f) for cast iron pipe Moody equation
fr2_Eng <- f2(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng)

# Romeo, et. al. equation
fr3_Eng <- f3(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng)

# Žarko Čojbašića and Dejan Brkić equation
fr4_Eng <- f4(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng)

# Colebrook-White equation
fr5_Eng <- f5(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng)

# Colebrook-White equation from Didier Clamond
colebrook_Eng <- colebrook(Re_Eng, K = drop_units(rel_roughness))

# Swamee-Jaine equation
fr6_Eng <- f6(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng)

# Zigrang-Sylvester equation
fr7_Eng <- f7(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng)

```

```

# Vatankhah equation
fr8_Eng <- f8(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng)

# friction loss for cast iron pipe
hf_Eng1 <- (f2(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

hf_Eng2 <- (f3(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

hf_Eng3 <- (f4(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

hf_Eng4 <- (f5(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

hf_Eng5 <- (colebrook(Re_Eng, K = drop_units(rel_roughness)) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

hf_Eng6 <- (f6(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

hf_Eng7 <- (f7(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

hf_Eng8 <- (f8(eps = drop_units(epsilon), D = drop_units(Di), Re = Re_Eng) * drop_units(L_Eng) *
  drop_units(V)^2)/(2 * drop_units(Di) * drop_units(g_Eng))

# result table
result_table_Eng <- data.table(V1 = c("Moody equation", "Romeo, et. al. equation",
  "Žarko Čojbašića and Dejan Brkić equation", "Colebrook-White equation",
  "Colebrook-White equation from Didier Clamond", "Swamee-Jaine equation", "Zigrang-Sylvester equation",
  "Vatankhah equation"), V2 = c(fr2_Eng, fr3_Eng, fr4_Eng, fr5_Eng, colebrook_Eng,
  fr6_Eng, fr7_Eng, fr8_Eng), V3 = c(hf_Eng1, hf_Eng2, hf_Eng3, hf_Eng4, hf_Eng5,
  hf_Eng6, hf_Eng7, hf_Eng8))

setnames(result_table_Eng, c("Darcy friction factor equation", "Darcy friction factor (f) for cast iron pipe",
  "Friction loss for cast iron pipe over total length"))

pander(result_table_Eng)

```

Darcy friction factor equation	Darcy friction factor (f) for cast iron pipe
Moody equation	0.02485
Romeo, et. al. equation	0.0224
Žarko Čojbašića and Dejan Brkić equation	0.02238
Colebrook-White equation	0.02444
Colebrook-White equation from Didier Clamond	0.02041
Swamee-Jaine equation	0.02464
Zigrang-Sylvester equation	0.02238

Darcy friction factor equation	Darcy friction factor (f) for cast iron pipe
Vatankhah equation	0.02444

Friction loss for cast iron pipe over total length
84.94
76.59
76.52
83.57
69.79
84.25
76.52
83.54

R. Shankar Subramanian calculated 83.7 feet for the head loss.

Works Cited

Charlie Young, P.E., EngineerExcel, “Colebrook Equation Solver in Excel”, <https://www.engineerexcel.com/colebrook-equation-solver-in-excel/>

Henryk Kudela, “Hydraulic losses in pipes”, page 5, Wrocław University of Science and Technology Department of Mechanical and Power Engineering, http://fluid.itcmp.pwr.wroc.pl/~znmp/dydaktyka/fundam_FM/Lecture11_12.pdf

Michael R. Lindeburg, PE, *Civil Engineering Reference Manual for the PE Exam*, Twelfth Edition, Belmont, California: Professional Publications, Inc., 2011, pages 17-5 - 17-7.

R. Shankar Subramanian, “Pipe Flow Calculations”, pages 6-7, Clarkson University Department of Chemical and Biomolecular Engineering, <https://web2.clarkson.edu/projects/subramanian/ch330/notes/Pipe%20Flow%20Calculations.pdf>

The NIST Reference on Constants, Units, and Uncertainty, Fundamental Constants Data Center of the NIST Physical Measurement Laboratory, “standard acceleration of gravity g_n ”, <https://physics.nist.gov/cgi-bin/cuu/Value?gn>.

Wikimedia Foundation, Inc. Wikipedia, 15 May 2019, “Conversion of units”, https://en.wikipedia.org/wiki/Conversion_of_units.

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