CH365 Chemical Engineering Thermodynamics

Lesson 3
Review

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Lesson 3 Problems

Problem 1.20

Verify that the SI unit of kinetic and potential energy is the joule.

Problem 1.22

The turbines in a hydroelectric plant are fed by water falling from a 50-m height. Assuming 91% efficiency for conversion of potential to electrical energy, and 8% loss of the resulting power in transmission, what is the mass flow rate of water required to power a 200-watt light bulb?

Problem 1.27

Energy costs vary greatly with energy source: coal @ \$35.00/ton, gasoline @ a pump price of \$2.75/gallon, and electricity @ \$0.1000/kWhr. Conventional practice is to put these on a common basis by expressing them in \$/GJ. For this purpose, assume gross heating values of 29 MJ/kg for coal and 37 GJ/m^3 for gasoline.

(a) Rank order the three energy sources with respect to energy cost in \$/GJ.

(b) Explain the large disparity in the numerical results of Part 9a). Discuss the advantages and disadvantages of the three energy sources.

Problem 1.29

A laboratory reports the following vapor-pressure (P^{sat}) data for a particular organic chemical:

t/ °C	P^{sat} / kPa
-18.5	3.18
-9.5	5.48
0.2	9.45
11.8	16.9
23.1	28.2
32.7	41.9
44.4	66.6
52.1	89.5
63.3	129
75.5	187

Correlate the data by fitting them to the Antoine equation:

$$\ln P^{sat} / \mathrm{kPa} = A - \frac{B}{T/\mathrm{K} + C}$$

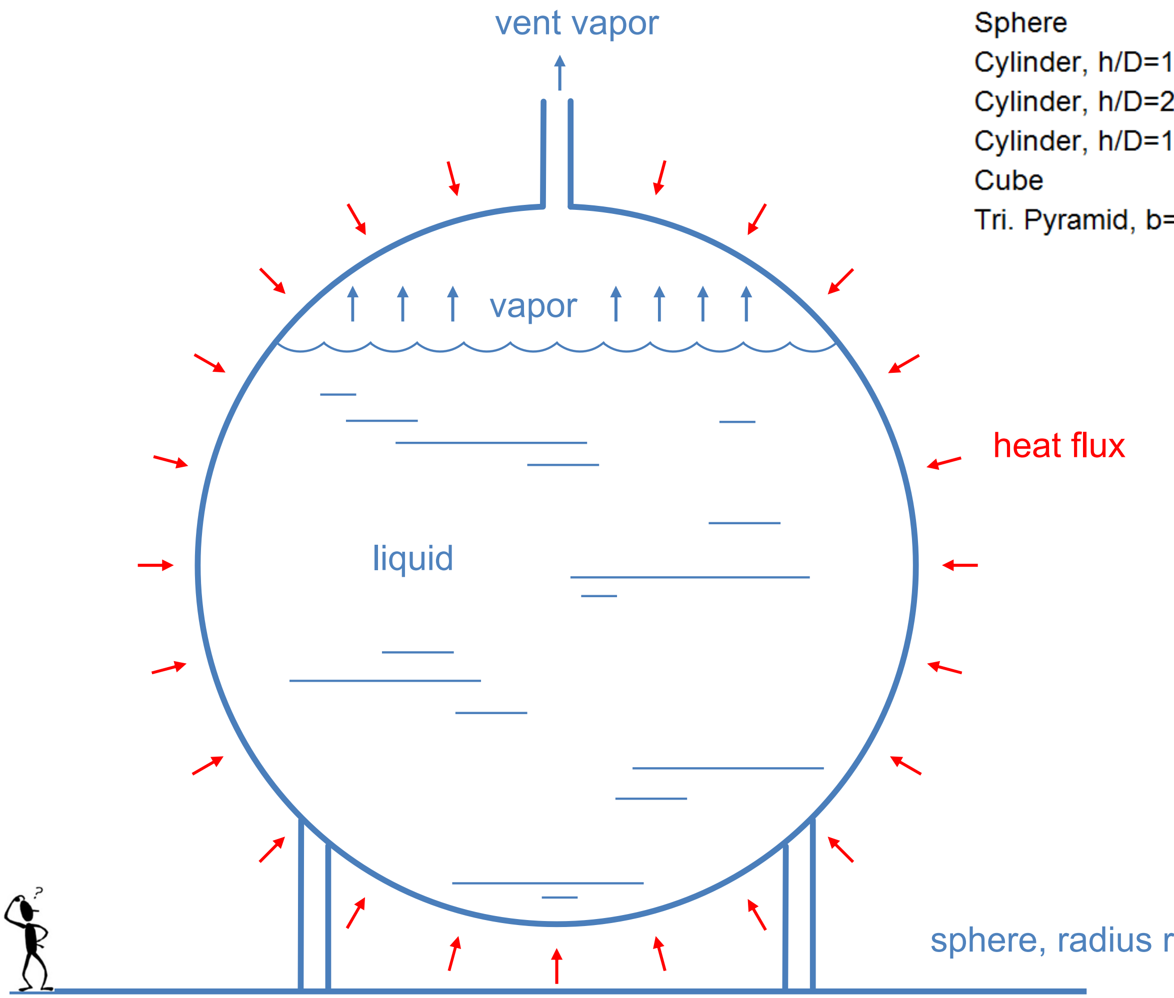
That is, find numerical values of parameters A, B, and C by an appropriate regression procedure. Discuss the comparison of correlated and experimental values. What is the predicted normal boiling point of this chemical (i.e., the temperature at which the vapor pressure is 1 atm).

Lesson 2 Problems

Problem 1.9

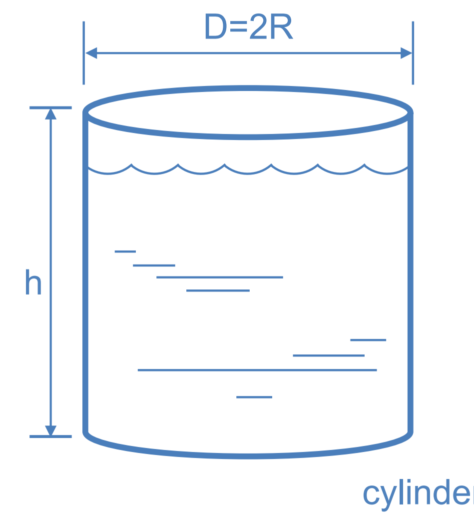
Liquids that boil at relatively low temperatures are often stored as liquids under their vapor pressures, which at ambient temperature can be quite large. Thus, n-butane stored as a liquid/vapor system is at a pressure of 2.581 bar for a temperature of 300 K. Large-scale storage (>50m^3) of this kind is sometimes done in spherical tanks. Suggest two reasons why.

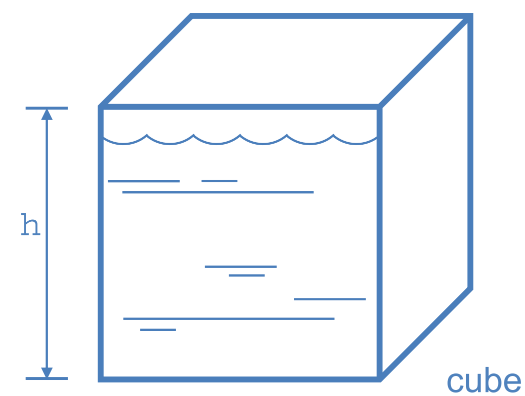
Illustration for Problem 1.9 for Spherical, Cylindrical, and Cubical Tank



Results (m^2 per 50 m^3):

Sphere	65.6348
Cylinder, h/D=1	75.1346
Cylinder, h/D=2	78.8840
Cylinder, h/D=1/2	79.5104
Cube	81.4325
Tri. Pyramid, b=h	89.6128





Heat flux is proportional to temperature difference,
Rate of heat transfer, CH485, RRW, Table 1.5 p.16

$$\frac{Q}{a} = U\left(T_{outside} - T_{inside}\right) \Rightarrow Q = Ua\left(T_{outside} - T_{inside}\right)$$

$$flux = \frac{Q}{a} = \frac{flow}{area} = \frac{J/s}{m^2}$$

If each vessel has a max capacity of 50 m^3 of ;liquid, what is the area of each vessel?

$$50m^3 = \frac{4}{3}\pi r^3 = 2\pi R^3 = l^3$$
$$(h = D)$$

Once r, R, and l are known, area for each shape can be calculated.

Problem 1.10

The first accurate measurements of the properties of high-pressure gases were made by E.H. Amagat in France between 1869 and 1893. Before developing the dead-weight gauge, he worked in a mine shaft, and used a mercury manometer for measurements of pressure to more than 400 bar. Estimate the height of the manometer required.

Émile Hilaire Amagat (2 January 1841 – 15 February 1915) was a French physicist, famous for his work on isotherms and pressure measurement. Amagat's Law, named in his honor, states that the volume of an ideal gas mixture is equal to the sum of the component volumes of each individual component in the gas mixture at the same temperature and total pressure of the mixture

Problem 1.15

A gas is confined in a 1.25-ft-diameter cylinder by a piston, on which rests a weight. The mass of the piston and weight together is 250lb_m. The local acceleration of gravity is 32.169 (ft/s^2),and the atmospheric pressure is 30.12 inches of Hg.

(a) What is the force in lb_f exerted on the gas by the atmosphere, the piston, and the weight, assuming no friction between the piston and the cylinder?

(b) What is the pressure of the gas in psia?

(c) If the gas in the cylinder is heated, it expands, pushing the piston and weight upward. If the piston and weight are raised 1.7 ft, what is the work done by the gas in ft*lb_f? What is the change in potential energy of the piston and the weight?

Lesson 1 Problems

Problem 1.1

What is the value of g_c and what are its units in a [unit] system in which the second, the foot, and the pound-mass are defined as in Section 1.2, and the unit of force is the poundal, defined as the force required to give 1 lb_m an acceleration of 1 ft/s^2? (See section 1.4)

The poundal is the unit of force in the foot-pound-second (FPS) system of units. The symbol for the poundal is pdl.

In SI units, this problem can be re-worded as follows, as in Slide 18: What is the value of g_c and what are its units in a [unit] system in which the second, the meter, and the kilogram are defined as in Section 1.2, and the unit of force is the Newton, defined as the force required to give 1 kg an acceleration of 1 m/s^2? (See Section 1.4)

Problem 1.4

At what absolute temperature do the Celsius and Fahrenheit temperature scales give the same numerical value?

Problem 1.5

Pressures up to 3,000 bar are measured with a dead-weight gauge. The piston diameter is 4 mm. What is the approximate mass in kg of the weights required?

Problem 1.8

The reading on a mercury manometer at 70 °F (open to the atmosphere at one end) is 25.62 inches. Atmospheric pressure is 29.86 inches of mercury (of mercury). What is the absolute pressure in psia being measured? The density of mercury at 70 °F is 13.543 gm/cm^3 and the local acceleration of gravity is 32.243 ft/s^2.