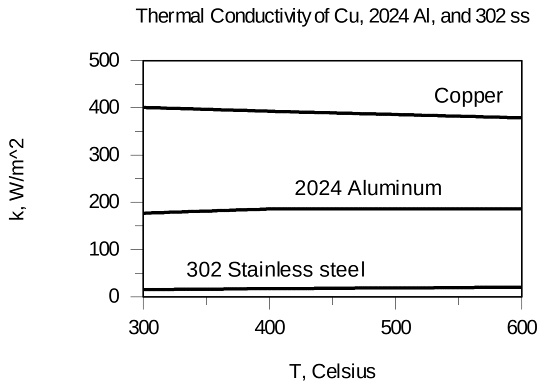
PROBLEM 2.21

KNOWN: Temperatures of various materials.

FIND: (a) Graph of thermal conductivity, k, versus temperature, T, for pure copper, 2024 aluminum and AISI 302 stainless steel for $300 \le T \le 600$ K, (b) Graph of thermal conductivity, k, for helium and air over the range $300 \le T \le 800$ K, (c) Graph of kinematic viscosity, ν, for engine oil, ethylene glycol, and liquid water for $300 \le T \le 360$ K, (d) Graph of thermal conductivity, k, versus volume fraction, φ, of a water-Al_2O_3 nanofluid for $0 \le \varphi \le 0.08$ and $T = 300$ K. Comment on the trends for each case.

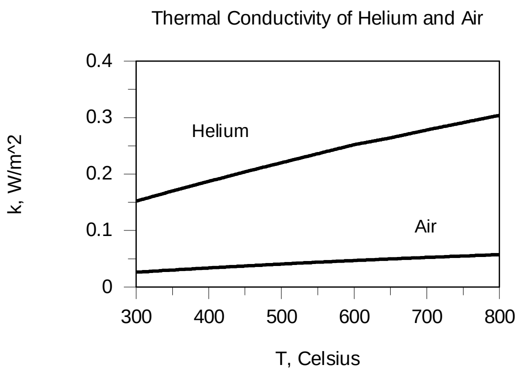
ASSUMPTION: (1) Constant nanoparticle properties.

ANALYSIS: (a) Using the *IHT* workspace of Comment 1 yields



Note the large difference between the thermal conductivities of these metals. Copper conducts thermal energy effectively, while stainless steels are relatively poor thermal conductors. Also note that, depending on the metal, the thermal conductivity increases (2024 Aluminum and 302 Stainless Steel) or decreases (Copper) with temperature.

(b) Using the *IHT* workspace of Comment 2 yields



Note the high thermal conductivity of helium relative to that of air. As such, He is sometimes used as a coolant. The thermal conductivity of both gases increases with temperature, as expected from inspection of Figure 2.8.

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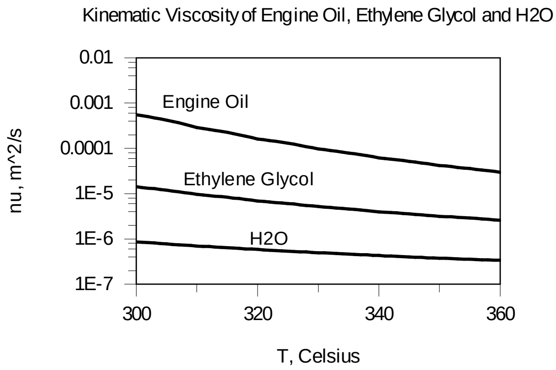
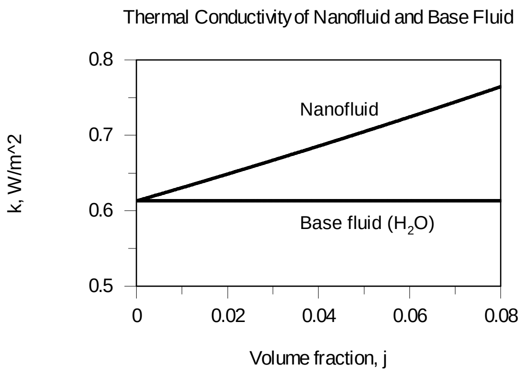
PROBLEM 2.21 (Cont.)

(c) Using the *IHT* workspace of Comment 3 yields



The kinematic viscosities vary by three orders of magnitude between the various liquids. For each case the kinematic viscosity decreases with temperature.

(d) Using the *IHT* workspace of Comment 4 yields



Note the increase in the thermal conductivity of the nanofluid with addition of more nanoparticles. The solid phase usually has a higher thermal conductivity than the liquid phase, as noted in Figures 2.5 and 2.9, respectively.

COMMENTS: (1) The *IHT* workspace for part (a) is as follows.

```
// Copper (pure) property functions : From Table A.1
// Units: T(K)
kCu = k_T("Copper",T)                          // Thermal conductivity,W/m·K

// Aluminum 2024 property functions : From Table A.1
// Units: T(K)
kAl = k_T("Aluminum 2024",T)                   // Thermal conductivity,W/m·K

// Stainless steel-AISI 302 property functions : From Table A.1
// Units: T(K)
kss = k_T("Stainless Steel-AISI 302",T)        // Thermal conductivity,W/m·K

T = 300                                        // Temperature, K
```

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(2) The *IHT* workspace for part (b) follows.

```
// Helium property functions : From Table A.4
// Units: T(K)
kHe = k_T("Helium",T)                        // Thermal conductivity, W/m·K

// Air property functions : From Table A.4
// Units: T(K); 1 atm pressure
kAir = k_T("Air",T)                          // Thermal conductivity, W/m·K

T = 300                                      // Temperature, K
```

(3) The *IHT* workspace for part (c) follows.

```
// Engine Oil property functions : From Table A.5
// Units: T(K)
nuOil = nu_T("Engine Oil",T)                 // Kinematic viscosity, m^2/s

// Ethylene glycol property functions : From Table A.5
// Units: T(K)
nuEG = nu_T("Ethylene Glycol",T)             // Kinematic viscosity, m^2/s

// Water property functions :T dependence, From Table A.6
// Units: T(K), p(bars);
xH2O =0                                      // Quality (0=sat liquid or 1=sat vapor)
nuH2O = nu_Tx("Water",T,xH2O)                // Kinematic viscosity, m^2/s

T = 300                                      // Temperature, K
```

(4) The *IHT* workspace for part (d) follows.

```
// Water property functions :T dependence, From Table A.6
// Units: T(K), p(bars);
xH2O =0                                      // Quality (0=sat liquid or 1=sat vapor)
kH2O = k_Tx("Water",T,xH2O)                  // Thermal conductivity, W/m·K
kbf = kH2O
T = 300

j = 0.01                                     // Volume fraction of nanoparticles

//Particle Properties

kp = 36                                      // Thermal conductivity, W/mK

knf = (num/den)*kbf
num = kp + 2*kbf-2*j*(kbf - kp)
den = kp + 2*kbf + j*(kbf - kp)
```