Course Supplement for the NCEES PE Mechanical Handbook

PE Mechanical Review Courses

Introduction

PPI is offering this document of tips and clarifications regarding the *NCEES PE Mechanical Handbook* to examinees to support their studies. This document is based on the expertise of the subject matter experts that PPI works with, and has not been verified by NCEES. NCEES does not publish *Handbook* errata.

This document applies to version 1.2 of the *NCEES PE Mechanical Handbook*.

There are also equations included in this document that PPI believes are important to know for the exam, even though they are not present in the *Handbook*. This document also notes instances where PPI's usage of variables differs from NCEES.

Summary of Contents

- **Clarifications**
  - additional information for a *Handbook* equation
  - indicated in slides by section or table title and page number in the *Handbook*
  - in the order of appearance in the *Handbook*
- **Tips**
  - helpful information for application of a *Handbook* equation
  - indicated in slides by section or table title and page number in the *Handbook*
  - in the order of appearance in the *Handbook*
- **Typos**
  - indicated in slides by section or table title and page number in the *Handbook*
  - in the order of appearance in the *Handbook*

Typo: Properties of Air at Low Pressure, per Pound

Page 23

- In *NCEES Handbook* table **Properties of Air at Low Pressure, per Pound**, the eighth column heading, viscosity, has a typographical error.
- Values should be multiplied by 10^{-7}, not 10^{7}.
- Units of viscosity should be lbm/sec-ft^2, not lbm/sec-ft.

Typo: Properties of Various Solids

Page 43

- In *NCEES Handbook* table **Properties of Various Solids**, the three formulas for the radius of gyration contain a misprint.
    - the digit '1' is used instead of lowercase *l*, the variable for length
- In the PE mechanical products, PPI uses uppercase *L* for length.

- revised equations (in PPI style):

$$K_{AA} = \frac{L}{\sqrt{12}}$$

$$K_{BB} = \frac{L}{\sqrt{3}}$$

$$K_{CC} = L\sqrt{\frac{\sin\alpha}{3}}$$

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Typo: Kirchoff's Voltage Law for Closed Path (Loop)

Page 82

- *NCEES Handbook* section **Kirchoff's Voltage Law for Closed Path (Loop)** contains a misspelling.
- Kirchhoff should have two h's: "Kirchhoff's Voltage Law for Closed Path (Loop)".
- The spelling in the *Handbook* will remain so for citations referring to this Handbook section.
- It will be spelled correctly everywhere else.

Typo: Dispersion, Mean, Median, and Mode Values

Page 103

- The equation for the population standard deviation in *NCEES Handbook* section **Dispersion, Mean, Median, and Mode Values** contains a misprint.
- The square root symbol should extend over all the remaining terms on the right-hand side of the equation.

- *Handbook* equation

$$\sigma_{\text{population}} = \sqrt{\left(\frac{1}{N}\right)}\sum\left(X_i - \mu\right)^2$$

- revised equation

$$\sigma_{\text{population}} = \sqrt{\left(\frac{1}{N}\right)\sum\left(X_i - \mu\right)^2}$$

Clarification: Elements of Kinetic Energy

Page 119

- In the equation for changing velocity in *NCEES Handbook* table **Elements of Kinetic Energy**, the two velocities are represented by V_1 and v_2.
- The same variable should be used for both; in PPI style, this is v.

- *Handbook* equation:

$$KE_2 - KE_1 = \frac{m\left(v_2^2 - V_1^2\right)}{2}$$

- equation (in PPI style):

$$\mathrm{KE}_2 - \mathrm{KE}_1 = \frac{m\left(\mathrm{v}_2^2 - \mathrm{v}_1^2\right)}{2}$$

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Typo: True Strain

Page 135

- In the equation in *NCEES Handbook* section **True Strain**, the term for areas is garbled.

- *Handbook* equation:

$$\varepsilon_{\mathrm{T}} = \ln \frac{L}{L_o} = \ln \frac{A}{A_o} \varepsilon = \ln(1+\varepsilon)$$

- revised equation (in PPI style):

$$\epsilon_T = \ln \frac{L}{L_o} = \ln \frac{A_o}{A} \epsilon = \ln(1+\epsilon)$$

Typo: Uniaxial Loading and Deformation

Page 136

- In *NCEES Handbook* section **Uniaxial Loading and Deformation**, the equation for the modulus contains a typographical error.
- σ (Greek sigma) in the final expression should be *P*.
- This can be verified by looking at the two equations earlier in the same section.

- *Handbook* equation:

$$E = \frac{\sigma}{\varepsilon} = \frac{\frac{\sigma}{A_o}}{\frac{\delta}{L}}$$

- revised equation (in PPI style):

$$E = \frac{\sigma}{\epsilon} = \frac{\frac{P}{A_o}}{\frac{\delta}{L}}$$

Clarification: Thermal Deformations

Page 136

- In *NCEES Handbook* section **Thermal Deformations**, α is defined as the "temperature coefficient of expansion."
- This term is common among engineers, but not entirely accurate.
- It is more accurate to define α in this context as the "coefficient of thermal expansion" or "thermal expansion coefficient".

Clarification: Vibration Transmissibility, Base Motion

Page 157

- In *NCEES Handbook* section **Vibration Transmissibility, Base Motion**, the equation for vibration transmissibility is the transmitted force when the base is excited and the force is transmitted to the mass.
- In MERM, the equation for vibration transmissibility is the transmitted force when the mass is excited and the force is transmitted to the base.
- Both equations are correct.

- *Handbook* equation:

$$\frac{F_{\mathrm{T}}}{F_o} = r^2 \left[\frac{1 + (2\zeta r)^2}{(1 - r^2)^2 + (2\zeta r)^2} \right]^{\frac{1}{2}}$$

- MERM equation (in PPI style):

$$\frac{F_t}{F_{\mathrm{st}}} = \frac{\sqrt{1 + (2\zeta r)^2}}{\sqrt{(1 - r^2)^2 + (2\zeta r)^2}}$$

Clarification: Mechanical Springs

Page 162

- In *NCEES Handbook* section **Mechanical Springs**, the shear stress correction factor is given as K_s.
- There are two versions of the shear stress correction factor.
    - Bergstrasser correction factor, K_s
    - Wahl correction factor, K_w
- K_s is nearly equal to K_w.
- The formula for K_s is more compact than the formula for K_w.
- K_s is used as the correction factor for NCEES exam purposes.

Clarification: Power Screws

Page 166

- The equations in *NCEES Handbook* section **Power Screws** only hold for square-threaded screws.
- Equations from other sources might have additional terms or corrections to account for the thread angle being something other than zero.
- Sometimes the collar friction can be a separate equation rather than wrapped into a single equation as it appears in the *Handbook*.
- Collar friction term is indicated in red in the *Handbook* equation to the right.

$$T_R = \left(\frac{FD_m}{2}\right)\left(\frac{L + \pi\mu D_m}{\pi D_m - \mu L}\right) + \frac{F\mu_c D_c}{2}$$

Typo: Torque Requirements

Page 193

- In *NCEES Handbook* section **Torque Requirements**, there is a typo in the units for the torque equation.
- The correct unit for torque is in-lbf, not ft-lb.
- *Handbook* equation:

$$T = KF_i d = \text{torque, in ft-lb}$$

- revised equation:

$$T = KF_i d = \text{torque, in in-lbf}$$

Typo: Basic Dimensions for Coarse Thread Series (UNC/UNRC)

Page 199

- In *NCEES Handbook* table **Basic Dimensions for Coarse Thread Series (UNC/UNRC)**, the units for tensile stress area (in the rightmost column) are given as inches (in).
- The units for tensile stress area should be in^2.

Typo: Cylindrical Pressure Vessel

Page 205

- In *NCEES Handbook* section **Cylindrical Pressure Vessel**, the wrong equation is given for axial stress in a thick-walled vessel.
- *Handbook* equation:

$$\sigma_a = P_i \frac{r_i^2}{r_o^2 - r_i^2}$$

- revised equation:

$$\sigma_a = \frac{p_i r_i^2 - p_o r_o^2}{r_o^2 - r_i^2}$$

- Also, the *Handbook* in this section defines a thin-walled vessel as one in which the wall thickness is greater than 10% of the diameter ($D/t > 10$), but doesn't say whether this is the inner diameter or the outer diameter.
- The definition for a thin-walled vessel should refer to the inner diameter ($D_{inner}/t > 10$).

Tip: Bernouilli Equation

Page 209

- When using the **Bernoulli Equation** in the *Handbook*, the kinetic energy can sometimes be neglected for fluids.
- While a calculation that neglects the kinetic energy will not be as accurate, the approximation is usually close enough for the purposes of solving the problem.
- This tip may save you time on the exam.
- This tip only works for calculations involving fluids, not gases.
- See the equation for total dynamic head (TDH) in the Additional Equations section of this slide deck for an abbreviated form of the Bernoulli equation.

Clarification: Special Cases of Closed Systems (With No Change in Kinetic or Potential Energy)

Page 259

- In three of the five equations given for work per unit mass in *NCEES Handbook* section **Special Cases of Closed Systems (With No Change in Kinetic or Potential Energy)**, the variable w is given the subscript b; in the other two equations, the variable w has no subscript.
- Though the Handbook doesn't say so anywhere, the subscript b stands for *boundary*, as in boundary work during expansion or compression.
- The subscript is not needed since under the given conditions, all work is boundary work.

Clarification: Steady-Flow Systems

Page 261

- In *NCEES Handbook* section **Steady-Flow Systems**, the first $\dot{m}$ in the following equation should have the subscript *i*.
- *Handbook* equation:

$$\sum \dot{m}\left(h_\mathrm{i} + \frac{V_\mathrm{i}^2}{2} + gZ_\mathrm{i}\right) - \sum \dot{m}_\mathrm{e}\left(h_\mathrm{e} + \frac{V_\mathrm{e}^2}{2} + gZ_\mathrm{e}\right) + \dot{Q}_\mathrm{out} - \dot{W}_\mathrm{out} = 0$$

- revised equation (in PPI style):

$$\sum \dot{m}_i\left(h_i + \frac{\mathrm{v}_i^2}{2} + gz_i\right) - \sum \dot{m}_e\left(h_e + \frac{\mathrm{v}_e^2}{2} + gz_e\right) + \dot{Q}_\mathrm{out} - \dot{W}_\mathrm{out} = 0$$

Typo: Second Law of Thermodynamics

Page 262

- In *NCEES Handbook* section **Second Law of Thermodynamics**, the second law uses an equals sign.
- As entropy, *S*, can either be constant or increase (but can never decrease), this should be a greater than or equals sign.

- *Handbook* equation:

$$\Delta S_{\text{reservoir}} = \frac{Q}{T_{\text{reservoir}}}$$

- revised equation:

$$\Delta S_{\text{reservoir}} \geq \frac{Q}{T_{\text{reservoir}}}$$

Typo: Entropy

Page 263

- In *NCEES Handbook* section **Entropy**, under the subheading "Increase of Entropy Principle," some of the lowercase *s*'s (specific entropy, units of Btu/lbm-°F or J/kg·K) should be uppercase *S*'s (entropy, units of Btu/°F or J/K).

- Handbook equations:

$$\Delta s_{\text{total}} = \Delta s_{\text{system}} + \Delta s_{\text{surroundings}} \geq 0$$

$$\Delta \dot{s}_{\text{total}} = \sum \dot{m}_{\text{out}} s_{\text{out}} - \sum \dot{m}_{\text{in}} s_{\text{in}} - \sum \frac{\dot{q}_{\text{external}}}{T_{\text{external}}} \geq 0$$

- revised equations:

$$\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}} \geq 0$$

$$\Delta \dot{S}_{\text{total}} = \sum \dot{m}_{\text{out}} s_{\text{out}} - \sum \dot{m}_{\text{in}} s_{\text{in}} - \sum \frac{\dot{q}_{\text{external}}}{T_{\text{external}}} \geq 0$$

Clarification: Phase Relations

Page 264

- In the nomenclature for the Clapeyron equation in *NCEES Handbook* section **Phase Relations**, v_{fg} is identified as “volume change”.
- It's actually change in **specific volume**, not volume.
- The variable v is correct.

Typo: Internal Combustion Engines

Page 267

- In the nomenclature for *NCEES Handbook* section **Internal Combustion Engines**, a value of 0.4566 is given for the constant *K* for SI units, but it should actually be 44.74.

Typo: Composite Plane Wall

Page 279

- In *NCEES Handbook* section **Composite Plane Wall**, the three equations at the top of page 277 are misleading. The Handbook is conflating thermal resistance, *R*, and *R*-value, which is thermal resistance multiplied by area, *AR*.
- In each case, what is designated as R_{total} is actually *R*-value, or AR_{total}.
- The units of thermal resistance are hr-°F/Btu or K/W. When you see units of hr-ft^2-°F/Btu or m^2·K/W, what you've actually got is the *R*-value.
- In addition, the *Handbook* uses h_1 to mean the inside film coefficient; this should be h_i to parallel the use of h_o for outside film coefficient.
- See the *NCEES Handbook* equations and revised equations on the next slide.
- *NCEES Handbook* section **Thermal Resistance (R)** correctly gives the equation for resistance to conduction through a plane wall as $R = L/kA$, and the equation for resistance to convection as $R = 1/hA$.

Typo: Composite Plane Wall (cont'd)

Page 279

- *Handbook* equations:

$$R_{total} = 1/h_1 + L_1/k_1 + L_2/k_2 + \cdots + L_n/k_n + 1/h_o$$

$$U = 1/R_{total}$$

$$R_{total} = 1/h_1 + R_1 + R_2 + \cdots + R_n + 1/h_o$$

- revised equations (in PPI style):

$$R_{total} = \frac{1}{h_i A} + \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A} + \cdots + \frac{L_n}{k_n A} + \frac{1}{h_o A}$$

$$R_{total} = \frac{1}{h_i A} + R_1 + R_2 + \cdots + R_n + \frac{1}{h_o A}$$

$$U = \frac{1}{A R_{total}}$$

Typo: Properties of Saturated Water and Steam (Temperature) - SI Units

Page 295

- In *NCEES Handbook* table **Properties of Saturated Water and Steam (Temperature) - SI Units**, two values for absolute pressure in the table should be changed.
  - The saturation pressure for 64°F should be 0.30 psi (not 0.36), and the saturation pressure for 66°F should be 0.32 psi (not 0.33). (Note that the table values for absolute pressure rise steadily as temperature rises — except for the drop from 64°F to 66°F.)
- The values of s_f and s_{fg} for 70°F should be changed in the table.
  - s_f should be 0.0746 (not 0.0760), and s_{fg} should be 1.9893 (not 1.9879). (Note that from 62°F to 74°F the values go up by 0.0038 for each increase of 2°F except at 70°F.)

Typo: Properties of Saturated Water and Steam (Temperature) - SI Units

Page 327

- In *NCEES Handbook* table **Properties of Saturated Water and Steam (Temperature) - SI Units**, the values given for the change in specific volume of evaporated water, v_{fg}, are incorrect in the range from 5°C to 50°C.
- The correct values of v_{fg} from 5°C to 50°C are obtained by subtracting v_f from v_g.

Clarification: Heating and Cooling Load Calculations

Page 416

- *NCEES Handbook* section **Heating and Cooling Load Calculations** focuses on non-residential loads rather than residential loads.
- Non-residential approaches to heating/cooling loads account for more factors and are more complicated than residential approaches.
- Non-residential approaches account for
  - external/internal infiltration systems
  - heat loads from people
  - heat loads from lighting
  - fenestration characteristics
- Residential approaches account for
  - time-varying heat flows (simplified $UA\Delta T$ calculations)
  - air changes
  - fenestration characteristics
- *ASHRAE Fundamentals Handbook* Chapters 17 and 18 include more detail on the differences between residential and non-residential loads.

Tip: Heat Gain Calculations Using Standard Air and Water Values

Page 425

- In *NCEES Handbook* section **Heat Gain Calculations Using Standard Air and Water Values**, the rate of heat transfer to or from water is given as

$$q_w = \dot{m}c_p\Delta T$$

- The basic, well-known form of this equation for heat transferred from one system to another is

$$q = \dot{m}c_p\Delta T$$

- In the *Handbook* equation, c_p is the specific heat of water, but the equation can be applied to other substances as long as the specific heat of the system is known.

Clarification: Moist-Air Cooling and Dehumidification

Page 449

- In *NCEES Handbook* section **Moist-Air Cooling and Dehumidification**, the equation at the bottom of the page for $\dot{q}_2$ has a subscript that may be confusing.
- The last term should be h_w instead of h_{w2}.

- *Handbook* equation:

$$\dot{q}_2 = \dot{m}_{\mathrm{da}}\left[\left(h_1 - h_2\right) - \left(W_1 - W_2\right) h_{\mathrm{w2}}\right]$$

- revised equation (in PPI style):

$$\dot{q}_2 = \dot{m}_{\mathrm{da}}\left(\left(h_1 - h_2\right) - \left(W_1 - W_2\right) h_{\mathrm{w}}\right)$$

- **Additional Equations**
  - alphabetical order of some important equations not included in the *NCEES Handbook*
  - well-known equations used in solutions to practice problems

Area of a Circle

- The equation for the area of a circle is

$$A = \pi r^2 = \frac{\pi D^2}{4}$$

- This equation is not given in the *NCEES Handbook*.

Carrier Equation

- Pressure losses in ductwork can be calculated using the following Carrier equation.

$$\Delta p = 0.03f\left(\frac{L}{D^{1.22}}\right)\left(\frac{\mathrm{v}}{1000}\right)^{1.82}$$

Joule's Constant

- Joule's constant, 778.2 ft-lbf/Btu, is used with U.S. units to convert between mechanical energy (in foot-pounds-force) and thermal energy (in British thermal units).
- The phrase "Joule's constant" does not appear in the *NCEES Handbook*, nor is this constant included in *NCEES Handbook* table **Fundamental Constants**.
- Joule's constant can be found in two places in the *NCEES Handbook*.
  - In *NCEES Handbook* table **Measurement Relationships**, 1 Btu is given as equal to 778 ft-lbf.
  - *NCEES Handbook* section **Temperature Rise Across Fans** contains the following:

$$J = \text{mechanical equivalent of heat} = 778.2\ \frac{\text{ft-lbf}}{\text{Btu}}$$

Moist Air Specific Enthalpy

- The moist air specific enthalpy equation for use with SI units is

$$h = 1.0T + W(2501 + 1.86T)$$

- This equation is not given in the *Handbook*.

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Nusselt Number

Several specific applications of this equation are included in the *NCEES Handbook*, but not this basic form.

$$\mathbf{Nu} = \frac{hD}{k}$$

h = film coefficient

D = diameter

k = thermal conductivity

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Separation Distance (Due to Coanda Effect)

- The Coanda effect describes the distance, x_s, for which the air will adhere to the ceiling.
- The equation for separation distance, x_s, is

$$x_s = 11.61 C_s K_c^{1/2} \left(\frac{\Delta T}{T} \right)^{-1/2} Q_o^{1/4} \Delta p^{3/8}$$

Total Dynamic Head (TDH)

- The total dynamic head (TDH) equation is a simpler form of the **Bernoulli Equation** in the *NCEES Handbook*.

$$\mathbf{TDH} = h_f + h_e \pm h_p$$

- Use of the equation:

1. Think of each head term as either "helping" the pump or "hurting" the pump.
    - Friction "hurts" the pump because it increases head (i.e., adds to TDH).
    - Elevation "hurts" the pump because it increases head (i.e., adds to TDH).
    - Positive pressure differences "help" the pump and decrease head (i.e., subtract from TDH).
    - Negative pressure differences "hurt" the pump and increase head (i.e., add to TDH).
2. Convert all terms to units of feet.
3. Add terms up to determine TDH.

- The TDH equation ignores the velocity head, which adds only a minimal amount of total head.