Final Review

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Final Review

- ***Congratulations to All, you almost completed the ENGR 292 Fluids and Thermodynamics;***
- ***Now it is time to do the final review.***

2

Final Review

- ***Let's check what we have achieved so far:***
  - *Topic: Fluid Mechanics, including Fluid Statics and Fluid Dynamics; Thermodynamics and Heat Transfer*
  - *Lectures: 20 Lectures*
  - *Assignments: 5 Assignments*
  - *Exam: 1 Midterm*

3

Final Review

- ***Today, we are going to have a final review to help you to review all you learnt so far before the final exam***
- ***As usual, at the end of the semester, we will have a course evaluation***

4

ENGR 292 Course Evaluations 2017W

- ***Course Evaluation Instructions:***
  - *A sufficient amount of time will be set aside so that you as a student do not feel pressured to quickly complete these forms.*
  - *Ten to fifteen minutes is usually ample time to complete this process.*

5

ENGR 292 Course Evaluations 2017W

- ***Course Evaluation Instructions:***
  - *These course evaluation forms have been supplied to invite feedback from the students of ENGR 292 2017 W on your educational experience and on the College services provided to you.*

6

ENGR 292 Course Evaluations 2017W

- ***Course Evaluation Procedure:***
  1) *Assign one student in the class to retain this envelope.*
  2) *The assigned student will distribute one evaluation form to each student. Blank(s)/extra form(s) please leave in envelope.*
  3) *Once the students have completed the evaluations they should be returned to the assigned student.*
  4) *Seal envelope and bring envelope to the School of Trades and Technology Office-TEC 169*

  Attn: Aaron Vitaliano–Trades and Technology.

7

Final Review

- ***Fluid Mechanics (~40%)***
  - *Fluid Statics*
  - *Fluid Dynamics*
- ***Thermodynamics and Heat Transfer (~60%)***

8

Evaluation

Assignments	30%	Note: • A weighted average of 50% must be attained on tests/examinations and a 50% must be attained on the final examination, otherwise an F will be awarded. • All assignments will have marks deducted; if handed in after assignments have been returned to the class, no mark will be given – but all assignments must be submitted in order to qualify to write the final exam
Midterm	30%	
Final	40%	

Review of Fluid Statics

- ***Key Equations:***
  - *Pressure*

$$P = \frac{F}{A}$$

  - *Bulk Modulus*

$$E = \frac{-\Delta P}{\frac{\Delta V}{V}}$$

10

Review of Fluid Statics

- ***Key Equations:***
  - *Density*

$$\rho = \frac{m}{V}$$

  - *Specific Weight*

$$\gamma = \frac{w}{V}$$

  - *Specific Weight (γ) and Density (ρ) Relationship or $\gamma - \rho$ Relation:*

$$\gamma = \rho g$$

11

Review of Fluid Statics

- ***Key Equations:***
  - *Weight(w)-Mass(m) Relationship*

$$w = mg$$

  - *Specific Gravity*

$$sg = \frac{\gamma_s}{\gamma_w@4℃} = \frac{\rho_s}{\rho_w@4℃}$$

12

Review of Fluid Statics

- **Key Equations:**
  - *Dynamic Viscosity* $(Pa \cdot s)$:

$$\eta = \frac{\tau}{\Delta v/\Delta y} = \tau\left(\frac{\Delta y}{\Delta v}\right)$$

  - *Shear Stress* (Pa):

$$\tau = \eta\left(\frac{\Delta v}{\Delta y}\right)$$

  - *Kinematic Viscosity* (m^2/s):

$$\upsilon = \frac{\eta}{\rho}$$

13

Review of Fluid Statics

- **Key Equations:**
  - *Absolute and Gage Pressure*

$$P_{abs} = P_{gage} + P_{atm}$$

  - *Pressure-Elevation Relationship*

$$\Delta p = \gamma h$$

  - *Resultant force on a rectangular wall*

$$F_R = \gamma\left(\frac{h}{2}\right)A$$

14

Review of Fluid Statics

- **Key Equations:**
  - *Resultant force on a submerged plane area*

$$F_R = \gamma h_c A$$

  - *Location of Center of Pressure*

$$L_p = L_c + \frac{I_c}{L_c A}$$

  - *Piezometric Head*

$$h_a = p_a/\gamma$$

15

Review of Fluid Statics

- **Key Equations:**
  - *Buoyant force*

$$F_b = \gamma_f V_d$$

  - *The distance to the metacenter from the Center of Buoyancy (MB)*

$$MB = I/V_d$$

  - *Location of Metacenter:*

$$y_{mc} = y_{cb} + MB$$

16

Review of Fluid Statics

- **Key Equations:**
  - *Metacentric Height (MG)*

$$MG = y_{mc} - y_{cg}$$

  - *Stability of Floating Bodies*

If $y_{mc} > y_{cg}$, or if $MG > 0$, the floating body is stable

If $y_{mc} < y_{cg}$, or if $MG < 0$, the floating body is unstable

17

Review of Fluid Dynamics

- **Key Equations:**
  - *Volume Flow Rate:*

$$Q = Av$$

  - *Weight Flow Rate:*

$$W = \gamma Q$$

  - *Mass Flow Rate:*

$$M = \rho Q$$

18

Review of Fluid Dynamics

- **Key Equations:**
  - ***Continuity Equation for any Fluid:***

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

  - ***Continuity Equation for Liquids:***

$$A_1 v_1 = A_2 v_2$$

19

Review of Fluid Dynamics

- **Key Equations:**
  - ***Bernoulli's Equation:***

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

  - ***Torricelli's Theorem:***

$$v_2 = \sqrt{2gh}$$

20

Review of Fluid Dynamics

- **Key Equations:**
  - ***General Energy Equation:***

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

21

Review of Fluid Dynamics

- **Key Equations:**
  - ***Reynolds Number – Circular Sections:***

$$N_R = \frac{vD\rho}{\mu}$$

  - ***Relative Roughness:***

$$\frac{D}{\varepsilon}$$

22

Review of Fluid Dynamics

- **Key Equations:**
  - ***Darcy's Equation for Energy Loss:***

$$h_L = (f\frac{L}{D})\frac{v^2}{2g}$$

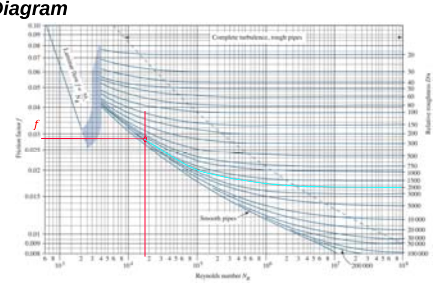
  - ***Friction Factor for Laminar Flow***

$$f = \frac{64}{N_R}$$

23

Review of Fluid Dynamics

- ***Friction Factor (f) for Turbulent Flow – Moody Diagram***



24

Review of Fluid Dynamics

- **Key Equations:**
  - *K Factor for Minor Losses:*

$$h_m = K\left(\frac{v^2}{2g}\right)$$

Review of Fluid Dynamics

- **Combined Head Loss Equation:**

$$h_L = \sum_{pipes} f\frac{L}{D}\frac{v^2}{2g} + \sum_{components} K\frac{v^2}{2g}$$

Review of Fluid Dynamics

- **Key Equations:**
  - *Power Added to A Fluid by A Pump:*

$$P_A = h_A \gamma Q$$

  - *Pump Efficiency:*

$$e_M = \frac{Power\ delivered\ to\ fluid}{Power\ put\ into\ pump} = \frac{P_A}{P_I}$$

Review of Fluid Dynamics

- **Key Equations:**
  - *Power Removed from a Fluid by a Motor:*

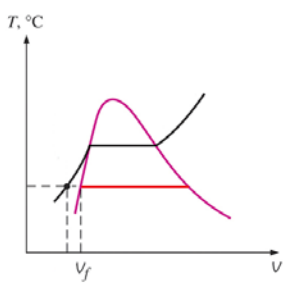
$$P_R = h_R \gamma Q$$

  - *Motor Efficiency:*

$$e_M = \frac{Power\ output\ from\ motor}{Power\ delievered\ by\ fluid} = \frac{P_O}{P_R}$$

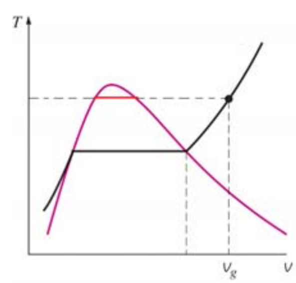
Review of Thermodynamics

- *Phase 1 - Compressed (Subcooled) Liquid*



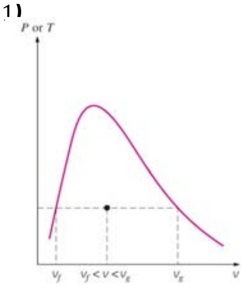
Review of Thermodynamics

- *Phase 2 - Superheated Vapor*



Review of Thermodynamics

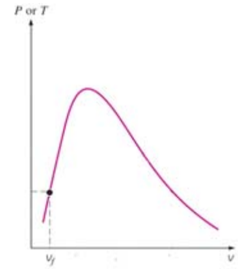
- **Phase 3 - Saturated Liquid-Vapor Mixture ($0 < x < 1$)**



31

Review of Thermodynamics

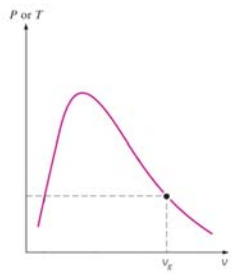
- **Phase 4 - Saturated Liquid ($x = 0$)**



32

Review of Thermodynamics

- **Phase 5 - Saturated Vapor ($x = 1$)**



33

Review of Thermodynamics

- **Entropy**

$$S_F - S_I = \int_I^F \left(\frac{dQ}{T}\right)_b + S_{gen}$$

$$S_{gen} \begin{cases} > 0 & \textit{Irreversible Process} \\ = 0 & \textit{Reversible Process} \\ < 0 & \textit{Impossible Process} \end{cases}$$

34

Review of Thermodynamics

- **Entropy**

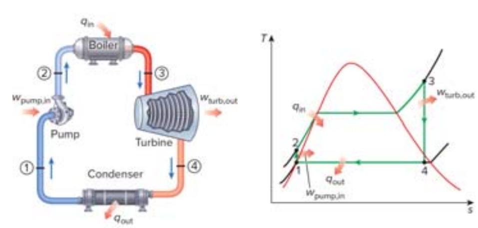
Isentropic – constant entropy processes

$$S_F - S_I = 0$$

35

Review of Thermodynamics

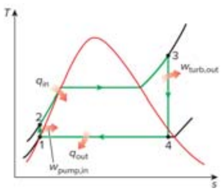
- **Heat Engine (HE)and Ideal Rankine Cycle:**



36

Review of Thermodynamics

❑ Heat Engine and Ideal Rankine Cycle:

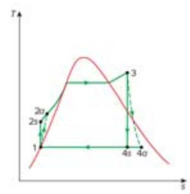


	Process
1-2	Isentropic Process
2-3	Isobaric Process
3-4	Isentropic Process
4-1	Isothermal & Isobaric Process

	Phase
1	Saturated Liquid ($x = 0$)
2	Compressed (Subcooled) Liquid
3	Superheated Vapor
4	Saturated Liquid-Vapor Mixture ($0 < x < 1$) Or Saturated Vapor ($x = 1$)

Review of Thermodynamics

❑ Isentropic Efficiency



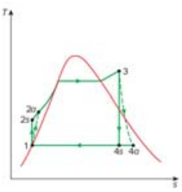
	Process
1-2	Non-Isentropic Process
2-3	Isobaric Process
3-4	Non-Isentropic Process
4-1	Isothermal & Isobaric Process

	Phase
1	Saturated Liquid ($x = 0$)
2	Compressed (Subcooled) Liquid
3	Superheated Vapor
4	Saturated Liquid-Vapor Mixture ($0 < x < 1$) Or Saturated Vapor ($x = 1$)

Review of Thermodynamics

❑ Isentropic Efficiency

Devices	Isentropic Efficiency
Output device Turbine	$\eta_T = \frac{\dot{W}_{T\_Actual}}{\dot{W}_{T\_Ideal}} = \frac{h_3 - h_{4a}}{h_3 - h_{4s}} < 1$
Input device Pump	$\eta_P = \frac{\dot{W}_{P\_Ideal}}{\dot{W}_{P\_Actual}} = \frac{h_{2s} - h_1}{h_{2a} - h_1} < 1$



Review of Thermodynamics

❑ Define the Properties (steam tables)

State	T (℃)	P(MPa)	v (m³/kg)	h (kJ/kg)	s (kJ/(kgK))	Condition
1						
2						
3						
4						

❑ *Note: The data given is labeled by **

Review of Thermodynamics

❑ Energy Analysis of the Heat Engine

Energy Analysis	Equations
Net Work	$\dot{W}_{net\ out} = \dot{W}_T - \dot{W}_P$
	$W_{net\ out} = Q_{in} - Q_{out}$
Heat Input	$\dot{Q}_{in} = \dot{Q}_B = \dot{m}_s(h_3 - h_4)$
Thermal Efficiency	$\eta = \frac{\dot{W}_{net\ out}}{\dot{Q}_{in}} = \frac{\dot{W}_T - \dot{W}_P}{\dot{Q}_{in}}$ $\eta = \frac{W_{net\ out}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}}$

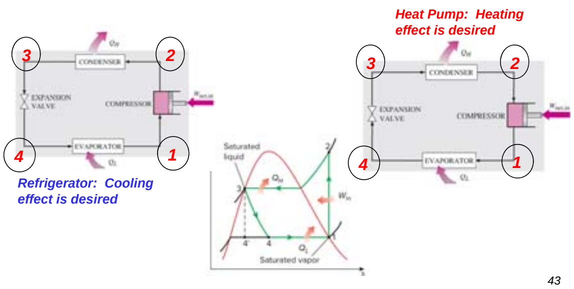
Review of Thermodynamics

❑ Energy Analysis of the Heat Engine

Energy Analysis	Equations
Net Power	$P_{net} = \dot{m}\dot{W}_{net\ out}$
Back Work Ratio	$\frac{\dot{W}_P}{\dot{W}_T}$

Review of Thermodynamics

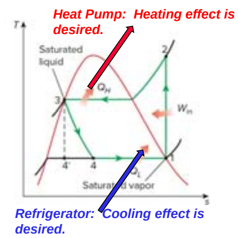
❑ **Refrigeration (R) and Heat Pump (HP)**



43

Review of Thermodynamics

❑ **Refrigeration (R) and Heat Pump (HP)**



	Process
1-2	Isentropic Process
2-3	Isobaric Process
3-4	Isenthalpic Process
4-1	Isothermal & Isobaric Process

	Phase
1	Saturated Vapor ($x = 1$)
2	Superheated Vapor
3	Saturated Liquid ($x = 0$)
4	Saturated Liquid-Vapor Mixture ($0 < x < 1$)

44

Review of Thermodynamics

❑ **Define the Properties (Refrigerants tables)**

State	T (℃)	P(MPa)	v (m³/kg)	h (kJ/kg)	s (kJ/(kgK))	Condition
1						
2						
3						
4						

❑ *Note: The data given is labeled by **

45

Review of Thermodynamics

❑ **Refrigeration (R) and Heat Pump (HP)**

Energy Analysis	Equations
Compressor	$\dot{W}_c = \dot{m}(h_2 - h_1)$
Expansion Valve	$h_3 = h_4 = h_{f4} + x(h_{g4} - h_{f4})$

46

Review of Thermodynamics

❑ **Refrigeration (R) and Heat Pump (HP)**

Energy Analysis	Equations		
Condenser / Evaporator (Rejected)	R	Condenser	$\dot{Q}_{out} = \dot{m}(h_1 - h_4)$
	HP	Evaporator	$\dot{Q}_{in} = \dot{m}(h_2 - h_3)$
Condenser / Evaporator (Desired)	R	Evaporator	$\dot{Q}_{in} = \dot{m}(h_1 - h_4)$
	HP	Condenser	$\dot{Q}_{out} = \dot{m}(h_2 - h_3)$
Coefficients of Performance (COP)	R		$COP_R = \frac{Cooling\ Effect}{Work\ Input} = \frac{\dot{Q}_{in}}{\dot{W}_c} = \frac{h_1 - h_4}{h_2 - h_1}$
	HP		$COP_{HP} = \frac{Heating\ Effect}{Work\ Input} = \frac{\dot{Q}_{out}}{\dot{W}_c} = \frac{h_2 - h_3}{h_2 - h_1}$

47

Review of Thermodynamics

❑ **Thermal Efficiency (η) vs. Coefficients of Performance (COP)**

Energy Analysis	Equations	
Thermal Efficiency (energy converting)		$\eta = \frac{\dot{W}_{net\ out}}{\dot{Q}_{in}} = \frac{\dot{W}_T - \dot{W}_P}{\dot{Q}_{in}} = \frac{\dot{W}_T - \dot{W}_P}{h_1 - h_4} < 1$
		$\eta = \frac{W_{net\ out}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}} < 1$
Coefficients of Performance (COP) (energy transferring)	R	$COP_R = \frac{Cooling\ Effect}{Work\ Input} = \frac{\dot{Q}_{in}}{\dot{W}_c} = \frac{h_1 - h_4}{h_2 - h_1}$
	HP	$COP_{HP} = \frac{Heating\ Effect}{Work\ Input} = \frac{\dot{Q}_{out}}{\dot{W}_c} = \frac{h_2 - h_3}{h_2 - h_1}$

48

Review of Heat Transfer

- **Key Equations:**
  - **Conduction**

$$\dot{Q} = -kA\frac{dT}{dx}$$

$$\dot{Q} = -\frac{kA}{L}(T_2 - T_1)$$

  - **Convection**

$$\dot{Q} = hA(T_s - T_\infty)$$

$$T_f = \frac{T_s + T_\infty}{2}$$

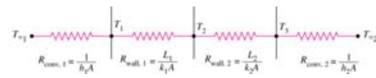
49

Review of Heat Transfer

- **To calculate the rate of heat transfer $\dot{Q}$:**

$$\dot{Q} = \frac{\Delta T}{R_{total}}$$

$$R_{Total} = \sum R_{Cond} + \sum R_{Conv}$$



50

Review of Heat Transfer

- **Thermal Resistance of Conduction**

Conduction Shape	$R_{Cond.}$	R	S
Plane Wall	$\frac{L}{kA}$	$\frac{1}{kS}$	$S = \frac{A}{L}$
Cylinder	$\frac{ln(r_2/r_1)}{2\pi Lk}$	$\frac{1}{kS}$	$S = \frac{2\pi L}{ln(r_2/r_1)}$
Sphere	$\frac{r_2 - r_1}{4\pi r_1 r_2 k}$	$\frac{1}{kS}$	$S = \frac{4\pi r_1 r_2}{r_2 - r_1}$
Others (Table 3-7)	$\frac{1}{kS}$	$\frac{1}{kS}$	

51

Review of Heat Transfer

- **Thermal Resistance of Convection:**

	R_{Conv_in}	R_{Conv_out}
Plane Wall	$\frac{1}{h_1 A}$	$\frac{1}{h_2 A}$
Cylinder	$\frac{1}{2\pi r_1 L h_1}$	$\frac{1}{2\pi r_2 L h_2}$
Sphere	$\frac{1}{4\pi r_1^2 h_1}$	$\frac{1}{4\pi r_2^2 h_2}$

52

Review of Heat Transfer

- ***To find conductive heat transfer coefficient k, just to look up its value in the tables, because it is the property of a material.***

Material	Thermal Conductivity k W/m °C
Metals:	
Silver (pure)	410
Copper (pure)	385
Aluminum (pure)	202
Nickel (pure)	93
Iron (pure)	73
Carbon Steel, 1% C	43
Lead (pure)	35
Chrome-nickel steel (18% Cr, 8% Ni)	16.3
Nonmetallic Solids:	
Quartz, parallel to axis	41.6
Magnesite	4.15
Marble	2.08-2.94
Sandstone	1.83
Glass, window	0.78
Maple or Oak	0.17
Sawdust	0.059
Glass wool	0.038
Liquids:	
Mercury	8.21
Water	0.556
Ammonia	0.054
Lubricating oil, SAE 50	0.147
Freon 12, CCl_2F_2	0.073
Gases:	
Hydrogen	0.175
Helium	0.141
Air	0.024
Water vapor (saturated)	0.0206
Carbon dioxide	0.0146

53

Review of Heat Transfer

- ***Determine the convective heat transfer coefficient h is not an easy task. Convection Heat Transfer Coefficient (h) is not a property of the material.***

54

Review of Heat Transfer

- ***Use Patterns defined in Table C-8 to calculate Nu to determine h***

$$h = \frac{(Nu)k}{L}$$

- ***by calculating Re for forced convection***
- ***by calculating Gr for natural convection***

55

Review of Heat Transfer

- ***Forced Convection***
  - ***Fluid was forced to move over a surface or in a tube by external means such as a pump or a fan.***

Table C-8

(A) Flow in circular tubes

(B) Boundary layer on a flat plate

(C) Single circular cylinder or sphere in cross flow

56

Review of Heat Transfer

- ***Natural Convection***
  - ***Any fluid motion occurs by natural means such as buoyancy***

Table C-8

(D) Natural convection from a horizontal cylinder

(E) Natural convection from vertical surfaces

57

Review of Heat Transfer

- ***Procedure for Calculating "h" – Forced Convection:***
  1. ***Determine the geometric parameter L;***
  2. ***Determine the type of the Forced Convection in Table C-8 (A), (B) or (C)***

  3. Assume a fluid temperature, T_f(°K) (if it is not given). Look up the thermo-physical properties ($\rho, k, \mu, \upsilon, Pr$) of the fluid used in the convection in Table A-18 (if Pr is not given, use $Pr = \frac{\mu C_p}{k}$)

58

Review of Heat Transfer

4. Calculate the Reynolds number (Re) or other information to determine the Flow type – Laminar or Turbulent

$$Re = \frac{vL\rho}{\mu} = \frac{vL}{\nu}$$

Please note:

Critical Reynolds Numbers

- ***Inside a Pipe***
  - $Re_{Cr} = 2000$
- ***Over a Flat Plate***
  - $Re_{Cr} = 500,000$

59

Review of Heat Transfer

5. Calculate Nusselt number (Nu)

$$Nu = CRe_L^m Pr^n$$

Find C, m, n as per flow type and thermal boundary layer condition

6. Calculate h

$$h = \frac{(Nu)k}{L}$$

60

Review of Heat Transfer

- **Procedure for Calculating "h" – Natural Convection:**
  1. **Determine the geometric parameter L;**
  2. **Determine the type of the Natural Convection in Table C-8 (D) or (E)**

  3. Assume a fluid temperature, T_f (°K) (if it is not given). Look up the thermo-physical properties ($\rho, k, \mu, \upsilon, Pr$) of the fluid used in the convection in Table A-18

61

Review of Heat Transfer

- **4. Calculate the Grashof number (Gr)**

$$Gr = \frac{g\beta(T_{surface} - T_\infty)L^3\rho^2}{\mu^2}$$

$\beta = \frac{1}{T_f}$ **for gas only** $(K = C + 273.15)$

5. Calculate Nusselt number (Nu)

$$Nu = C(Gr \times Pr)^n$$

Find C **and** n **as per the value of** $(Gr \times Pr)$

6. Calculate h

$$h = \frac{(Nu)k}{L}$$

62

Review of Heat Transfer

- **Key Equations:**
  - **Fin Efficiency**

$$\eta_{Fin} = \frac{\dot{Q}_{Fin}}{\dot{Q}_{Fin,Max}}$$

$$\dot{Q}_{Fin,Max} = hA_{Fin}(T_b - T_\infty)$$
$$A_{Fin} = A_{Fin\_Sides} + A_{Fin\_Tip}$$

$$\dot{Q}_{Fin} = \eta_{Fin}\dot{Q}_{Fin,Max} = \eta_{Fin}hA_{Fin}(T_b - T_\infty)$$

63

Review of Heat Transfer

- **Key Equations:**
  - **Fin Effectiveness**

$$\varepsilon_{Fin} = \frac{\dot{Q}_{Fin}}{\dot{Q}_{No\ Fin}} = \frac{\eta_{Fin}hA_{Fin}(T_b - T_\infty)}{hA_b(T_b - T_\infty)} = \frac{\eta_{Fin}A_{Fin}}{A_b}$$

64

Review of Heat Transfer

- **Key Equations:**
  - **Multiple Fins:**

$$\dot{Q}_{Total\ Fin} = \dot{Q}_{UnFin} + \dot{Q}_{Fin} = h(A_{UnFin} + \eta_{Fin}A_{Fin})(T_b - T_\infty)$$

65

Review of Heat Transfer

- **Heat Sink Selection:**

$$R_{required} = \frac{\Delta T}{\dot{Q}}$$

Selection Criteria:

$$R_{Heat\ Sink} < R_{required}$$

66

Final Exam Information

- ENGR 292 Final Exam is a closed book exam. However, the Cheat Sheet is allowed in the final exam. Here is the detail information about the Cheat Sheet:

You may bring two double-sided 8½"×11" sheet of paper with anything you like written on both sides (Four single-sided sheets are okay). However, Cheat sheets must be hand-written, not photocopied or printed.

67

Final Exam Information

- What will be provided in the Final Exam if needed:
  - Unit Conversion Factors
  - Material Properties, such as density, viscosity, etc.
  - Properties of Areas
  - Dimensions of Steel Pipes
  - Pipe Roughness
  - Moody Diagram
  - Figures and Tables of K Factors of Minor Losses

68

Final Exam Information

- What will be provided in the Final Exam if needed:
  - Thermal Conductivity k
  - Table 3-7 Conduction Shape Factor S for Common Configurations
  - Table C-8 for convective heat transfer coefficient h
  - Steam Tables & R134a Properties
  - Figures 8-59 & 8-60 for Finned Surface Heat Transfer
  - Table 8-6 for Heat Sink Selection

69

Final Exam Information

- You are permitted to use your own calculator, but you are not permitted to store any course-related information in your calculator and to use it.
- Cell phone is not allowed in the Final Exam.

70

Final Exam Information

- Organize yourself before the Final Exam:
  - Use course objective to study
  - Review the ENGR 292 Website and ENGR 292 D2L; Read through the notes, examples, tutorials etc.
  - Review your assignments and against the posted solutions.

71

Final Exam Information

- Organize yourself before the Final Exam:
  - Prepare your cheat sheet
    - Concepts
    - Key Equations
    - Make sure to remember: Circle Area: $A = \pi r^2 = \frac{\pi D^2}{4}$
    - Anything you think is important

72

Final Exam Information

- ***During the Final Exam:***
  - ***Show you work:***
    - ***Numerical Questions: make sure to show your work!***
    - ***Descriptive Questions: answer clearly and concisely. Spelling and Grammar count!***
  - ***Budget your time: Look at how much each question is worth.***
  - ***Attempt all the questions. You do not have to do questions in numerical order.***
  - ***Do not get stuck on one question***
  - ***Do not leave any answers blank***
  - ***Good Luck !***

73

What is Next?

- ***Apr.07 No Class***
  - ***Reading Assignment***
  - ***Assignment 5***
- ***Apr.11, Self-Study or Questions time?***

74

What is Next?

- ***Final Exam (3 hrs):***
  - ***Time: Apr.18, 18:00 pm – 21:00 pm***
  - ***Location: CBA 285***

75