

AME 101, Fall 2016
Final exam review
12/8/2016 & 12/13/2016

The full 120 minutes of time will be allowed. The format of the exam will be the same as the midterms - open book *to the extent of the course lecture notes, your own notes, homework assignments and solutions, and the optional Wickert textbook only*. No electronic devices other than calculators will be allowed, so be sure you have hard copies of all the lecture notes.

The material covered on the exam may include **any** material in the lecture part of the class (i.e. I won't ask anything about SolidWorks or other graphics-oriented subjects.) There will be more emphasis on the last part of the lecture material (i.e. energy and thermal systems) since you haven't been tested on that yet. Roughly speaking the breakdown of the problems will be as follows (**this is not guaranteed**):

- 1 problem on units and/or scrutiny
- 1 problem on statics / materials / structures OR fluid mechanics
- 3 problems on energy and thermal systems

The material presented since the last midterm includes

- First Law of Thermodynamics – conservation of energy
 - Control mass (fixed mass of material)
 - Control volume (fixed volume in space)
 - Types of energy – Internal, kinetic, potential
 - Types of energy transfers – heat, work
 - Heating value of fuels
 - Steady flow
- Second Law of Thermodynamics – entropy always increases
 - Heat is always transferred from hot to cold, never the reverse
 - Carnot cycle engines – best possible efficiency cycle - heat addition at temperature T_H , heat rejection at temperature T_L ; efficiency $\eta = 1 - T_L/T_H$
 - Other cycles
 - Otto – model for gasoline-type internal combustion engines
 - Brayton – model for gas turbines
 - Rankine – model for steam turbines
- Heat transfer
 - Conduction $\dot{Q} = -kA \frac{\Delta T}{\Delta x}$
 - Convection $\dot{Q} = hA\Delta T = hA(T_{surface} - T_{fluid})$
 - Radiation $\dot{Q} = \sigma\epsilon A(T_H^4 - T_L^4)$

Traps and pitfalls to avoid

- Check your units
- Check your units
- Check your units (get the message now???)
- Use the right equation! Some examples:
 - Materials and stresses
 - Moment of inertia – cross sections – rectangular vs. solid cylinder vs. hollow cylinder
 - Point load vs. distributed load
 - Fluid mechanics
 - Areas – cross-section area or surface area?
 - Definition of Reynolds number – which length scale?
 - Pipe, sphere, cylinder – diameter, not length!
 - Flat plate - length
 - Laminar vs. turbulent flow – depends on Reynolds number – use the right formula or chart!
 - Incompressible ($\rho = \text{constant}$) vs. compressible
- Temperatures – “to be absolutely sure, use absolute temperature!”

Sample final exam from a previous year (average was 78/100)

Problem #1 (units) (20 points total)

The Froude number (Fr) of the flow around an object such as a sailboat is defined by $Fr = gL/v^2$, where g = acceleration of gravity, L = characteristic length of object, and v = velocity of object.

- Calculate the Froude number of the flow around a 40 foot long sailboat (that is, $L = 40$ ft) cruising through the water at 25 miles per hour.
- Calculate the Reynolds number of the flow of the water around the sailboat, again using $L = 40$ ft as the characteristic dimension (see the table in Chapter 6 for water properties).
- It is desired to simulate the flow around this sailboat in a laboratory experiment with mercury (see the table in Chapter 6 for mercury properties) (do not attempt this at home!) What model length (L) (in feet) and fluid speed (v) (in feet per second) would be required to have the same Froude and Reynolds numbers as determined in parts (a) and (b)?
- Since the Froude and Reynolds numbers are the same for the two cases (in water and mercury), the drag coefficient C_D will be the same for the two cases. Which case (water or mercury) would have the larger drag force? **No credit without explanation.**

Problem #2 (scrutiny, thermodynamics #1) (24 points total)

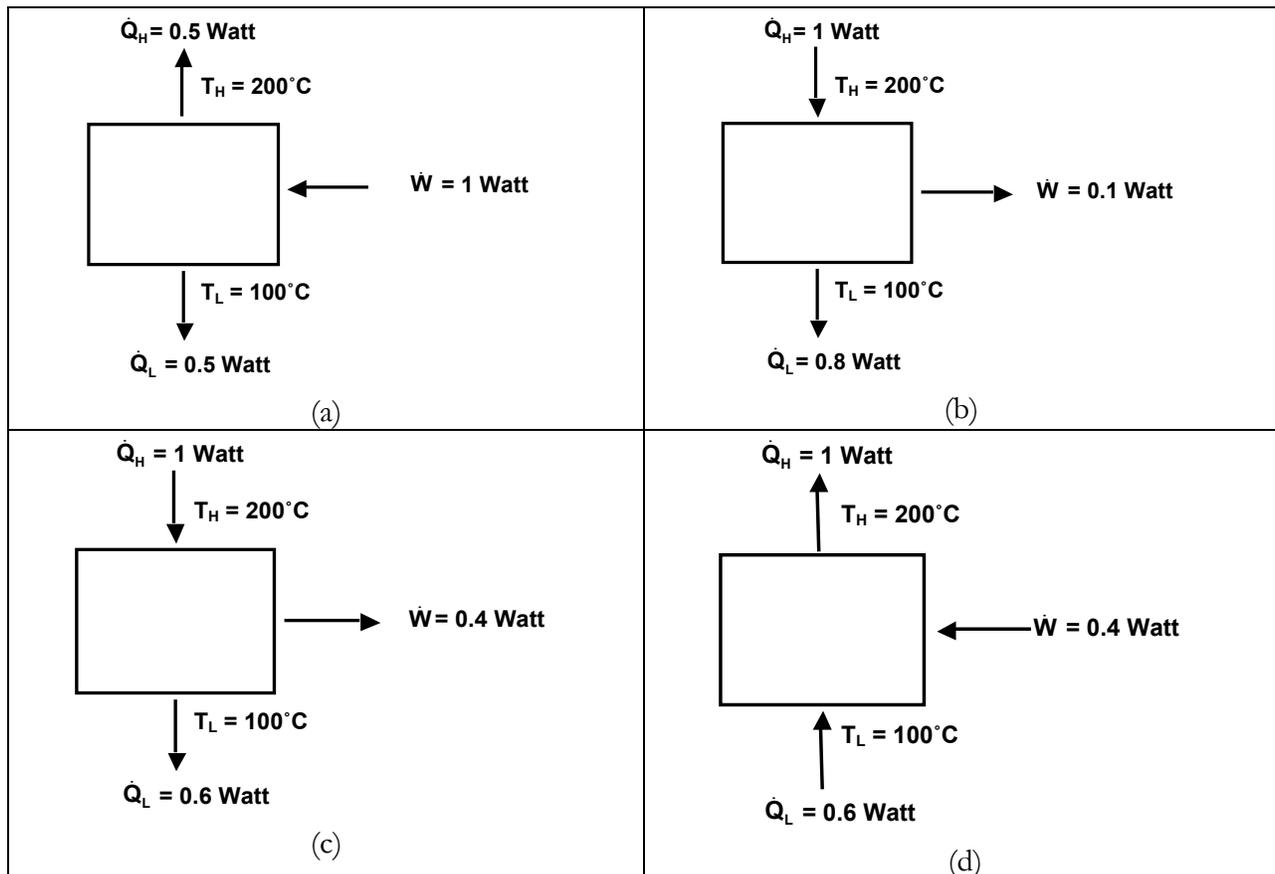
Using the Control Volume form of First Law of Thermodynamics I derived the following formula for the power output (\dot{W}) of a new type of steady-flow engine in terms of the mass flow rate through the engine (\dot{m}), the temperature at the outlet of the engine (T_{out}), the temperature at the inlet of the engine (T_{in}) and the specific heat at constant volume (C_v):

$$\dot{W}_{1-2} = \dot{m}C_v(T_{out} - T_{in})$$

- (a) (9 points) There are two mistakes in this equation, *i.e.*, it's not possible to derive this result from the First Law of Thermodynamics. What are these two mistakes and how can the formula be corrected?
- (b) (15 points) Which of the following assumptions were required to obtain the above result, besides fixing the mistakes? **No credit for simple yes or no answers, you must state a reason for your answer.**
- No change in velocity between states 1 and 2
 - No change in pressure between states 1 and 2
 - No change in density between states 1 and 2
 - No heat transfer between states 1 and 2
 - Working fluid has no viscosity

Problem #3 (thermodynamics #2) (16 points total, 4 points each part)

Which of the devices (a) – (d) below are possible, which are impossible according to the First Law of Thermodynamics, and which are impossible according to the Second Law of Thermodynamics? Explain each in 1 or 2 sentences. **No credit without explanation!**



Problem #4 (thermodynamics #3) (25 points total)

A 0.25 lbm **spherical** meteor of diameter 3 cm enters the earth's atmosphere at an elevation of 400,000 ft with a velocity of 30,000 mi/hr. The meteor's temperature is 200K. The specific heat at constant volume (C_v) of the meteor is 800 J/kg°C.

- (a) If the meteor has a temperature of 500°C just before it hits the earth's surface ($z \approx 0$), what would its velocity be in ft/sec? Assume that there is no heat transfer to or from the atmosphere and no work done on or by the atmosphere (due to air drag) on the meteor.
- (b) If instead you assumed that the meteor experienced air drag, what would its terminal velocity be in the lower atmosphere where the air properties are those given in Table 3?
- (c) If just above the earth's surface ($z \approx 0$) the meteor had the terminal velocity determined in part (b) and had a temperature of 25°C , how much work was done on or by the atmosphere? Is the work positive or negative? Again assume no heat transfer to or from the atmosphere.

Problem #5 (heat transfer) (15 points total, 5 points each part)

An infrared lamp is used to keep the top surface of an 18" diameter $\frac{1}{2}$ " thick pizza at a temperature of 60°C .

- (a) If the pizza loses heat only by conduction through the pizza to a 25°C plate on which the pizza lies, and the thermal conductivity of the pizza is 0.3 W/mK , what heating power (in Watts) must the infrared lamp supply?
- (b) If the pizza loses heat only by radiation to the environment at 25°C , and the emissivity of the pizza is 0.8, what heating power (in Watts) must the infrared lamp supply?
- (c) If the pizza loses heat only by convection to the atmosphere at 25°C , and the convective heat transfer coefficient $h = 10 \text{ W/m}^2\text{C}$, what heating power (in Watts) must the infrared lamp supply?