CAE 208 / MMAE 320: Thermodynamics
Fall 2023

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Basic Concepts of Thermodynamics (I)

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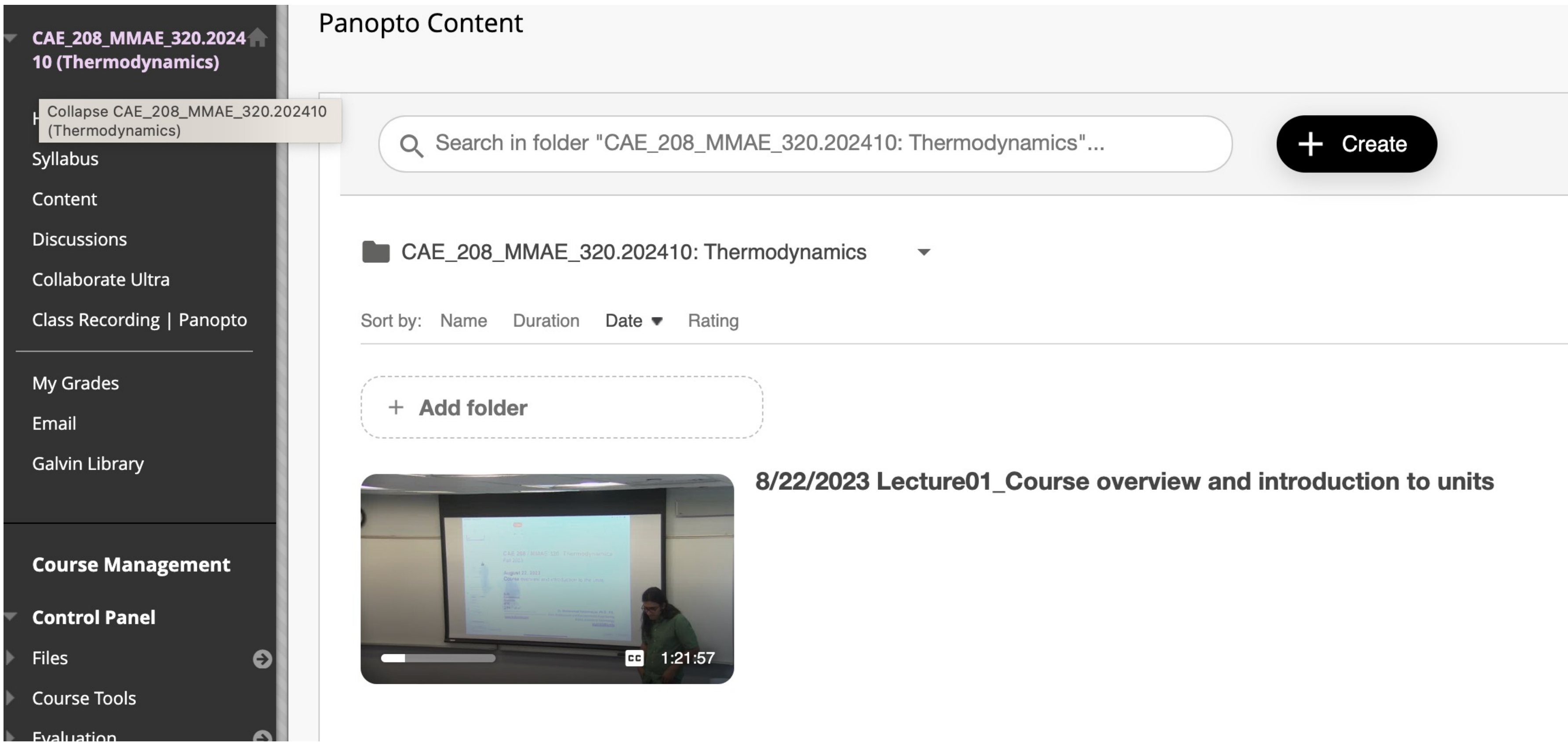
ANNOUNCEMENTS

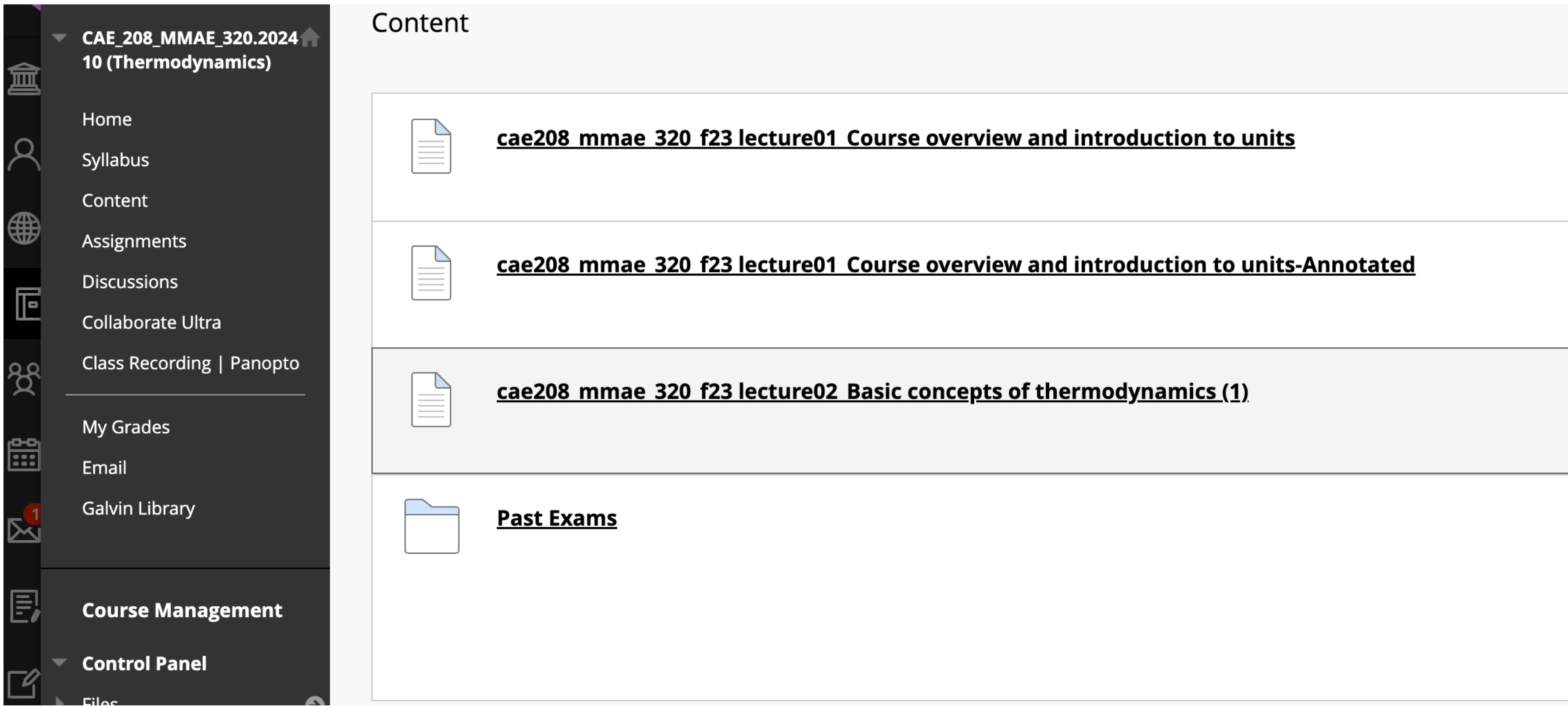
Announcements

- Lecture recordings are available on Blackboard:



Announcements

- The annotated lectures are also available on Blackboard:



Announcements

- Assignment 1 is posted (Due next week)

RECAP

Recap

- Dimensions defines any physical quantity
- The magnitude of dimensions is expressed in units
- Relevant primary or fundamental units are:
  - ❑ Temperature (θ)
  - ❑ Length (L)
  - ❑ Time (T)
  - ❑ Mass (m)

Recap

- Others are secondary or derived:
  - ❑ Velocity (LT^{-1})
  - ❑ Acceleration (LT^{-2})
  - ❑ Volume (L^3)

Recap

- Two systems of units are
  - ❑ SI: International System which is based on scientific and engineering work
    - 1 m = 100 cm
    - 1 km = 1,000 m
  - ❑ IP or English which has no apparent systematic numerical base
    - 1 ft = 12 in
    - 1 mile = 5280 ft
    - 4 qt = 1 gal

Recap

- Examples of the two systems of units are
  - ❑ Speed limit

What does this mean?

Recap

- Examples of the two systems of units are
  - ❑ Who likes to bake?

Recap

- Common units are:

Dimension	SI Unit	IP Unit
Length	m	ft or inch
Mass	kg	lb
Time	s	s
Temperature	K	F or R

See Table 1-1 and 1-2

Recap

- Some important SI and IP units
  - Force = (Mass)(Acceleration)

$$1\,N = (1\,kg)\left(1\,\frac{m}{s^2}\right) = 1\,kg.\frac{m}{s^2}$$

$$1\,lbf = \underbrace{(32.174\,lbm)}_{=\,1\,slug}\left(1\,\frac{ft}{s^2}\right) = 32.174\,lbm.\frac{ft}{s^2}$$

Units and Dimensions

- Some important SI and IP units
  - ❑ Weight = (Mass)(Gravitational Acceleration)

$$W = (1kg)\left(9.81\frac{m}{s^2}\right) = 9.81\ N$$

$$W = (1lbm)\left(32.174\frac{ft}{s^2}\right) = 32.174\ lbm\times\frac{ft}{s^2} = 1lbf$$

UNITS

Units

- Some important SI and IP units
  - Work = (Force)(Distance)

$$1\,J = (1N)(1m) = 1N.m$$

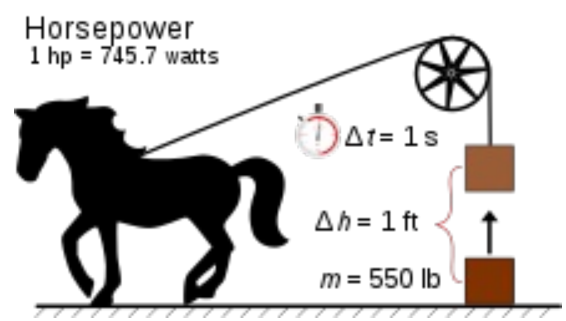
  - What's 1 kJ?
  - 1 Btu (British Thermal Unit) = Energy required to increase 1 lbm of water at 68 °F by 1 °F
  - 1 Btu = 1.0551 kJ
  - 1 Calorie = The amount of energy needed to raise the temperature of 1 g of water at 14.5 °C by 1 °C (1 calorie = 4.1868 J)

Units and Dimensions

- Some important SI and IP units
  - ❑ Power = Rate of Energy

$$1\,W = 1\,\frac{J}{s}$$

$$1\,hp = 746\,W$$



  - ❑ Be careful electrical power is usually provided in kWh

CLASS ACTIVITY

Unit Conversion

- A small diesel power plant could have a capacity of 5 MW. Could we convert this to hp?

Class Activity

- Convert 12 ft to meter

Class Activity

- Convert 24 inch to meter

Class Activity

- Convert 5 ft/s to km/h

CLASS ACTIVITY

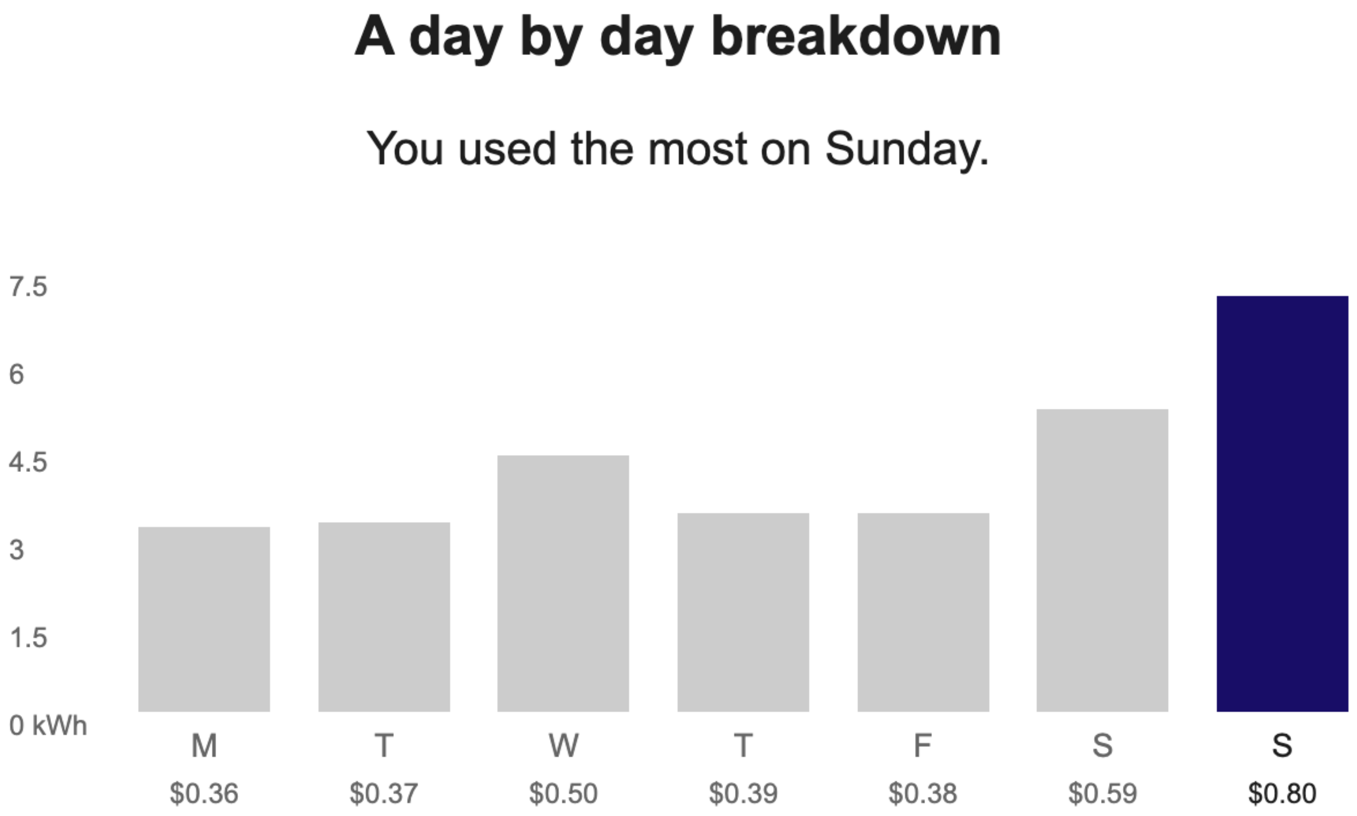
Class Activity

- Calculate the mass of water (in both kg and lbm) for a tank with a volume of 2 m^3 (assume density of water is 1000 kg/m^3)

CLASS ACTIVITY

Class Activity

- Electricity bills are usually expressed in kWh



Class Activity

- Assuming someone buys a USB power adaptor for an iPhone. If an iPhone requires about 3 hours to get fully charged, calculate the total energy used and also the electricity cost (Note: ComEd’s rate is about 10 cents per kWh).

UNIT CONVERSION

Unit Conversion

- Can we convert 1 m^3/min to 1 m^3/hr?

Unit Conversion

- How about converting this range hood from ft^3/min (or CFM) to m^3/min.

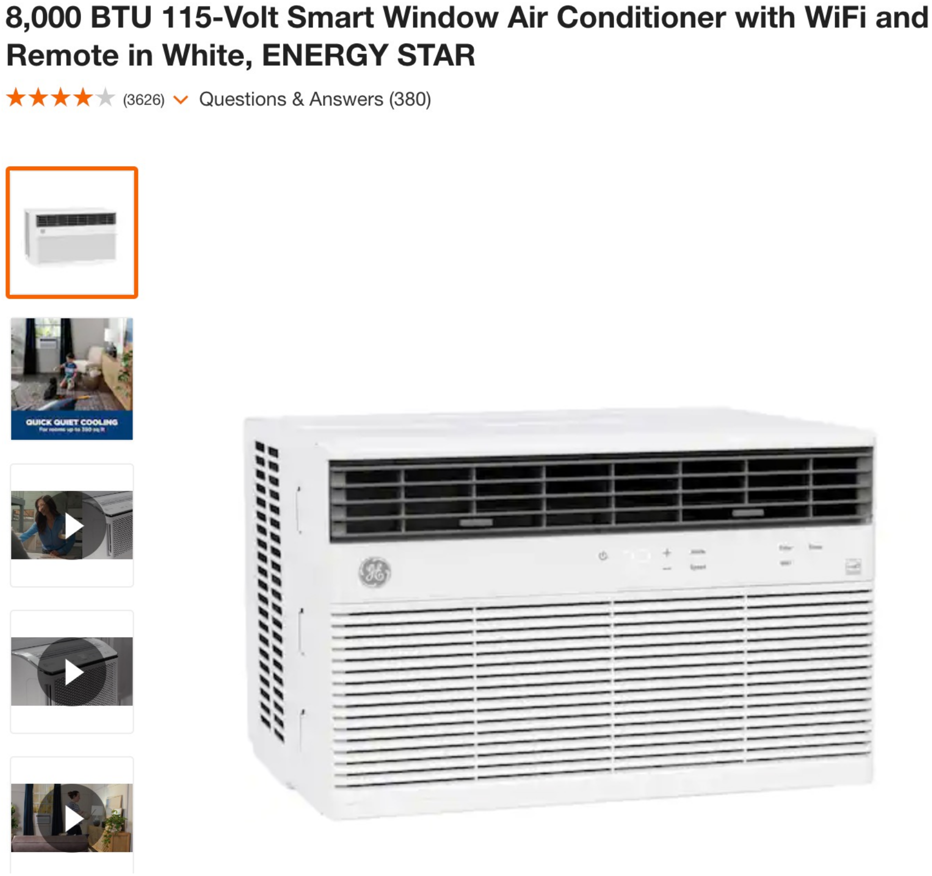
30 in. 900 CFM Ducted Wall Mount with LED Light Range Hood in Stainless Steel

★★★★★ (15) Questions & Answers (19)

CLASS ACTIVITY

Class Activity

- Given the heatwave today, you are asked to confirm the following window unit can fully cool a room of 500 ft^2. What do you do? (A rule of thumb for the cooling load is to assume 20 Btu/ft^2).



SYSTEMS AND CONTROL VOLUMES

Systems and Control Volume

- A system is defined as quantity of matter or a region in space chosen for study
- A few important aspects of a system: Boundary (movable or fixed) and surrounding

Systems and Control Volume

- A system could be
  - ❑ Closed system known as “control mass”
  - ❑ Open system known as “control volume”

Systems and Control Volume

- Closed system known as "control mass"
  - ❑ No Mass
  - ❑ Energy Yes (if no energy we call it isolated)

Systems and Control Volume

- Open system known as "control volume"
  - ❑ Mass Yes
  - ❑ Energy Yes

PROPERTIES OF A SYSTEM

Properties of a System

- Property = Any characteristics of a system
  - ❑ Pressure (P)
  - ❑ Temperature (T)
  - ❑ Volume (V)
  - ❑ .
  - ❑ .
  - ❑ .
  - ❑ Thermal conductivity (k)

Properties of a System

- Properties are.
  - ❑ Intensive: Independent of mass
  - ❑ Extensive: Depends on the size – extent - of a system

Properties of a System

- Is there a criterion for understanding intensive vs extensive properties?

Properties of a System

- Can we convert an extensive property to an intensive property?

DENSITY AND SPECIFIC GRAVITY

Density and Specific Gravity

- Density = Mass per unit volume

- Specific volume = Volume per mass

Density and Specific Gravity

- What is the density of water and air?

Material	SI (kg/m^3)	IP (lb/ft^3)
Water	997	62.4
Air	1.2754	0.763

Density and Specific Gravity

- Density in general of is a function of pressure and temperature

Material	Temperature	Pressure
Gas		
Liquid		
Solid		

Density and Specific Gravity

- Specific gravity or relative density is the ratio of the density of a substance to the density of some standard substance at a specific temperature (usually water 4°C and ρ = 1000)

$$SG = \frac{\rho}{\rho_{H2O}}$$

Density and Specific Gravity

- Specific weight

$$\gamma_s = \rho g$$

CLASS ACTIVITY

Class Activity

- The density of water liquid is defined as $\rho = 1000 - \frac{T}{2}$ with T in Celsius. If the temperature increases, what happens to the density and specific volume.

CLASS ACTIVITY

Class Activity

- A 1 m^3 container is filled with 0.12 m^3 of granite, 0.15m^3 of sand and 0.2 m^3 of liquid water at 25 °C, and the rest of the volume, 0.53 m^3, is air. Find the overall (average) specific volume and density.

- The following densities could be used for the calculations
  - ❑ $\rho_{granite} = 2750\,\frac{kg}{m^3}$
  - ❑ $\rho_{sand} = 1500\,\frac{kg}{m^3}$
  - ❑ $\rho_{water} = 997\,\frac{kg}{m^3}$
  - ❑ $\rho_{air} = 1.15\,\frac{kg}{m^3}$

Class Activity