



وزارة التعليم العالي والبحث العلمي
الجامعة التقنية الشمالية
المعهد التقني الموصل



الحقية التعليمية



القسم العلمي: قسم تقنيات ميكانيك القدرة

اسم المقرر: مبادئ ديناميك الحرارة

المرحلة / المستوى: الاول

الفصل الدراسي: الأول

السنة الدراسية: 2025-2024



معلومات عامة

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المرحلة / المستوى		الأول			
الفصل الدراسي:		الأول			
عدد الساعات الاسبوعية:		نظري	٢	عملي	٢
عدد الوحدات الدراسية:		٤			
الرمز:		PMTR137			
نوع المادة		نظري		عملي	كلهما نعم
هل يتوفر نظير للمقرر في الاقسام الاخرى		لا يوجد			
اسم المقرر النظير		لا يوجد			
القسم		لا يوجد			
رمز المقرر النظير		لا يوجد			
معلومات تدريسي المادة					
اسم مدرس (مدرسي) المقرر:		عمر محمود جمعة			
اللقب العلمي:		مدرس			
سنة الحصول على اللقب		٢٠٢١			
الشهادة :		ماجستير			
سنة الحصول على الشهادة		٢٠١٧			
عدد سنوات الخبرة (تدريس)		٧ سنة			

الوصف العام للمقرر

يشكل هذا المقرر مادة أساسية في منهاج قسم ميكانيك القدرة بشكل عام وفرع تقنيات التبريد بشكل خاص والذي يعمل على تحقيق أهداف علمية وعملية تواكب التطور العلمي في تكنولوجيا الفيزياء والميكانيك والرياضيات، كما يحقق ربطا للحقائق والمفاهيم التي يدرسها الطالب.

الاهداف العامة

- سيتعلم الطالب المبادئ الأساسية لعلم ديناميك الحرارة
- سيتمكن الطالب من التعرف على الأنظمة الحرارية المختلفة وكيفية تحليلها.
- سيتمكن الطالب من تحليل العمليات الحرارية والقدرة على تطبيق مبادئ علم ديناميك الحرارة على مجموعة متنوعة من العمليات الحرارية.
- سيتعلم الطالب استخدام القانون الأول لديناميك الحرارة لتحليل التوازن الطاقى وتحول الطاقة.

الأهداف الخاصة

- إكساب المتعلم فهم القانون الصفري وأنواع المحارير وتمدد المواد.
- المام المتعلم بالعلاقة بين الطاقة، الحرارة، الشغل، والقوانين الأولية لديناميك الحرارة وسيتمكن من حل المسائل المتعلقة بها
- اكساب الطالب المعرفة التامة بالنظمة الحرارية المختلفة (مثل الأنظمة المغلقة، المفتوحة والمعزولة) وكيفية تحليلها الحرارة .

الأهداف السلوكية او نواتج التعلم

- بعد الانتهاء من المحاضرة سيكون الطالب قادر على ان:
- يعرف القانون الصفري.
- يميز بين أنواع المحارير
- يحلل عناصر المواد وتمدها.
- يعرف أنواع الطاقة، الحرارة، الشغل
- يستخدم القانون الأول لديناميك الحرارة في حل المسائل المتعلقة بها.

المتطلبات السابقة

- على الطالب ان يكون له المعرفة في مادة الفيزياء للمراحل الإعدادية.

الأهداف السلوكية او مخرجات التعليم الأساسية		
ت	تفصيل الهدف السلوكي او مخرج التعليم	آلية التقييم
1	. ان يعرف القانون الصفري.	الامتحان اليومي
2	ان يميز بين أنواع المحارير	الامتحان اليومي
3	ان يحلل عناصر المواد وتمدها.	الامتحان اليومي
4	يعرف أنواع الطاقة، الحرارة، الشغل	الامتحان اليومي
5	يستخدم القانون الأول لديناميك الحرارة في حل المسائل المتعلقة بها.	الامتحان اليومي

أساليب التدريس (حدد مجموعة متنوعة من أساليب التدريس لتناسب احتياجات الطلاب ومحتوى المقرر)

الاسلوب او الطريقة	مبررات الاختيار
١. عرض المحاضرات وشرحها ومناقشتها.	مفردات المنهج تطلب ذلك
٢. طرح المسائل الرياضية وحلها	لتسهيل عملية الشرح
٣. عرض الوسائل الايضاحية وتفسير الفكرة العلمية لها	لزيادة فهم الطالب للمادة
٤.	
٥.	
٦.	

الفصل الاول من المحتوى العلمي						
				الوقت		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان	العملي	النظري	التوزيع الزمني
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	Chapter one 1.1Temperature and the Zeroth Law of Thermodynamics 1.2Thermometers and the Celsius Temperature Scale 1.3The Constant-Volume Gas the Absolute Temperature Scale Thermometer and	٢	٢	الأسبوع الأول
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	1.4Thermal Expansion of Solids and Liquids 1.5 Macroscopic Description of an Ideal Gas	٢	٢	الأسبوع الثاني
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	Chapter Two: 2.1Heat and the First Law of Thermodynamics 2.2Heat and Internal Energy 2.2Heat Capacity and Specific Heat 2.4Latent Heat	٢	٢	الأسبوع الثالث
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	2.5Energy Transfer Mechanisms: 2.5.1Thermal conduction 2.5.2Convection 2.5.3Radiation	٢	٢	الأسبوع الرابع
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	2.6Work and Heat in Thermodynamic Processes 2.7The First Law of Thermodynamics	٢	٢	الأسبوع الخامس
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	2.8Some Applications of the First Law of Thermodynamics	٢	٢	الأسبوع السادس
امتحان فصلي			First Exam			الأسبوع السابع

الفصل الثاني						
				الوقت بالساعة		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان	العملي	النظري	التوزيع الزمني
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	Chapter Three: 3.1The Kinetic Theory of Gases	٢	٢	الأسبوع الثامن
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	3.2Molecular Model of an Ideal Gas 3.3Molar Specific Heat of an Ideal Gas	٢	٢	الأسبوع التاسع
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	3.4Distribution of Molecular Speeds	٢	٢	الأسبوع العاشر
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	3.5The Equipartition of Energy	٢	٢	الأسبوع الحادي عشر
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	3.6Adiabatic Processes for an Ideal Gas 3.7The Boltzmann Distribution Law Mean Free Paths	٢	٢	الأسبوع الثاني عشر
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	Examples	٢	٢	الأسبوع الثالث عشر
الامتحان اليومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	Examples	٢	٢	الأسبوع الرابع عشر
امتحان شهري			Second exam	٢	٢	الأسبوع الخامس عشر

المحتوى العلمي

خارطة القياس المعتمدة

عدد الفقرات	الأهداف السلوكية						الأهمية النسبية	عناوين الفصول	المحتوى التعليمي
	التقييم	التحليل	التطبيق	الفهم	المعرفة				
						النسبة			
	%15	%15	%5	%10	%15		%20	Thermodynamics of Principles	الفصل الاول
	%15	%15	%10	%20	%15		%20	Heat and the First Law of Thermodynamics	الفصل الثاني
	%30	%30	%40	%40	%35		30%	Energy Transfer Mechanisms	الفصل الثالث
	%30	30%	%45	%20	%35		30%	Work and Heat in Thermodynamic Processes	الفصل الرابع
	100%	100%	100%	100%	100%		100%		المجموع

المحاضرة الثانية	Thermodynamics of Principles and and the Zeroth Law
عنوان المحاضرة:	عمر محمود جمعة
اسم المدرس:	المستوى الأول من قسم تقنيات التبريد
الفئة المستهدفة :	تعريف الطالب ماهي المبادئ الأساسية لعلم ديناميك الحرارة
الهدف العام من المحاضرة :	• ان يتعرف الطالب على Application Areas of Thermodynamics
الأهداف السلوكية او مخرجات التعلم:	١- ان يتعرف الطالب على - Thermodynamics ٢- ان يتعرف الطالب على - IMPORTANCE OF DIMENSIONS AND UNITS
استراتيجيات التيسير المستخدمة	محاضرة وعمل تعاوني ومناقشة
المهارات المكتسبة	اكساب المتعلم المعرفة Application Areas of Thermodynamics و- IMPORTANCE OF DIMENSIONS AND UNITS
طرق القياس المعتمدة	التغذية الراجعة

٤ - الاسئلة القبليّة :

- ١ - ماذا يقصد بمصطلح Thermodynamics
- ٢ - ماهي الأشياء المحيطة بنا التي تعتمد على علم Thermodynamics

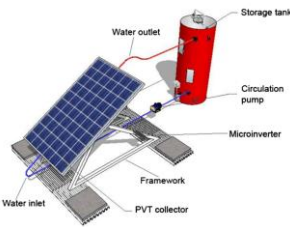
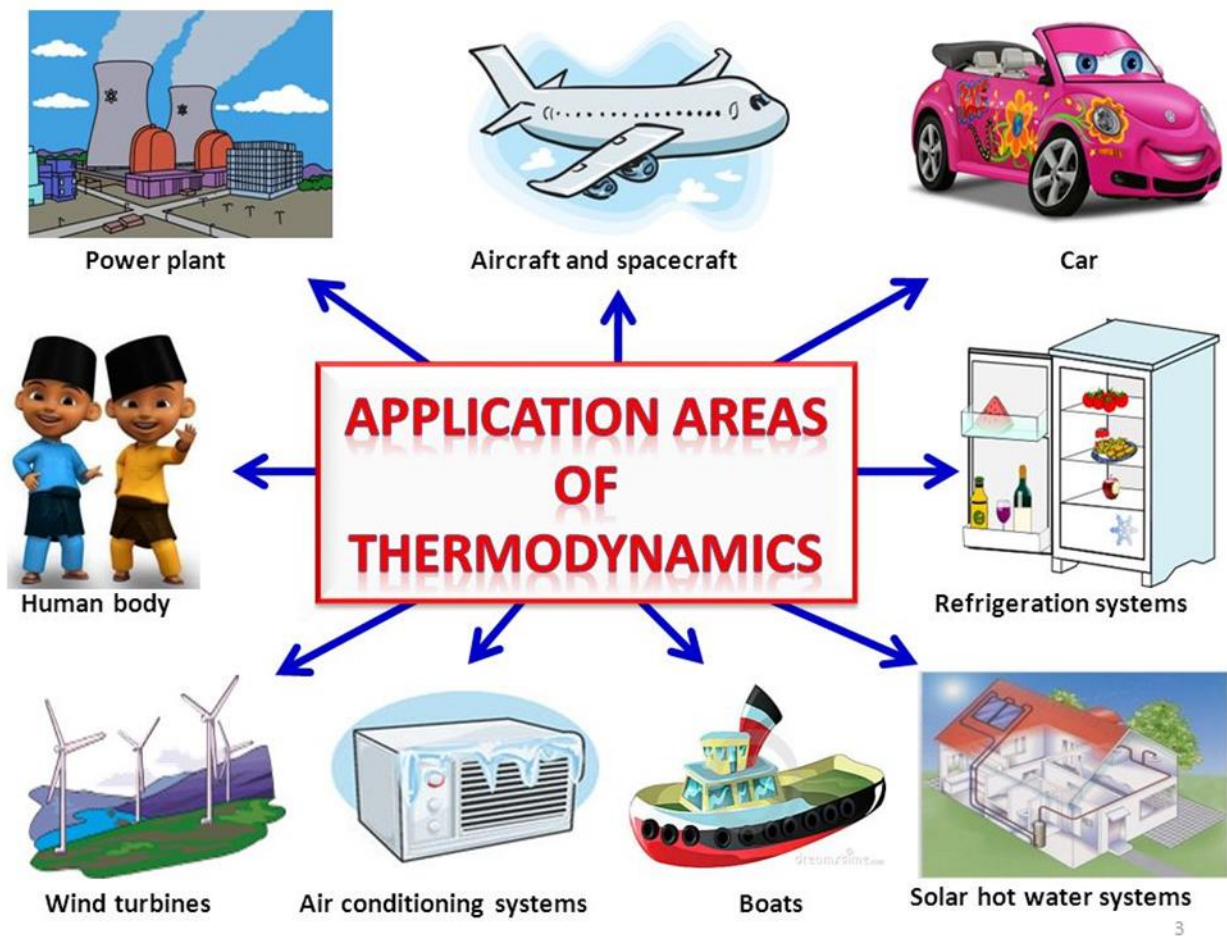
٥- المحتوى العلمي:

1.1.Thermodynamics

General definition of thermodynamic is derived from Greek words "*therm*" meaning "*heat* " and "*dynamics*" meaning "*strength*" particularly applied to motion , then thermodynamics would mean the heat liberated by the burning of wood , coal or oil.

Thermodynamic: is the science that deals with energy transformations, the conversion of heat to work or work to heat or chemical into electrical energy etc. .

1.2. Application Areas of Thermodynamics



1.3. IMPORTANCE OF DIMENSIONS AND UNITS

Symbol	Quantity	المصطلحات	SI Units
A	Area	المساحة	m^2
a	Acceleration	التعجيل	m/s^2
c	Specific heat	الحرارة النوعية	$J/kg \cdot K$
D	Diameter	القطر	m
E	Energy	الطاقة	J
F	Force	القوة	N

g	Local acceleration of gravity	التعجيل الارضي	m/s ²
H	Enthalpy	الانثالبي	J
h	Specific enthalpy	الانثالبي النوعي	J/kg
L	Length	الطول	m
m	Mass	الكتلة	kg
m	Mass flow rate	معدل التدفق الكتلي	kg/s
p	Pressure	الضغط	Pa
p	Power	القدرة	J
Q	Heat	الحرارة	J
Q̇	Heat rate	معدل الحرارة	J/s
t	Time	الزمن	s
v	Velocity	السرعة	m/s
V	Volume	الحجم	m ³
v	Specific volume	الحجم النوعي	m ³ /kg
ρ	Density	الكثافة	kg/m ³

Table 1.2 Prefixes for SI Units

Multiplication Factor	Prefix	Symbol
10 ¹²	tera	T
10 ⁹	giga	G
10 ⁶	mega	M
10 ³	kilo	k
10 ⁻²	centi*	c
10 ⁻³	mili	m
10 ⁻⁶	micro	μ
10 ⁻⁹	nano	n
10 ⁻¹²	pico	p

1.4 . Principles

Force (F) : is required energy to move 1 kg of mass in an acceleration of 1 m/s². "" N or kN ""

$$F = m * a \quad \text{" kg. m/s}^2 = \text{N"}$$

m: mass " g or Kg""

a: acceleration $\frac{m}{s^2}$

EXAMPLE (1-1)

Man 90kg has weight in the aircraft that its acceleration is 6 g's (in multiples of the standard acceleration of gravity). Determine the upward force, in N?

$$F = m \cdot a$$

$$= m \cdot (6)g$$

$$= 90 \cdot 6 \cdot 9.81 = \mathbf{5297 \text{ N}}$$

Density (ρ): is the mass per unit volume .

$$\rho = \frac{m}{V} \text{ " kg/m}^3 \text{ "}$$

$$\rho: \text{density " kg/m}^3 \text{ "} \quad m = \text{mass " kg" } \quad V = \text{volume "m}^3$$

EXAMPLE (1-2)

Find **density** of water has mass 1000kg and volume 1 m³.

Solution:

$$\rho = \frac{m}{V} \quad \rho = \frac{1000 \text{ kg}}{1 \text{ m}^3} = 1000 \text{ kg/m}^3$$

Volume (V) : is the space that fill by mass of material "V"

$$V = \text{volume "m}^3$$

EXAMPLE (1-3)

Find volume of water has $\rho = 1000 \text{ kg/m}^3$ and mass of 1kg.

Solution:

$$\rho = 1000 \text{ kg/m}^3, \quad m = 1 \text{ kg},$$

$$\rho = \frac{m}{V} \quad V = \frac{m}{\rho} \quad V = \frac{1}{1000} = 0.001 \text{ m}^3$$

Specific volume (\mathcal{V}) is the volume per unit mass.

$$\mathcal{V} = \frac{V}{m} \text{ " m}^3/\text{kg} \text{ "}$$

EXAMPLE(1-4)

Find **volume** of 1/2 m³/kg specific volume and mass of 1000kg.

Solution:

$$\mathcal{V} = \frac{1}{2} \text{ m}^3/\text{kg} , \quad m = 1000 \text{ kg} ,$$

$$\mathcal{V} = \frac{V}{m} \implies V = \mathcal{V} \cdot m = 0.5 \cdot 1000 = 500 \text{ m}^3$$

Specific Weight γ

The specific weight is the weight per unit volume of a material. The symbol of specific weight is γ (the Greek letter Gamma). A commonly used value is the specific weight of water on Earth at 4°C which is 9.807 kN/m³ " γ " Specific Weight is related to density through

$$\gamma = \frac{\text{Weight}}{\text{Volume}} = \frac{m \cdot g}{V} = \rho \cdot g \text{ " N/m}^3 \text{ "}$$

EXAMPLE (1-5)

The mass of air in a room $3\text{m} \times 5\text{m} \times 20\text{m}$ is known to be 350 kg. Determine the density, specific volume, and specific weight of the air.

$$V = 3 * 5 * 20 \text{ (m}^3\text{)}, \quad \rho = ??, \quad \mathcal{V} = ?? \quad \text{And } \gamma = ??$$

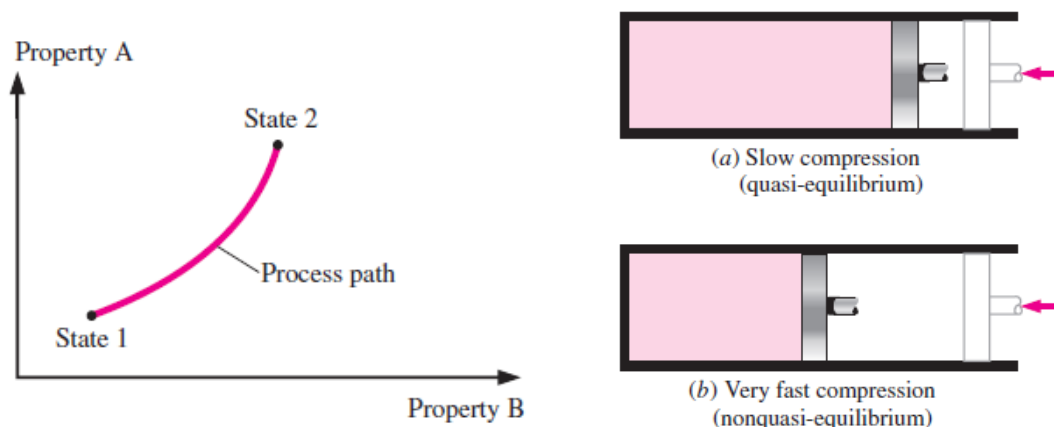
$$\rho = \frac{m}{V} = \frac{350}{3 * 5 * 20} = 1.167 \text{ kg/m}^3$$

$$\mathcal{V} = \frac{1}{\rho} = \frac{1}{1.167} = 0.857 \text{ m}^3/\text{kg}$$

$$\gamma = \rho \cdot g = 1.167 * 9.81 = 11.45 \text{ N/m}^3$$

1.5. PROCESSES

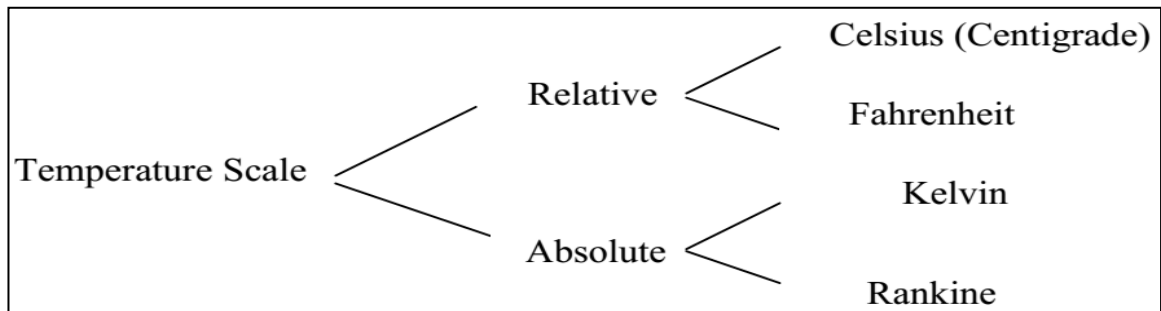
Any change that a system undergoes from one equilibrium state to another is called a process, and the series of states through which a system passes during a process is called the path of the process (Fig. 1–26). To describe a process completely, one should specify the initial and final states of the process, as well as the path it follows, and the interactions with the surroundings.

**1.6. TEMPERATURE AND THE ZEROTH LAW OF THERMODYNAMICS**

The word temperature comes from the Latin word *temperatura* meaning “*proper mixing or tempering*”, implying attainment of thermal equilibrium. The zeroth law of thermodynamics states that if two thermodynamic systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other. Accordingly, thermal equilibrium between systems is a transitive relation.

TEMPERATURE (T)

Temperature is an indication of the thermal energy stored in a thermodynamic system. Temperature is therefore called the *driving force of heat*. Temperature is measurable and is one of the most important properties of a thermodynamic system. The absolute temperature scales are the **Rankine (R°)** scale and the



Kelvin (K) scale, respectively.

The most common type of temperature measuring device is the **thermometer**. **Metric temperature** scales are selecting reference temperatures corresponding to reproducible state points (**ice point and steam point**). In the English unit system and SI unit system, the metric temperature scales are the **Fahrenheit (F°)** scale and the **Celsius (C°)** scale respectively.

$$^{\circ}\text{F} = (9/5)^{\circ}\text{C} + 32 \quad \text{and} \quad ^{\circ}\text{C} = (5/9)(^{\circ}\text{F} - 32)$$

The absolute temperature scale is related to the metric temperature scale by the relationships:

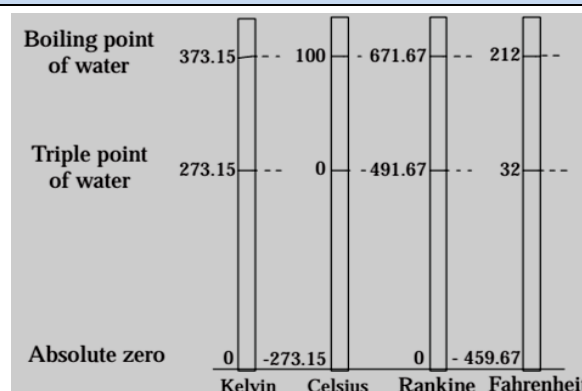
$$\text{K} = ^{\circ}\text{C} + 273^{\circ} \quad \text{and} \quad \text{R} = ^{\circ}\text{F} + 460^{\circ}$$

Example,(1- 6): If $T_C = (-1)$ find T_F , T_K and T_R .

$$T_F = 1.8 T_C + 32 = 1.8 * (-1) + 32 = 30.2 \text{ (F)}$$

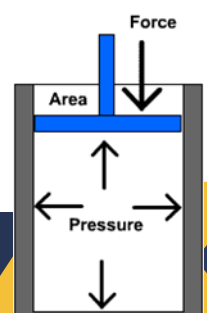
$$T_R = T_F + 460 = 30.2 + 460 = 490.2 \text{ }^{\circ}\text{R}$$

$$T_K = T_C + 273 = (-1) + 273 = 272 \text{ K}$$



1.7. PRESSURE

Pressure is defined as a normal force exerted by a system per unit area. We speak of pressure only when we deal with a gas or a liquid. Since pressure is defined as force per unit area, it has the unit of newton per square meter (N/m^2), which is called a Pascal (Pa).



PRESSURE: is the force per unit area.

$$P = \frac{F}{A} \quad " \frac{N}{m^2} = Pascal$$

P: pressure " N/m² " , F= Force " N" and A=Area "m²"

Pressure is measurable and is one of the most important properties of a thermodynamic system

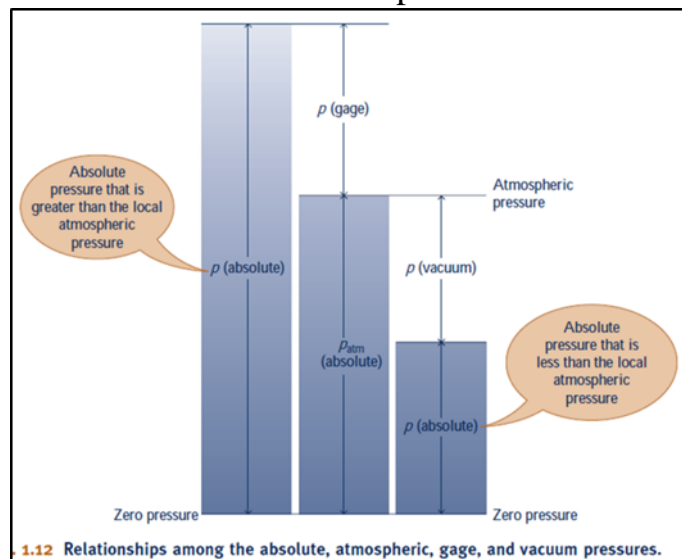
There are two different pressures are common in engineering practice: (1) **gage** pressure and (2) **absolute** pressure. The difference between gage and absolute pressure should be understood.

Absolute Pressure (p_{abs}) is defined as a vacuum that has zero pressure. The cases in which this pressure is used include the readings of atmospheric pressure in which air pressure, boiling point of the water or mean pressure of the sea level can be determined.

Gage Pressure(p_{gage}) is the value measured by a pressure gauge, which indicates the pressure difference between a system and its ambient, usually the atmosphere.

Atmospheric Pressure(p_{atm}) is due to the weight of the air per unit horizontal area in the earth's gravitational field.

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



The units of pressure commonly used are inch or mm of mercury (Hg), kPa, MPa, bar, psi, etc. The most used thermodynamic unit of pressure in **SI unit** is kilo-Pascal (kPa) or kilo-newton per square meter, and **(psi) or pound force per square inch** in English unit. Sometimes the unit bar is used for pressure.

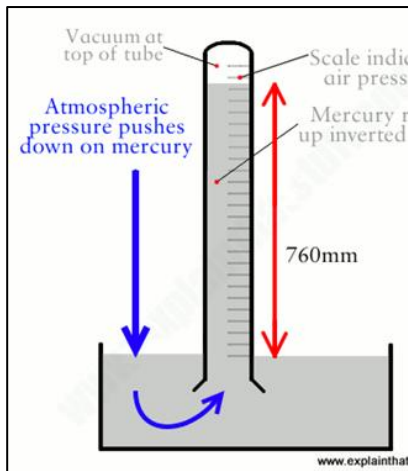
$$1 \text{ bar} = 100 \text{ kPa.} \quad \text{Or} \quad 1 \text{ bar} = 10^5 \text{ Pa} \quad 1 \text{ N/m}^2 = \text{pa} , \quad 1 \text{ Kpa} = 1000 \text{ pa} ,$$

The standard atmospheric pressure at sea level is (**29.92 in Hg, 760 mm Hg, 101.3 kPa, 0.1013 MPa, 1.013 bar and 14.69 psi**) depending upon the units used.

Devices Measure Pressures

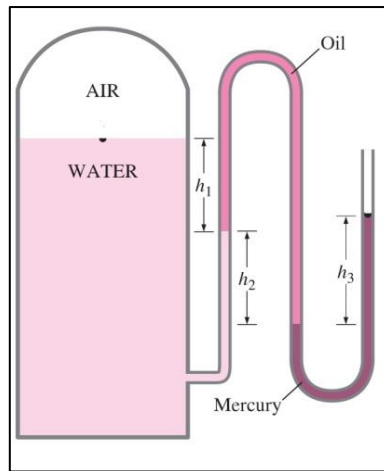
Barometers are used to measure atmospheric pressure, and usually use mercury as a manometer fluid. Common devices for measuring pressures are a Bourdon gage and a manometer as shown in Figures.

a) Barometer.



gage

b) Manometer



c) Borden



EXAMPLE (1-7)

: prove that $P = \rho g h$ for liquid columns or tanks (statics liquid)?

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

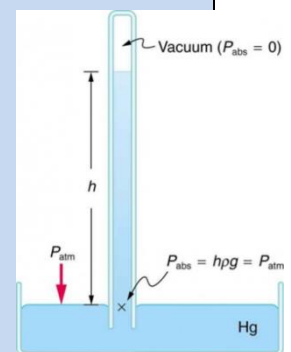
For liquid $F = W_{\text{water}} = m * g$ substitute in pressure equation

$$P = \frac{m \cdot g}{A}$$

$$P = \frac{m \cdot g}{A} \times \frac{h}{h}$$

$$P = \frac{m \cdot g \cdot h}{V}$$

$$P = \rho \cdot g \cdot h$$



Example (1-8):

If barometer read 10cm Hg (mercury) find the pressure must be in (psi) unit.
1bar =14.7 psi

Solution:- $\rho_{\text{Hg}} = 13600 \text{ kg/m}^3$ & $h = 10 \text{ cm Hg} = 0.1 \text{ m Hg}$

$P = \rho \cdot g \cdot h = 13600 * 9.81 * 0.1 = 13341.6 \text{ Pa}$

$$P = 13341.6 / 100000 = 0.133 \text{ bar}$$

$$P = 0.133 * 14.7 = 1.955 \text{ psi}$$

Example (1-9)

Pressure of 29.4 (psi) find the height of barometer must be, if contain mercury (Hg).

Solution:- $P = 29.4 \text{ psi}$, $h = ?$

$$P = 29.4 / 14.7 = 2 \text{ bar}$$

$$P = 2 * 100000 = 200000 \text{ Pa} = \text{N/m}^2$$

$$P = \rho \cdot g \cdot h \quad h = \frac{P}{\rho \cdot g} = \frac{200000}{13600 * 9.81} = 1.49 \text{ m}$$

Example (1-10)

Atmospheric pressure is 1bar and gage pressure is (152 cm Hg) find absolute pressure.

Note: take ($g = 9.81 \text{ m/s}^2$, $\rho_{\text{Hg}} = 13600 \text{ kg/m}^3$ and $\rho_w = 1000 \text{ kg/m}^3$).

Solution:- $P_{\text{atm}} = 1 \text{ bar}$, $h = 152 \text{ cm Hg}$, $P_{\text{abs}} = ?$

$$h = 152 / 100 = 1.52 \text{ m}$$

$$P_{\text{gage}} = \rho \cdot g \cdot h = 13600 * 9.81 * 1.52 = 202792.32 \text{ Pa}$$

$$P_{\text{gage}} = 202792.32 / 100000 = 2.027 \text{ bar}$$

$$P_{\text{abs}} = P_{\text{atm}} + P_{\text{gage}} = 1 + 2.027 = 3.027 \text{ bar}$$

٦- الاسئلة البعدية

- 1- Atmospheric pressure is 1bar and gage pressure is (130 cm Hg) find absolute pressure.
- 2- prove that $P = \rho g h$ for liquid columns or tanks (statics liquid)?

المحاضرة الثالثة	Energy
عنوان المحاضرة:	عمر محمود جمعة
اسم المدرس:	المستوى الأول من قسم تقنيات التبريد
الفئة المستهدفة :	تعريف الطالب ماهي Energy
الهدف العام من المحاضرة :	• ١- ان يتعرف الطالب على Stored Energies • ٢- ان يتعرف الطالب على Transit Energy
الأهداف السلوكية او مخرجات التعلم:	محاضرة وعمل تعاوني ومناقشة
استراتيجيات التيسير المستخدمة	اكساب المتعلم المعرفة بانواع الطاقة وطريقة حسابها
المهارات المكتسبة	التغذية الراجعة
طرق القياس المعتمدة	

٤ - الاسئلة القبلية :

١ - ماذا يقصد بمصطلح Energy

٢ - كيف يمكن حساب Energy

٥- المحتوى العلمي:

Energy

2.1. ENERGY: is a thing capable to produce an effect on the masses.

It is divided into two types:

- **Stored Energies:** like potential energy, kinetic energy, internal energy, chemical energy, electrical energy
- **Transit Energy:** like work and heat which they are the only energy that capable to transit the boundary of the system.

1. **Potential Energy (P E):** energy possessed by a mass due to its position from a certain reference line (i.e. it is a function of height).

$$PE = m. g. h \quad "J \text{ or } KJ"$$

(h) is the height of each particle of substance. And change in its magnitude is given by the following equ.

$$\Delta PE = m. g. (h_2 - h_1)$$



EXAMPLE (2-1):

A mass of 30kg is positioned at 5 m from a reference line (*R.L*). Calculate its *P.E.* and if position became 12 m from the same *R.L*, Calculate the change in *PE*.

Solution:

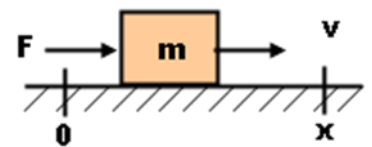
$$\begin{aligned}
 P.E &= m. g. h \\
 &= 30 * 9.81 * 5 = 1500 J \\
 \Delta PE &= m. g. (h_2 - h_1) \\
 &= 30 * 9.81(12 - 5) = 2060.1J
 \end{aligned}$$

2. Kinetic Energy (*K'E*): is energy possessed by a mass (fluid or solid body) due to its motion with a certain velocity (*v*),

$$K.E = \frac{1}{2}mv^2 \quad "J \text{ or } KJ"$$

And change in its magnitude is given by the following equ

$$\Delta K.E = \frac{1}{2}m(v_2^2 - v_1^2)$$

**EXAMPLE (2-2):**

A mass of 50 kg moves with velocity of 8 m/sec . Calculate its *K.E.* and if the velocity changed to 3 m/sec, Calculate the changed in the magnitude of the *K.E.*

Solution: $K.E = \frac{1}{2}mv^2 = \frac{1}{2} * 50 * 8^2 = 25 * 64 = 1600J$

$$\begin{aligned}
 \Delta K.E &= \frac{1}{2}m(v_2^2 - v_1^2) = \frac{1}{2}50(3^2 - 8^2) \\
 &= 25 * (-55) = -1375 J
 \end{aligned}$$

EXAMPLE (2-3):

A site evaluated for a wind farm is observed to have steady winds at a speed of 8.5 m/s. Determine the wind energy (a) per unit mass, (b) for a mass of 10 kg, and (c) for a flow rate of 1154 kg/s for air.

Solution: A site with a specified wind speed is considered. Wind energy per unit mass, for a specified mass, and for a given mass flow rate of air are to be determined.

(a) Wind energy per unit mass of air is

$$e = \frac{1}{2}v^2 = \frac{1}{2} * 8.5^2 = 36.1J/kg$$

b) Wind energy for an air mass of 10 kg is

$$E = \frac{1}{2} v^2 * m = 10 * 36.1 = 361 J$$

c) Wind energy for a mass flow rate of 1154 kg/s

$$E = e\dot{m} = 1154 * 36.1 = 41.7 kw$$

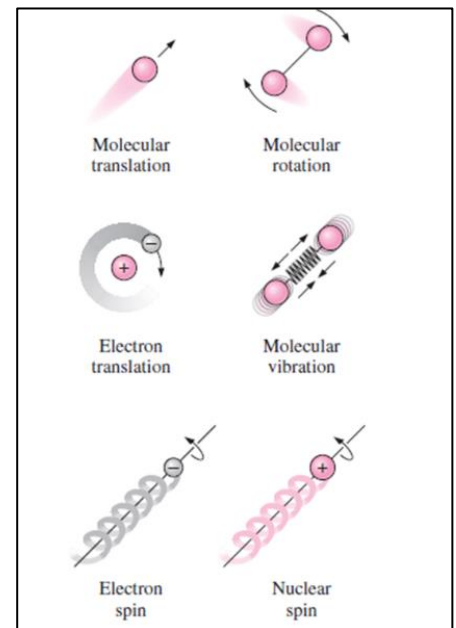
3- Internal Energy (I.E) (U) is energy possessed by a mass due to its temperature (hotness or coldness of the mass) i.e. $I.E(U) = f(T)$ and its magnitude is given by the equ.

$$I.E(U) = mcT$$

Where (c) is Specific heat capacity

And the change in its magnitude is given by the equ.

$$I.E(\Delta U) = mc\Delta T = mc(T_2 - T_1)$$



EXAMPLE (2-5):

A fluid of mass 10 kg temperature of 20 C°. Calculate its I.E (U) and if its temperature is increased to 50 C°. the change in its magnitude; c is equal to 0.714 kJ/kg. K°.

Solution :

$$T_1 = 20 + 273 = 293 K^\circ \quad \& \quad T_2 = 50 + 273 = 323 K^\circ$$

$$I.E(U) = mC_v T = 10 * 714 * 293 = 2092020 J = 2092.02 KJ$$

$$I.E(\Delta U) = mC_v(T_2 - T_1) = 10 * 714(323 - 293) = 214200 J = 214.2 KJ$$

4- Total Energy (T.E): possessed by a mass is equal to sum of the three magnitude energy above .ie.

$$T.E = P.E + K.E + I.E$$

And the change in its magnitude is

$$\Delta T.E = \Delta P.E + \Delta K.E + \Delta I.E$$

EXAMPLE (2-6):

A gas of mass rate (\dot{m}) 32 kg/ sec is transferred during a pipe rises 61m from sea level at a temperature 150 C° and velocity of 6m/sec if the specific heat at constant volume (c) for it is equal to 0.6741 kJ/kg.k°, find $P.E$, $K.E$, $I.E$ and $T.E$ for the gas.

Solution $c = 0.6741 \text{ kJ/kg.k}^\circ = 674.1 \text{ J/kg.k}^\circ$

$$P.E = mgh = 32 * 9.81 * 61 = 191149 \text{ J/sec} = 19.149 * 10^3 \text{ watt}$$

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}32 * 6^2 = 576 \text{ J/sec} = 576 \text{ watt}$$

$$I.E = mcT = 32 * 674.1 * (150 + 273) = 9124617 \text{ J/s} = 9124617 \text{ watt}$$

$$T.E = P.E + K.E + I.E$$

$$= 191149 + 576 + 9124617 = 9144342 \text{ watt}$$

٦ - الاسئلة البعدية

- 1- A gas of mass rate (\dot{m}) 40 kg/ sec is transferred during a pipe rises 65m from sea level at a temperature 155 C° and velocity of 7m/sec if the specific heat at constant volume (c) for it is equal to 0.6741 kJ/kg.k°, find $P.E, K.E, I.E$ and $T.E$ for the gas.

المحاضرة الثالثة	عنوان المحاضرة:
Pure Substance and Steam Table	اسم المدرس:
عمر محمود جمعة	الفئة المستهدفة :
المستوى الأول من قسم تقنيات التبريد	الهدف العام من المحاضرة :
• تعريف الطالب ماهي المادة النقية وما هي جداول البخار	الأهداف السلوكية او مخرجات التعلم:
٣- ان يتعرف الطالب على Pure Substance	استراتيجيات التيسير المستخدمة
٤- ان يتعرف الطالب على Steam Table	المهارات المكتسبة
محاضرة وعمل تعاوني ومناقشة وحل للمسائل	طرق القياس المعتمدة
اكساب المتعلم المعرفة	
Pure Substance and Steam Table	
التغذية الراجعة	

٤ - الاسئلة القبلية :

١ - ماذا يقصد بمصطلح Pure Substance

٢ - كيف يمكن ان نستخدم جداول البخار

٥ - المحتوى العلمي:

PURE SUBSTANCE

A substance that has a *fixed chemical composition throughout* is called a *pure substance*. Water, nitrogen, helium, and carbon dioxide, for example, are all pure substances. A pure substance does not have to be of a single chemical element or compound, however. A mixture of various chemical elements or compounds also qualifies as a pure substance as long as the mixture is homogeneous.

Air, for example, is a mixture of several gases, but it is often considered to be a pure substance because it has a uniform chemical composition (Fig. 3–1). However, a mixture of oil and water is not a pure substance. Since oil is not soluble in water, it will collect on top of the water, forming two chemically dissimilar regions.

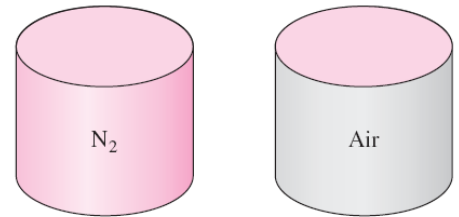


FIGURE 3–1

Nitrogen and gaseous air are pure substances.

PHASES OF A PURE SUBSTANCE

We all know from experience that substances exist in different phases. At room temperature and pressure, copper is a solid, mercury is a liquid, and nitrogen is a gas. Under different conditions, each may appear in a different phase. Even though there are three principal phases—solid, liquid, and gas—a substance may have several phases within a principal phase, each with a different molecular structure. Carbon, for example, may exist as graphite or diamond in the solid phase. Helium has two liquid phases; iron has three solid phases. Ice may exist at seven different phases at high pressures. A phase is identified as having a distinct molecular arrangement that is homogeneous throughout and separated from the others by easily identifiable boundary surfaces. The two phases of H_2O in iced water represent a good example of this.

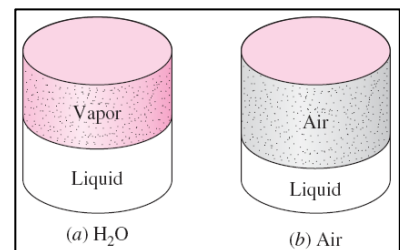


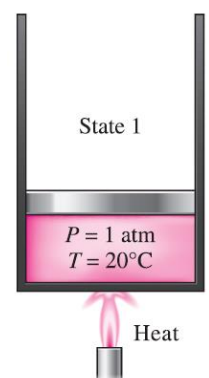
FIGURE 3–2

A mixture of liquid and gaseous water is a pure substance, but a mixture of liquid and gaseous air is not.

Phase – Change Processes of Pure Substances

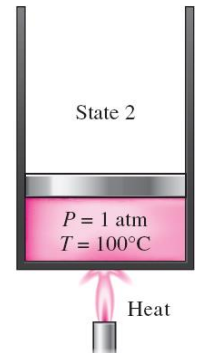
At this point, it is important to consider the liquid to solid phase change process. Not so much solid to liquid because thermodynamics deals only with liquid to gases (or vice versa) to generate power.

- 1- Consider water at room temperature (20°C) and normal atmospheric pressure (1atm) in a piston-cylinder device. The water is in liquid phase, and it is called **compressed liquid** or **subcooled liquid** (not about to vaporize). (Point 1)

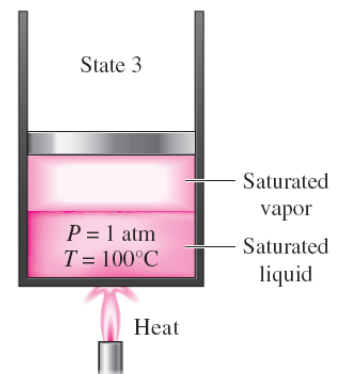


If we add heat to water, its temperature will increase; let us say until 50°C . Due to the increase in temperature, the specific volume v will increase. As a consequence, the piston will move slightly upward therefore maintaining constant pressure (1 atm).

- 2- Now, if we continue to add heat to the water, the temperature will increase further until 100°C . At this point, any additional addition of heat will vaporize some water. This specific point where water starts to vaporize is called **saturated liquid**. (Point 2)



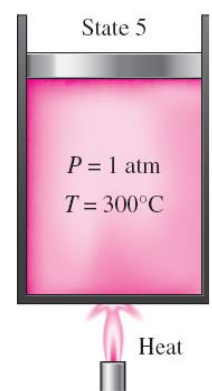
- 3- The state between saturated liquid (only liquid) and saturated vapor (only vapor) where two phases exist is called **saturated liquid-vapor mixture**. (Point 3)



- 4- If we continue to add heat to water, more and more vapor will be created, while the temperature and the pressure remain constant ($T = 100^{\circ}\text{C}$ and $P = 1 \text{ atm}$). The only property that changes is the specific volume. These conditions will remain the same until the last drop of liquid is vaporized. At this point, the entire cylinder is filled with vapor at 100°C . This state is called **saturated vapor** (Point 4)



- 5- After the saturated vapor phase, any addition of heat will increase the temperature of the vapor, this state is called **superheated vapor** (Point 5).



If the entire process between state 1 and 5 described in the figure is reversed by cooling the water while maintaining the pressure at the same value, the water will go back to state 1, retracing the same path, and in so doing, the amount of heat released will exactly match the amount of heat added during the heating process.

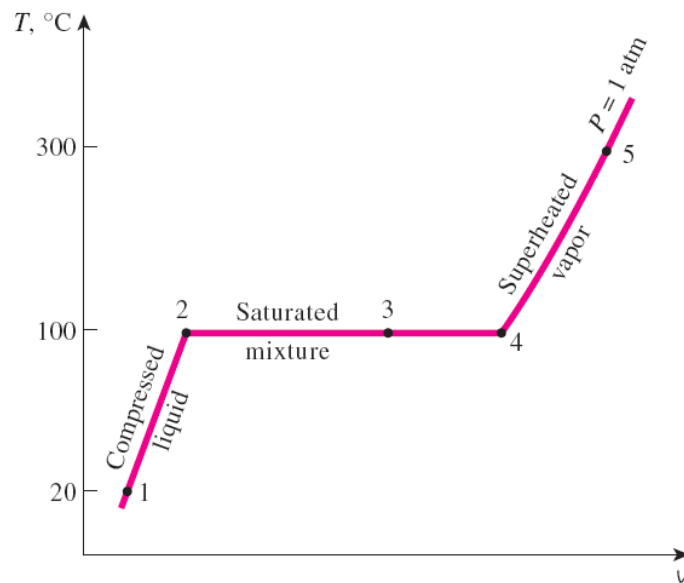


Figure 1 T-v diagram for the heating process of water at constant pressure.

PROPERTY TABLES

For most substances, the relationships among thermodynamic properties are too complex to be expressed by simple equations. Therefore, properties are frequently presented in the form of tables. Some thermodynamic properties can be measured easily, but others cannot and are calculated by using the relations between them and measurable properties. The results of these measurements and calculations are presented in tables in a convenient format.

In thermodynamics analysis, we will encounter the combination of properties $U+PV$ frequently. For simplicity this combination is defined as a new property called **enthalpy**

Enthalpy: is a property for the working substance (fluid) and is equal to the sum of two properties internal energy & flow energy (flow work), i.e

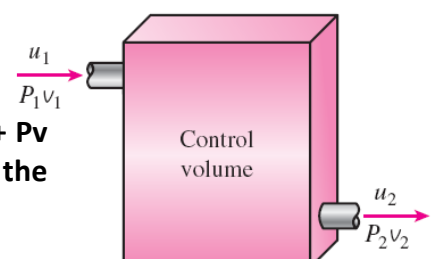
$$H = U + PV$$

And for unit mass

$$mh = m(u + pv) =$$

$$h = u + pv$$

Figure 2 The combination $u + Pv$ is frequently encountered in the analysis of control volumes.



H: is the total enthalpy of the fluid kJ.
 U: is the total internal energy of the fluid kJ.
 P: is the pressure of the fluid flowing kPa.
 V: is the volume of the fluid flowing m³
 h: is the enthalpy of the fluid per unit mass,
 u: is the internal energy of the fluid per unit mass.
 v: is the volume per unit mass (specific volume).

Saturated Liquid and Saturated Vapor States

The properties of saturated liquid and saturated vapor for water are listed in Tables A–4 and A–5. Both tables give the same information. The only difference is that in Table A–4 properties are listed under temperature and in Table A–5 under pressure. Therefore, it is more convenient to use Table A–4 when *temperature* is given and Table A–5 when *pressure* is given. The use of Table A–4 is illustrated in Fig. 3–30.

The subscript f is used to denote properties of a saturated liquid, and the subscript g to denote the properties of saturated vapor. These symbols are commonly used in thermodynamics and originated from German. Another subscript commonly used is *fg* which denotes the difference between the saturated vapor and saturated liquid values of the same property. For example,

v_f = specific volume of saturated liquid

v_g = specific volume of saturated vapor

v_{fg} = difference between v_g and v_f that is, $v_{fg} = (v_g - v_f)$

TABLE A–4

Saturated water—Temperature table

Temp., <i>T</i> °C	Sat. press., <i>P</i> _{sat} kPa	Specific volume, m ³ /kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg · K		
		Sat. liquid, <i>v</i> _f	Sat. vapor, <i>v</i> _g	Sat. liquid, <i>u</i> _f	Evap., <i>u</i> _{fg}	Sat. vapor, <i>u</i> _g	Sat. liquid, <i>h</i> _f	Evap., <i>h</i> _{fg}	Sat. vapor, <i>h</i> _g	Sat. liquid, <i>s</i> _f	Evap., <i>s</i> _{fg}	Sat. vapor, <i>s</i> _g
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556

The quantity h_{fg} is called the **enthalpy of vaporization** (or latent heat of vaporization). It represents the amount of energy needed to vaporize a unit mass of saturated liquid at a given temperature or pressure. It decreases as the temperature or pressure increases and becomes zero at the critical point.

EXAMPLE 3–1 Pressure of Saturated Liquid in a Tank

A rigid tank contains 50 kg of saturated liquid water at 90°C. Determine the pressure in the tank and the volume of the tank.

Solution A rigid tank contains saturated liquid water. The pressure and volume of the tank are to be determined.

Analysis The state of the saturated liquid water is shown on a T - v diagram in Fig. 3–31. Since saturation conditions exist in the tank, the pressure must be the saturation pressure at 90°C:

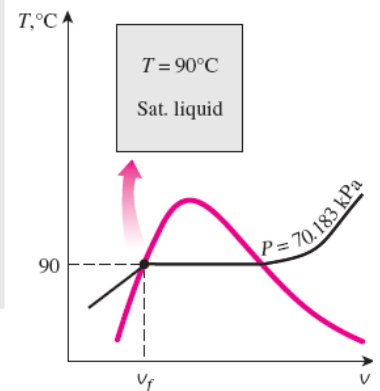
$$P = P_{\text{sat @ } 90^\circ\text{C}} = \mathbf{70.183 \text{ kPa}} \quad (\text{Table A-4})$$

The specific volume of the saturated liquid at 90°C is

$$v = v_f @ 90^\circ\text{C} = 0.001036 \text{ m}^3/\text{kg} \quad (\text{Table A-4})$$

Then the total volume of the tank becomes

$$V = m v = (50 \text{ kg})(0.001036 \text{ m}^3/\text{kg}) = \mathbf{0.0518 \text{ m}^3}$$



Example 3-2: A piston—cylinder device contains 2 m³ of saturated water vapor at 350 kPa pressure. Determine the temperature and the mass of the vapor inside the cylinder.

Solution A cylinder contains saturated water vapor. The temperature and the mass of vapor are to be determined.

$$\mathbf{T = T_{\text{sat @ } 350 \text{ kPa}} = 138.86^\circ\text{C}} \quad (\text{Table A-5})$$

The specific volume of the saturated vapor at 350 kPa is

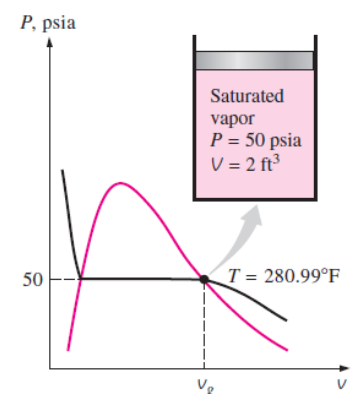
$$v_g = 0.52422 \text{ m}^3/\text{kg} \quad (\text{Table A-5})$$

The mass of the vapor inside the cylinder

$$m = V / v_g$$

$$= 2 \text{ m}^3 / 0.52422 \text{ m}^3/\text{kg}$$

$$\mathbf{= 3.815 \text{ kg}}$$



Saturated Liquid–Vapor Mixture

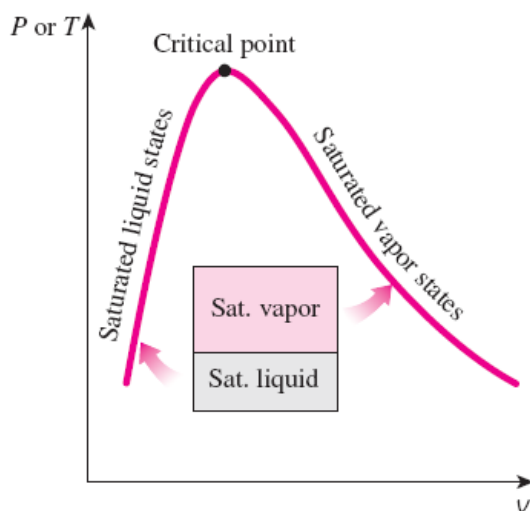
During a vaporization process, a substance exists as part liquid and part vapor. That is, it is a mixture of saturated liquid and saturated vapor (Fig. 3–34). To analyze this mixture properly, we need to know the proportions of the liquid and vapor phases in the mixture. This is done by defining a new property called the **quality** x as the ratio of the mass of vapor to the total mass of the mixture:

$$x = \frac{m_{\text{vapor}}}{m_{\text{total}}}$$
$$m_{\text{total}} = m_{\text{liquid}} + m_{\text{vapor}} = m_f + m_g$$

Quality, x : The ratio of the mass of vapor to the total mass of the mixture.

Quality is between 0 and 1 0: sat. liquid, 1: sat. vapor.

The properties of the saturated liquid are the same whether it exists alone or in a mixture with saturated vapor.



The relative amounts of liquid and vapor phases in a saturated mixture are specified by the quality x .

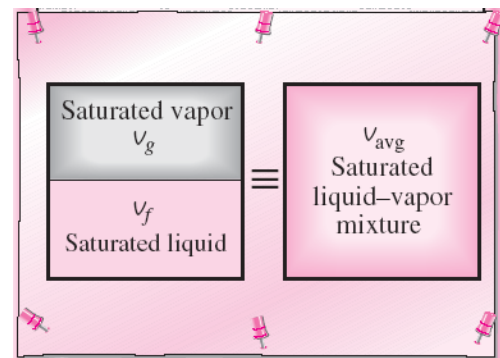


Figure . A two-phase system can be treated as a homogeneous mixture for convenience.

$$V = V_f + V_g$$

$$V = mV \longrightarrow m_t V_{\text{avg}} = m_f V_f + m_g V_g$$

$$m_f = m_t - m_g \longrightarrow m_t V_{\text{avg}} = (m_t - m_g) V_f + m_g V_g$$

Dividing by m_t yields

$$v_{\text{avg}} = (1 - x) v_f + x v_g$$

since $x = m_g/m_t$. This relation can also be expressed as

$$v_{\text{avg}} = v_f + x v_{fg} \quad (\text{m}^3/\text{kg})$$

where $v_{fg} = v_g - v_f$. Solving for quality, we obtain

$$x = \frac{v_{\text{avg}} - v_f}{v_{fg}}$$

Based on this equation, quality can be related to the horizontal distances on a P - v or T - v diagram (Fig. 3–36). At a given temperature or pressure, the numerator of Eq. 3–5 is the distance between the actual state and the saturated liquid state, and the denominator is the length of the entire horizontal line that connects the saturated liquid and saturated vapor states. A state of 50 percent quality lies in the middle of this horizontal line. The analysis given above can be repeated for internal energy and enthalpy with the following results:

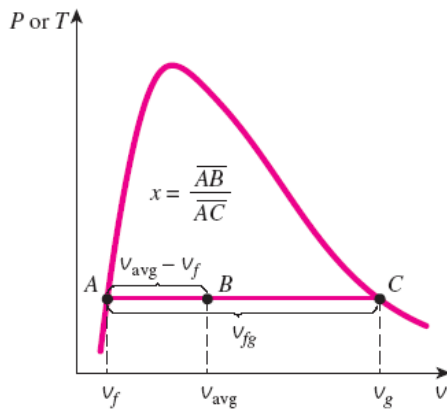


FIGURE 3–34

Quality is related to the horizontal distances on P - v and T - v diagrams.

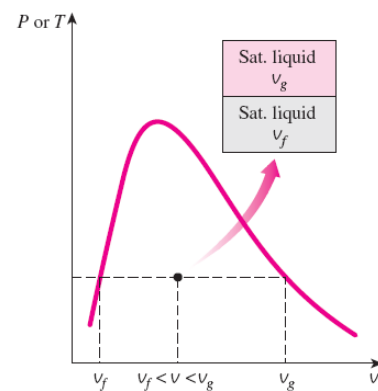


FIGURE 3–35

The v value of a saturated liquid–vapor mixture lies between the v_f and v_g values at the specified T or P .

$$u_{\text{avg}} = u_f + x u_{fg} \quad (\text{kJ/kg})$$

$$h_{\text{avg}} = h_f + x h_{fg} \quad (\text{kJ/kg})$$

EXAMPLE 3–4 Pressure and Volume of a Saturated Mixture

A rigid tank contains 10 kg of water at 90°C. If 8 kg of the water is in the liquid form and the rest is in the vapor form, determine (a) the pressure in the tank and (b) the volume of the tank.

Solution A rigid tank contains saturated mixture. The pressure and the volume of the tank are to be determined.

Analysis (a) The state of the saturated liquid–vapor mixture is shown in Fig. 3–38. Since the two phases coexist in equilibrium, we have a saturated mixture, and the pressure must be the saturation pressure at the given temperature:

$$P = P_{\text{sat @ } 90^\circ\text{C}} = \mathbf{70.183 \text{ kPa}} \quad (\text{Table A-4})$$

(b) At 90°C, we have $\nu_f = 0.001036 \text{ m}^3/\text{kg}$ and $\nu_g = 2.3593 \text{ m}^3/\text{kg}$ (Table A-4). One way of finding the volume of the tank is to determine the volume occupied by each phase and then add them:

$$\begin{aligned} V &= V_f + V_g = m_f \nu_f + m_g \nu_g \\ &= (8 \text{ kg})(0.001036 \text{ m}^3/\text{kg}) + (2 \text{ kg})(2.3593 \text{ m}^3/\text{kg}) \\ &= \mathbf{4.73 \text{ m}^3} \end{aligned}$$

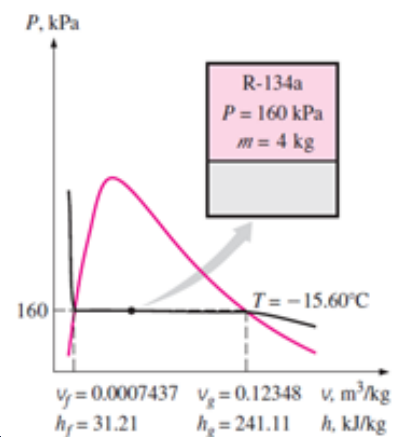
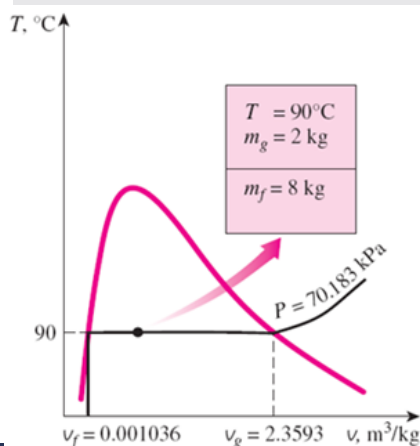
Another way is to first determine the quality x , then the average specific volume ν , and finally the total volume:

$$x = \frac{m_g}{m_t} = \frac{2 \text{ kg}}{10 \text{ kg}} = 0.2$$

$$\begin{aligned} \nu &= \nu_f + x \nu_{fg} \\ &= 0.001036 \text{ m}^3/\text{kg} + (0.2)[(2.3593 - 0.001036) \text{ m}^3/\text{kg}] \\ &= 0.473 \text{ m}^3/\text{kg} \end{aligned}$$

and

$$V = m\nu = (10 \text{ kg})(0.473 \text{ m}^3/\text{kg}) = 4.73 \text{ m}^3$$



EXAMPLE 3–5 Properties of Saturated Liquid–Vapor Mixture

An 80-L vessel contains 4 kg of refrigerant-134a at a pressure of 160 kPa. Determine (a) the temperature, (b) the quality, (c) the enthalpy of the refrigerant, and (d) the volume occupied by the vapor phase.

Solution A vessel is filled with refrigerant-134a. Some properties of the refrigerant are to be determined.
specific volume:

$$v = \frac{V}{m} = \frac{0.080 \text{ m}^3}{4 \text{ kg}} = 0.02 \text{ m}^3/\text{kg}$$

At 160 kPa, we read

$$\begin{aligned} v_f &= 0.0007437 \text{ m}^3/\text{kg} \\ v_g &= 0.12348 \text{ m}^3/\text{kg} \end{aligned} \quad (\text{Table A-12})$$

Obviously, $v_f < v < v_g$, and, the refrigerant is in the saturated mixture region. Thus, the temperature must be the saturation temperature at the specified pressure:

$$T = T_{\text{sat @ 160 kPa}} = -15.60^\circ\text{C}$$

(b) Quality can be determined from

$$x = \frac{v - v_f}{v_{fg}} = \frac{0.02 - 0.0007437}{0.12348 - 0.0007437} = 0.157$$

(c) At 160 kPa, we also read from Table A-12 that $h_f = 31.21 \text{ kJ/kg}$ and $h_{fg} = 209.90 \text{ kJ/kg}$. Then,

$$\begin{aligned} h &= h_f + xh_{fg} \\ &= 31.21 \text{ kJ/kg} + (0.157)(209.90 \text{ kJ/kg}) \\ &= 64.2 \text{ kJ/kg} \end{aligned}$$

(d) The mass of the vapor is

$$m_g = xm_t = (0.157)(4 \text{ kg}) = 0.628 \text{ kg}$$

and the volume occupied by the vapor phase is

$$V_g = m_g v_g = (0.628 \text{ kg})(0.12348 \text{ m}^3/\text{kg}) = 0.0775 \text{ m}^3 \text{ (or 77.5 L)}$$

The rest of the volume (2.5 L) is occupied by the liquid.

2 Superheated Vapor

In the region to the right of the saturated vapor line and at temperatures above the critical point temperature, a substance exists as superheated vapor. Since the superheated region is a single-phase region (vapor phase only), temperature and pressure are no longer dependent properties and they can conveniently be used as the two independent properties in the tables. The format of the superheated vapor tables is illustrated in Fig. 3–40. In these tables, the properties are listed against temperature for selected pressures starting with the saturated vapor data. The saturation temperature is given in parentheses following the pressure value. Compared to saturated vapor, superheated vapor is characterized by

Lower pressures ($P < P_{\text{sat}}$ at a given T)

Higher temperatures ($T > T_{\text{sat}}$ at a given P)

Higher specific volumes ($\nu > \nu_g$ at a given P or T)

Higher internal energies ($u > u_g$ at a given P or T)

Higher enthalpies ($h > h_g$ at a given P or T)

	ν	u	h
$T, ^\circ\text{C}$	m^3/kg	kJ/kg	kJ/kg
$P = 0.1 \text{ MPa } (99.61^\circ\text{C})$			
Sat.	1.6941	2505.6	2675.0
100	1.6959	2506.2	2675.8
150	1.9367	2582.9	2776.6
\vdots	\vdots	\vdots	\vdots
1300	7.2605	4687.2	5413.3
$P = 0.5 \text{ MPa } (151.83^\circ\text{C})$			
Sat.	0.37483	2560.7	2748.1
200	0.42503	2643.3	2855.8
250	0.47443	2723.8	2961.0

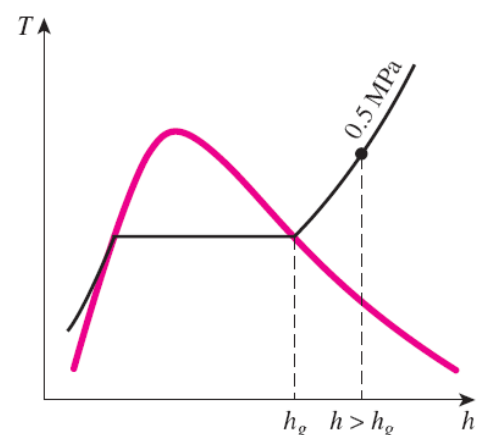


Figure 3A partial listing of Table A–6

EXAMPLE 3–7 Temperature of Superheated Vapor

Determine the temperature of water at a state of $P = 0.5$ MPa and $h = 2890$ kJ/kg.

Solution The temperature of water at a specified state is to be determined.

Analysis At 0.5 MPa, the enthalpy of saturated water vapor is $h_g = 2748.1$ kJ/kg. Since $h > h_g$, as shown in Fig. 3–41, we again have superheated vapor. Under 0.5 MPa in Table A–6 we read

$T, ^\circ\text{C}$	$h, \text{kJ/kg}$
200	2855.8
250	2961.0

Obviously, the temperature is between 200 and 250°C. By linear interpolation it is determined to be

$$T = 216.3^\circ\text{C}$$

The Ideal Gas Equation of State

When a vapor of a substance has relatively low density (temperatures are in excess of the critical temperatures , and also at very low pressures) , the vapor of the fluid tends to obey the equation;

$$\frac{Pv}{T} = \text{constant} = R$$

Where; P – is absolute pressure $\frac{N}{m^2}$

T – is absolute temperature (K° , R).

v – is specific volume $\frac{m^3}{kg}$

R – is a constant which is called the gas constant, and each gas has a different gas constant.

In practice, no gases obey this equation rigidly, but many gases tend toward it. Any gas for which this equation is valid, is called an ideal – gas or a perfect gas, and the equation is called the characteristic equation of state of a perfect gas.

The characteristic equation is usually written as:

$$Pv = RT \quad \text{or} \quad P = \rho R T$$

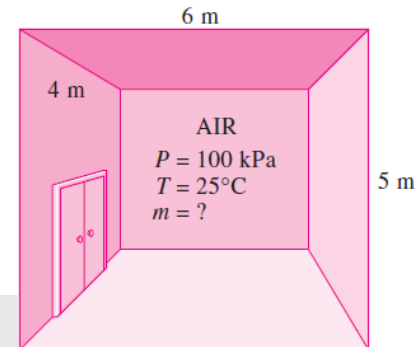
Where, ρ – is the density $\frac{\text{kg}}{\text{m}^3}$

For $m = \text{kg}$, occupying $V = \text{m}^3$ we can drive the following:

$$Pv = mRT$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Ideal gas equation at two states for a fixed mass



EXAMPLE 3–10 Mass of Air in a Room

Determine the mass of the air in a room whose dimensions are 4 m \times 5 m \times 6 m at 100 kPa and 25°C.

Solution The mass of air in a room is to be determined.

Analysis A sketch of the room is given in Fig. 3–48. Air at specified conditions can be treated as an ideal gas. From Table A–1, the gas constant of air is $R = 0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K}$, and the absolute temperature is $T = 25^\circ\text{C} + 273 = 298 \text{ K}$. The volume of the room is

$$V = (4 \text{ m})(5 \text{ m})(6 \text{ m}) = 120 \text{ m}^3$$

The mass of air in the room is determined from the ideal-gas relation to be

$$m = \frac{PV}{RT} = \frac{(100 \text{ kPa})(120 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(298 \text{ K})} = \mathbf{140.3 \text{ kg}}$$

EXAMPLE (3-11)

The pressure in an automobile tire depends on the temperature of the air in the tire. When the air temperature is 25°C, the pressure gage reads 210 kPa. If the volume of the tire is 0.025 m³, determine the pressure rise in the tire when the air temperature in the tire rises to 50°C. Also, determine the amount of air that must be bled off to restore pressure to its original value at this temperature. Assume the atmospheric pressure is 100 kPa.

Assumptions 1 At specified conditions, air behaves as an ideal gas. 2 The volume of the tire remains constant.

Properties The gas constant of air is $R = 0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K}$ (Table A-1).

Analysis Initially, the absolute pressure in the tire is

$$P_1 = P_g + P_{\text{atm}} = 210 + 100 = 310 \text{ kPa}$$

Treating air as an ideal gas and assuming the volume of the tire to remain constant, the final pressure in the tire can be determined from

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \longrightarrow P_2 = \frac{T_2}{T_1} P_1 = \frac{323 \text{ K}}{298 \text{ K}} (310 \text{ kPa}) = 336 \text{ kPa}$$

Thus the pressure rise is

$$\Delta P = P_2 - P_1 = 336 - 310 = 26 \text{ kPa}$$

The amount of air that needs to be bled off to restore pressure to its original value is

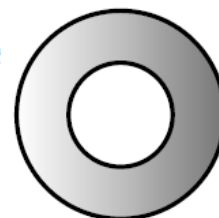
$$m_1 = \frac{P_1 V}{RT_1} = \frac{(310 \text{ kPa})(0.025 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(298 \text{ K})} = 0.0906 \text{ kg}$$

$$m_2 = \frac{P_1 V}{RT_2} = \frac{(310 \text{ kPa})(0.025 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(323 \text{ K})} = 0.0836 \text{ kg}$$

$$\Delta m = m_1 - m_2 = 0.0906 - 0.0836 = 0.0070 \text{ kg}$$

Tire

25°C



EXAMPLE 22

An automobile tire with a volume of 0.6 m^3 is inflated to a gage pressure of 200 kPa . Calculate the mass of air in the tire if the temperature is 20°C and $R = 287 \text{ J/kg} \cdot \text{K}$.

Solution:

Air is assumed to be an ideal gas at the condition of the example. The ideal gas equation:

$$PV = mRT \Rightarrow m = \frac{PV}{RT}$$

At 20°C , $P_{\text{atm}} = 100 \text{ kPa}$, $P_{\text{gage}} = 200 \text{ kPa}$

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

$$P_{\text{abs}} = 100 + 200 = 300 \text{ kPa}$$

$$T_{\text{K}} = T_{\text{C}} + 273 = 20 + 273 = 293^\circ \text{K}$$

$$m = \frac{PV}{RT} = \frac{300 \times 10^3 \frac{\text{N}}{\text{m}^2} \times 0.6 \text{ m}^3}{287 \frac{\text{N} \cdot \text{m}}{\text{kg} \cdot ^\circ \text{K}} \times 293^\circ \text{K}} = 2.14 \text{ kg}.$$

EXAMPLE 23

Air is at 25°C and 101.325 kPa . If the gas constant $R = 287 \text{ J/kg} \cdot \text{K}$, find the specific volume and the molar mass of this gas, assuming it behaves as an ideal gas.

Solution:

$$T_k = T_C + 273 = 25 + 273 = 298^\circ \text{K}$$

$$Pv = RT \Rightarrow v = \frac{RT}{P} = \frac{0.287 \frac{\text{kJ}}{\text{kg} \cdot ^\circ \text{K}} \times 298^\circ \text{K}}{101.325 \text{ kPa}}$$
$$= 0.8445 \frac{\text{m}^3}{\text{kg}}$$

٦- الاسئلة البعدية

- 1- A piston–cylinder device initially contains 50 L of liquid water at 40°C and 200 kPa. Heat is transferred to the water at constant pressure until the entire liquid is vaporized.
- What is the mass of the water?
 - What is the final temperature?
 - Determine the total enthalpy change.
 - Show the process on a T-v diagram with respect to saturation lines.

المحاضرة الرابعة	
Pure Substance and Steam Table	عنوان المحاضرة:
عمر محمود جمعة	اسم المدرس:
المستوى الأول من قسم تقنيات التبريد	الفئة المستهدفة :
• تعريف الطالب ماهي المادة النقية وما هي جداول البخار	الهدف العام من المحاضرة :
٥- ان يتعرف الطالب على Pure Substance ٦- ان يتعرف الطالب على Steam Table	الأهداف السلوكية او مخرجات التعلم:
محاضرة وعمل تعاوني ومناقشة وحل للمسائل	استراتيجيات التيسير المستخدمة
اكساب المتعلم المعرفة	المهارات المكتسبة
Pure Substance and Steam Table	
التغذية الراجعة	طرق القياس المعتمدة

٤ - الاسئلة القبلية :

- ١- ماذا يقصد بمصطلح systems, boundary, surroundings
- ٢- كيف يمكن ان نحسب work and heat in thermodynamic processes

٥- المحتوى العلمي:

1.3. Defining Systems

System

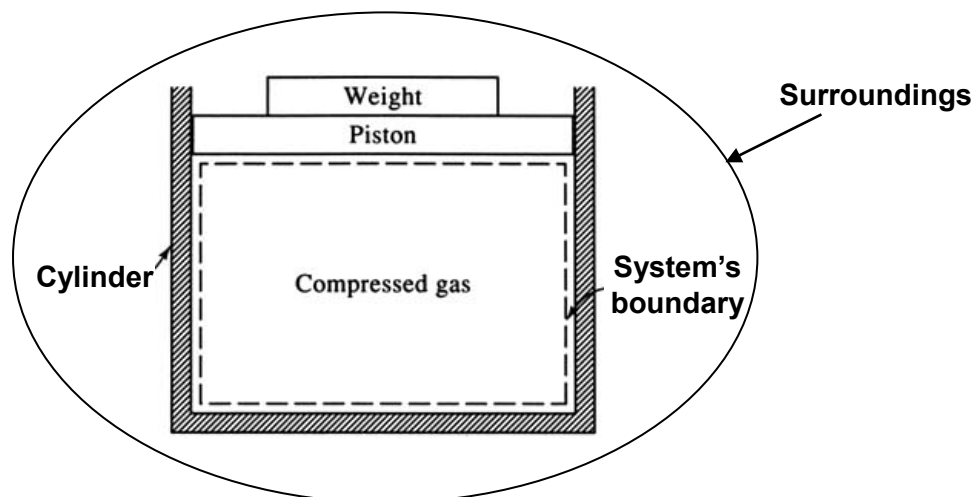
A system is defined as a quantity of matter or a region in space chosen for study.

Surroundings

Everything external to the system is considered to be part of the system's surroundings..

Boundary

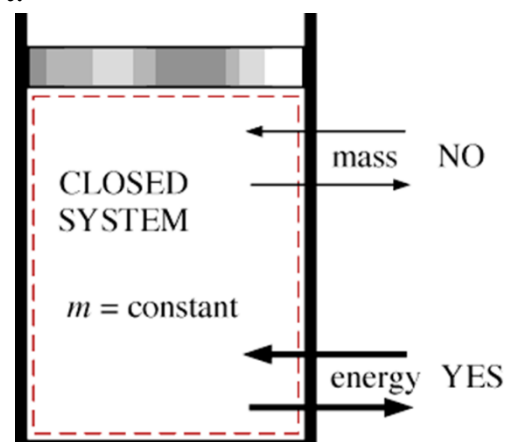
The system is distinguished from its surroundings by a specified *boundary*.



Thermodynamic system

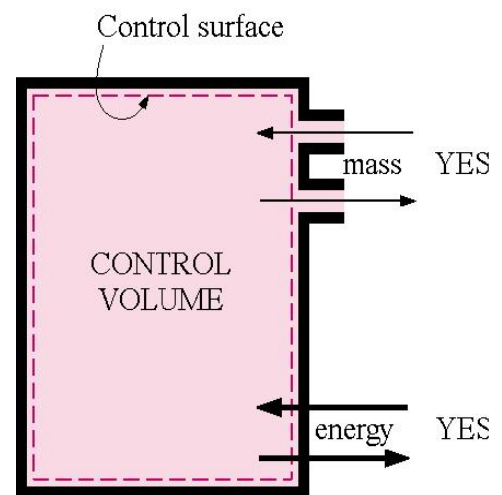
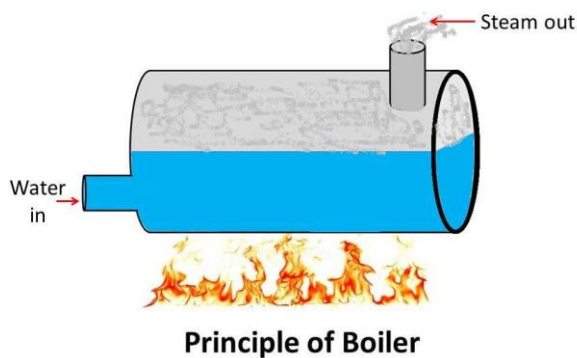
System is defined as a certain region in which the changes occurred in the working substance studied due to energy transfer mass transfer or both of them into or out of this region. Systems can be classified into three types:

- **Closed system:** is that system in which energy can penetrate it's boundary into or out of the system but material cannot.

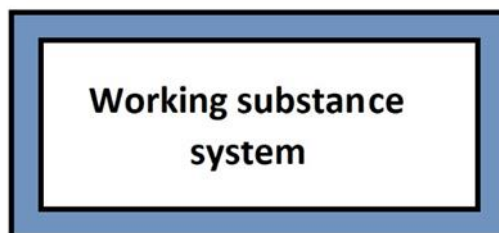




- **Open system:** is that system in which energy & material can penetrate its boundary into or out of the system.



- **Isolated system:** is that system in which neither energy nor material penetrate boundary of the system.



WORK AND HEAT IN THERMODYNAMIC PROCESSES

In this part we will discuss the two quantities that result from energy transfer across the boundary of a system: **work** and **heat**. This will lead into the first law of thermodynamics.

Heat transferred by **conduction, convection, or radiation to systems** or control volumes will either be given information will be provided that it can be determined in our study of thermodynamics; it will not be calculated from **temperature information**, as is done in a heat transfer course.

State Variables

- **State variables** describe the state of a system.
 - **Variables** may include: **Pressure, temperature, volume, internal energy**
 - The state of an **isolated system** can be specified only if the system is in **thermal equilibrium internally**. For a gas in a container, this means every part of the gas must be at the **same pressure and temperature**.

Transfer Variables

- Transfer Variables are zero unless a process occurs in which energy is transferred across the boundary of system •
- Transfer Variables are not associated with any given state of the system, only with changes in the state.
 - Heat and work are transfer variables.
- Transfer Variables can be positive or negative, depending on whether energy is entering or leaving the system

WORK

is defined as the product of a force and the distance moved in the direction of the force. Consider a simple closed system as a gas trapped between a piston and cylinder, assume the pressure and temperature of the gas are uniform and there is no friction between the piston and the cylinder walls as shown in Figure. Let cross – sectional area of the piston be **A** , and the pressure of the gas at any instant be **P** .Let the piston move under the action of the force exerted by the gas a distance **dl** to the right , then the work done by the gas is given by force times the distance moved ;

$$W_{\text{done by gas}} = P * A * dl = Pdv$$

Where **dv** is a small increase in volume or considering unit mass :

Hence, the work done is given by the area under the line of the process plotted on

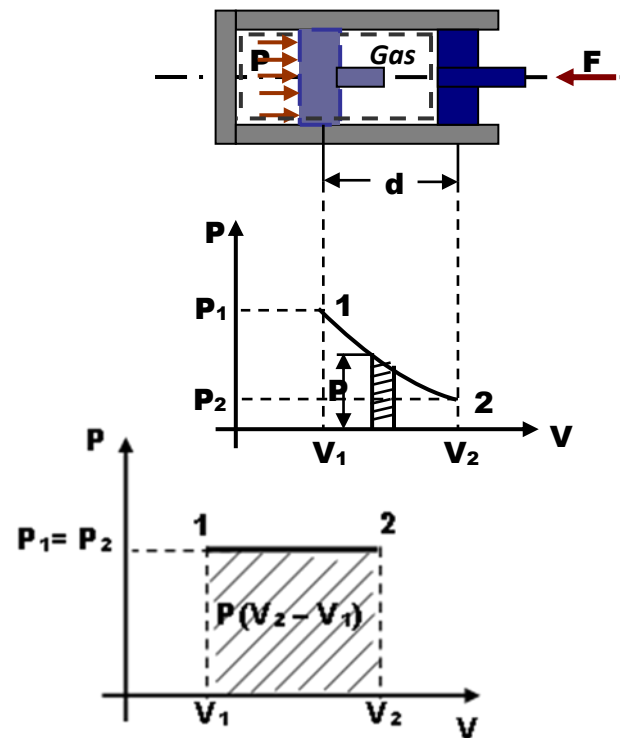
P – V diagram .

$$W = \int_{v_1}^{v_2} P dv$$

In the special case of a constant pressure, then the work is ;

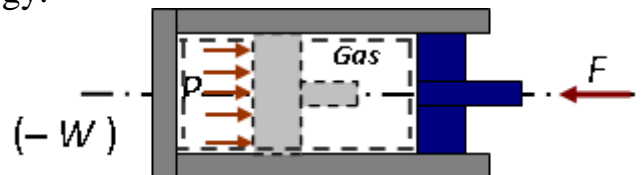
$$W = \int_{v_1}^{v_2} P dv$$

$$W = P \int_{v_1}^{v_2} dv = P(v_2 - v_1)$$

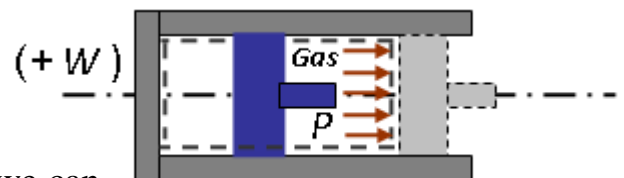


The **work** interaction in each case is represented by the area $\int_1^2 P dv$ underneath the corresponding path. This means that the **work** is not property or a state function rather, it is a path function because it depends how the system was changed from one state to another. Therefore, the system does not possess work; instead, work is mode of transfer of energy.

Work done on the system by the surroundings is considered negative (- ev)



Work done by the system on the surroundings is considered positive (+ ev) .



If **1000 J** of work is done on a **system**, we can write **W = -1000 J** , or **W in = 1000 J** , and Wout means work done by a system.

Units Of Energy Transfer By Work: The units of work in SI of units are the (J) and (kJ);

$$1 \text{ J} = 1 \text{ N m} = 1 \text{ kg} \frac{\text{m}^2}{\text{s}^2} \quad \text{and per unit mass} \quad \frac{\text{N m}}{\text{kg}} = \frac{\text{J}}{\text{kg}} \quad \text{or} \quad \frac{\text{kJ}}{\text{kg}}$$

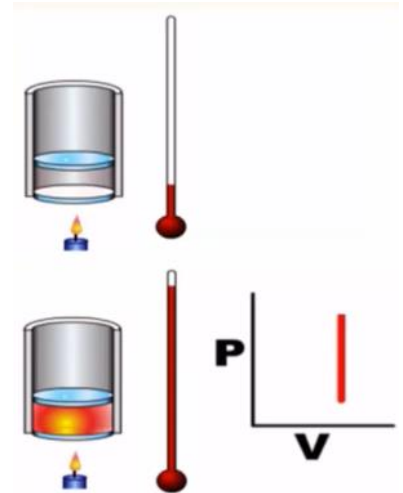
Thermodynamic processes

(1) Isovolumetric (Isochoric) Processes

- An isovolumetric process is one in which there is no change in the volume.
 - This may be accomplished by clamping the piston at a fixed position.
- Since the volume does not change, $W = 0$
- Format the first law, $\Delta E_{int} = Q$

$$Q = m C_v \Delta T$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$



If energy is added by heat to system kept at constant volume all of the remains in the system as an increase in its internal energy. transferred energy

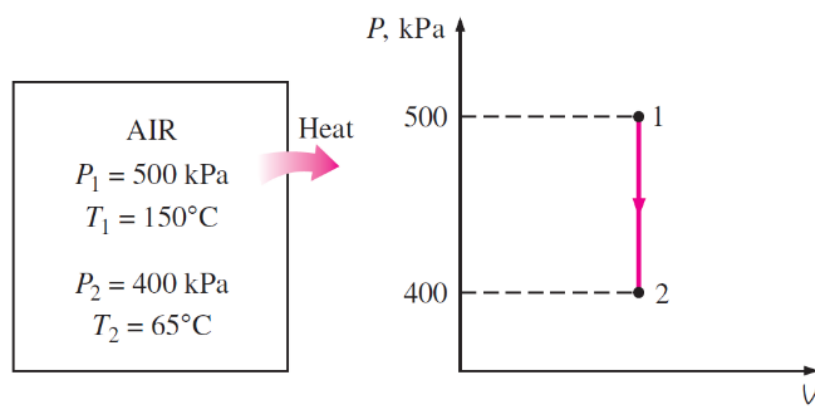
EXAMPLE 4–1 Boundary Work for a Constant-Volume Process

A rigid tank contains air at 500 kPa and 150°C. As a result of heat transfer to the surroundings, the temperature and pressure inside the tank drop to 65°C and 400 kPa, respectively. Determine the boundary work done during this process.

Solution Air in a rigid tank is cooled, and both the pressure and temperature drop. The boundary work done is to be determined.

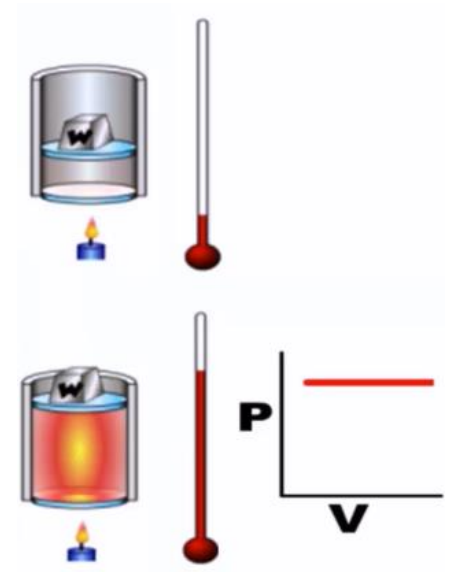
Analysis A sketch of the system and the P - V diagram of the process are shown in Fig. 4–6. The boundary work can be determined from Eq. 4–2 to be

$$W_b = \int_1^2 P dV = 0$$



(2) Isobaric Processes

- An isobaric process is one that occurs at a constant pressure.
- May be accomplished by allowing the **piston to move freely** so that it is always in **equilibrium** between the **net force from the gas pushing upward** and **the weight of the piston plus the force due to atmospheric pressure pushing downward**.
- The values of the **heat** and the **work** are generally both **nonzero**
- The **work done is**
- $W = P \int_{v_1}^{v_2} dv = P(v_2 - v_1)$ where **P** is the constant pressure.



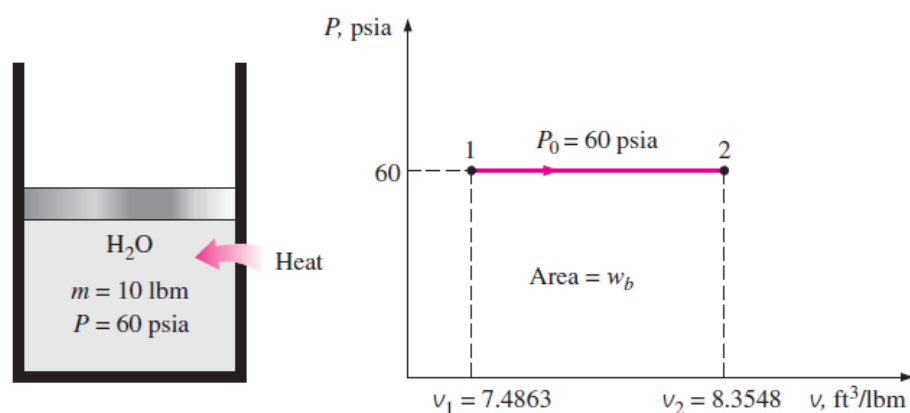
$$\frac{v_1}{T_1} = \frac{v_2}{T_2}$$

EXAMPLE 4–2 Boundary Work for a Constant-Pressure Process

A frictionless piston–cylinder device contains 10 lbm of steam at 60 psia and 320°F. Heat is now transferred to the steam until the temperature reaches 400°F. If the piston is not attached to a shaft and its mass is constant, determine the work done by the steam during this process.

Solution Steam in a piston cylinder device is heated and the temperature rises at constant pressure. The boundary work done is to be determined.

Analysis A sketch of the system and the P - v diagram of the process are shown in Fig. 4–7.



$$W_b = \int_1^2 P dV = P_0 \int_1^2 dV = P_0(V_2 - V_1) \quad (4-6)$$

or

$$W_b = mP_0(v_2 - v_1)$$

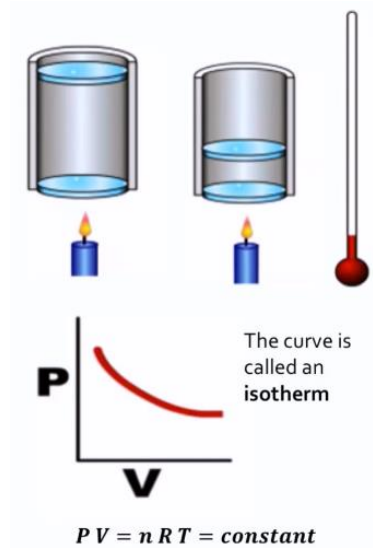
since $V = mv$. From the superheated vapor table (Table A-6E), the specific volumes are determined to be $v_1 = 7.4863 \text{ ft}^3/\text{lbm}$ at state 1 (60 psia, 320°F) and $v_2 = 8.3548 \text{ ft}^3/\text{lbm}$ at state 2 (60 psia, 400°F). Substituting these values yields

$$W_b = (10 \text{ lbm})(60 \text{ psia})[(8.3548 - 7.4863) \text{ ft}^3/\text{lbm}] \left(\frac{1 \text{ Btu}}{5.404 \text{ psia} \cdot \text{ft}^3} \right) \\ = \mathbf{96.4 \text{ Btu}}$$

(3) Isothermal Process

- An isothermal process is one that occurs at a constant temperature.
- This can be accomplished by putting the cylinder in contact with some **constant- temperature reservoir**.
- Since there is no change in temperature,
- $\Delta E_{int} = 0$
- Therefore, $Q = W$
- Any energy that enters the system by heat must leave the system by work.

$$p_1 v_1 = p_2 v_2$$



- Isothermal Compression

$$W = - \int_{v_f}^{v_i} P dv = - \int_{v_f}^{v_i} \frac{nRT}{v} dv = -nRT \int_{v_f}^{v_i} \frac{dv}{v} = \mathbf{nRT \ln \frac{v_f}{v_i}}$$

- Isothermal Expansion

$$W = - \int_{v_i}^{v_f} P dv = - \int_{v_i}^{v_f} \frac{nRT}{v} dv = -nRT \int_{v_i}^{v_f} \frac{dv}{v} = \mathbf{nRT \ln \frac{v_i}{v_f}}$$

Numerically, the work equals the negative of the area under the PV diagram.

If the gas **expands**, $V_f > V_i$, and the value of the **work done on the gas is negative**.

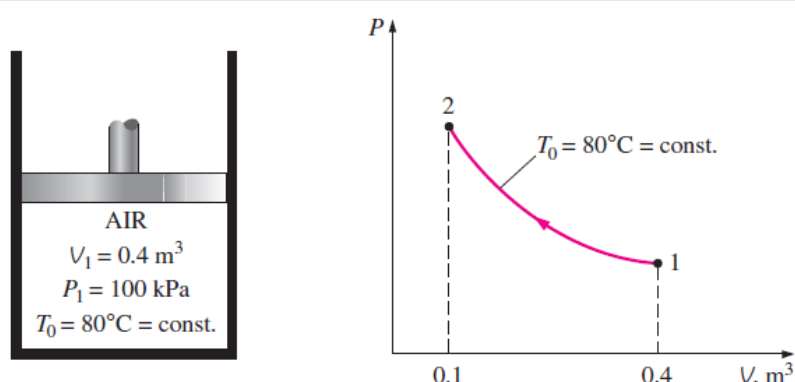
If the gas is **compressed**, $V_f < V_i$ and the value of the **work done on the gas is positive**.

EXAMPLE 4–3 Isothermal Compression of an Ideal Gas

A piston–cylinder device initially contains 0.4 m^3 of air at 100 kPa and 80°C . The air is now compressed to 0.1 m^3 in such a way that the temperature inside the cylinder remains constant. Determine the work done during this process.

Solution Air in a piston–cylinder device is compressed isothermally. The boundary work done is to be determined.

Analysis A sketch of the system and the P - V diagram of the process are shown in Fig. 4–8.



Assumptions 1 The compression process is quasi-equilibrium. 2 At specified conditions, air can be considered to be an ideal gas since it is at a high temperature and low pressure relative to its critical-point values.

Analysis For an ideal gas at constant temperature T_0 ,

$$PV = mRT_0 = C \quad \text{or} \quad P = \frac{C}{V}$$

where C is a constant. Substituting this into Eq. 4–2, we have

$$W_b = \int_1^2 P dV = \int_1^2 \frac{C}{V} dV = C \int_1^2 \frac{dV}{V} = C \ln \frac{V_2}{V_1} = P_1 V_1 \ln \frac{V_2}{V_1} \quad (4-7)$$

In Eq. 4–7, P_1V_1 can be replaced by P_2V_2 or mRT_0 . Also, V_2/V_1 can be replaced by P_1/P_2 for this case since $P_1V_1 = P_2V_2$.

Substituting the numerical values into Eq. 4–7 yields

$$W_b = (100 \text{ kPa})(0.4 \text{ m}^3) \left(\ln \frac{0.1}{0.4} \right) \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) \\ = -55.5 \text{ kJ}$$

(4) Adiabatic Processes

- An adiabatic process is any process occurring without gain or loss of heat within a system.
- Adiabatic processes can occur if the container of the system has thermally-insulated walls or the process happens in an extremely short time.

$$Q = 0$$

$$\Delta E_{int} = W$$

$$W = \frac{p_1 v_1 - p_2 v_2}{\gamma - 1}$$

or

$$W = mR \frac{T_1 - T_2}{\gamma - 1}$$

Example 4-4

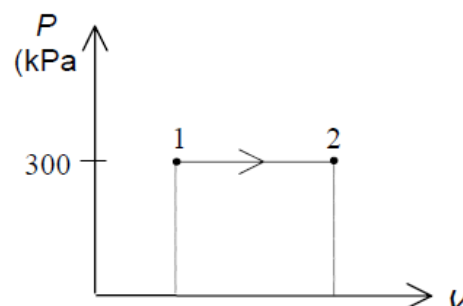
A mass of 5 kg of saturated water vapor at 300 kPa is heated at constant pressure until the temperature reaches 200°C. Calculate the work done by the steam during this process.

Assumptions The process is quasi-equilibrium.

Properties Noting that the pressure remains constant during this process, the specific volumes at the initial and the final states are (Table A-4 through A-6)

$$\left. \begin{array}{l} P_1 = 300 \text{ kPa} \\ \text{Sat. vapor} \end{array} \right\} \nu_1 = \nu_g @ 300 \text{ kPa} = 0.60582 \text{ m}^3/\text{kg}$$

$$\left. \begin{array}{l} P_2 = 300 \text{ kPa} \\ T_2 = 200^\circ\text{C} \end{array} \right\} \nu_2 = 0.71643 \text{ m}^3/\text{kg}$$



Analysis The boundary work is determined from its definition to be

$$\begin{aligned} W_{b,\text{out}} &= \int_1^2 P dV = P(V_2 - V_1) = mP(\nu_2 - \nu_1) \\ &= (5 \text{ kg})(300 \text{ kPa})(0.71643 - 0.60582) \text{ m}^3/\text{kg} \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) \\ &= \mathbf{165.9 \text{ kJ}} \end{aligned}$$

Discussion The positive sign indicates that work is done by the system (work output).

Example 4-4

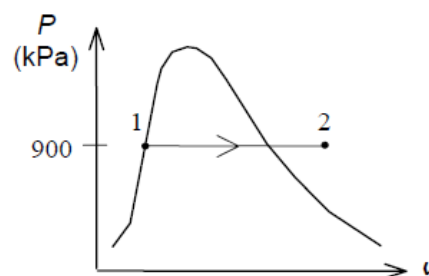
A frictionless piston–cylinder device initially contains 200 L of saturated liquid refrigerant-134a. The piston is free to move, and its mass is such that it maintains a pressure of 900 kPa on the refrigerant. The refrigerant is now heated until its temperature rises to 70°C . Calculate the work done during this process.

Assumptions The process is quasi-equilibrium.

Properties Noting that the pressure remains constant during this process, the specific volumes at the initial and the final states are (Table A-11 through A-13)

$$\left. \begin{array}{l} P_1 = 900 \text{ kPa} \\ \text{Sat. liquid} \end{array} \right\} \nu_1 = \nu_f @ 900 \text{ kPa} = 0.0008580 \text{ m}^3/\text{kg}$$

$$\left. \begin{array}{l} P_2 = 900 \text{ kPa} \\ T_2 = 70^\circ\text{C} \end{array} \right\} \nu_2 = 0.027413 \text{ m}^3/\text{kg}$$



Analysis The boundary work is determined from its definition to be

$$m = \frac{V_1}{\nu_1} = \frac{0.2 \text{ m}^3}{0.0008580 \text{ m}^3/\text{kg}} = 233.1 \text{ kg}$$

and

$$\begin{aligned} W_{b,\text{out}} &= \int_1^2 P dV = P(V_2 - V_1) = mP(\nu_2 - \nu_1) \\ &= (233.1 \text{ kg})(900 \text{ kPa})(0.027413 - 0.0008580) \text{ m}^3/\text{kg} \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right) \\ &= \mathbf{5571 \text{ kJ}} \end{aligned}$$

Discussion The positive sign indicates that work is done by the system (work output).

ENERGY TRANSFER BY HEAT

Energy can cross the boundary of a closed system in two distinct forms: heat and work (Fig. 2-11). It is important to distinguish between these two forms of energy. Therefore, they will be discussed first, to form a sound basis for the development of the laws of thermodynamics. We know from experience that a can of cold soda left on a table eventually warms up and that a hot baked potato on the same table cools down. When a body is left in a medium that is at a different temperature, energy transfer takes place between the body and the surrounding medium until thermal equilibrium is established, that is, the body and the medium reach the same temperature. The direction of energy transfer is always from the higher temperature body to the lower temperature one. Once the temperature equality is established, energy transfer stops. In the processes described above, energy is said to be transferred in the form of heat.

Heat is defined as *the form of energy that is transferred between two systems (or a system and its surroundings) by virtue of a temperature difference* (Fig. 2-12). That is, an energy interaction is heat only if it takes place because of a temperature difference. Then it follows that there cannot be any heat transfer between two systems that are at the same temperature.

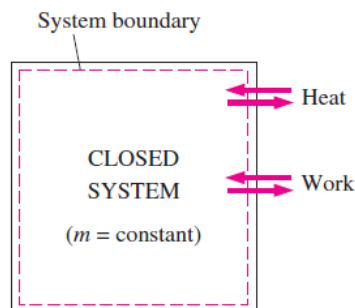


FIGURE 2-11

Energy can cross the boundaries of a closed system in the form of heat and work.

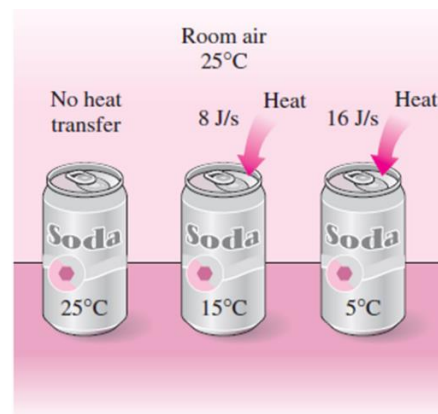


FIGURE 2-12

Several phrases in common use today such as heat How, heat addition, heat rejection, heat absorption, heat removal, heat gain, heat loss, heat storage, heat generation, electrical heating, resistance heating, frictional heating, gas heating, heat of reaction, liberation of heat, specific heat, sensible heat, latent heat, waste heat, body heat, process heat, heat sink, and heat source are not consistent with the strict thermodynamic meaning of the term *heat*, which limits its use to the *transfer* of thermal energy during a process. However, these phrases are deeply rooted in our vocabulary, and they are used by both ordinary people and scientists without causing any misunderstanding since

they are usually interpreted properly instead of being taken literally. (Besides, no acceptable alternatives exist for some of these phrases.) For example, the phrase *body heat* is understood to mean *the thermal energy content* of a body. Likewise, *heat flow* is understood to mean *the transfer of thermal energy*, not the flow fluidlike substance called heat, although the latter incorrect interpretation, which is based on the caloric theory, is the origin of this phrase. Also, the transfer of heat into a system is frequently referred to as *heat addition* and the transfer of heat out of a system as *heat rejection*. Perhaps there are thermodynamic reasons for being so reluctant to replace *heat* by *thermal energy*: It takes less time and energy to say, write, and comprehend *heat* than it does *thermal energy*.

Heat is energy in transition. It is recognized only as it crosses the boundary of a system. Consider the hot baked potato one more time. The potato contains energy, but this energy is heat transfer only as it passes through the skin of the potato (the system boundary) to reach the air, as shown in Fig. 2-13. Once in the surroundings, the transferred heat becomes part of the internal energy of the surroundings. Thus, in thermodynamics, the term *heat* simply means *heat transfer*.

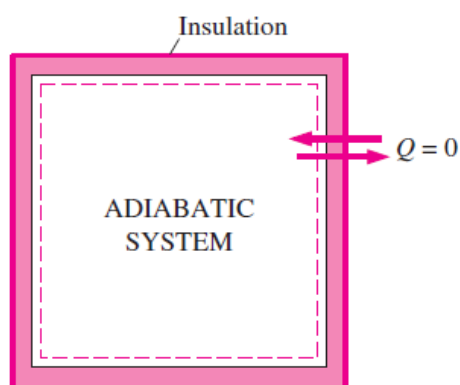


FIGURE 2-14

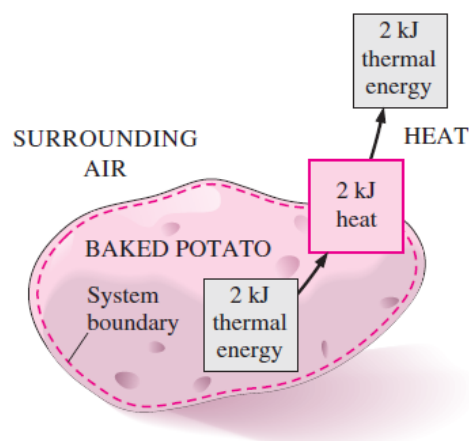


FIGURE 2-13

A process during which there is no heat transfer is called an **adiabatic process** (Fig. 2-14). The word *adiabatic* comes from the Greek word *adiabatic*, which means *not to be passed*. There are two ways a process can be adiabatic: Either the system is well insulated so that only a negligible amount of heat can pass through the boundary, or both the system and the surroundings are at the same temperature and therefore there is no driving force (temperature difference) for heat transfer. An adiabatic process should not be confused with an isothermal process. Even though there is no heat transfer during an

adiabatic process, the energy content and thus the temperature of a system can still be changed by other means such as work.

As a form of energy, heat has energy units, kJ (or Btu) being the most common one. The amount of heat transferred during the process between two states (states 1 and 2) is denoted by Q_{12} or just Q . Heat transfer *per unit mass* of a system is denoted q and is determined from

$$q = \frac{Q}{m} \quad (\text{kJ/kg}) \quad (2-14)$$

Sometimes it is desirable to know the *rate of heat transfer* (the amount of heat transferred per unit time) instead of the total heat transferred over some time interval (Fig. 2-15). The heat transfer rate is denoted \dot{Q} , where the over dot stands for the time derivative, or “per unit time.” The heat transfer rate \dot{Q} has the unit kJ/s, which is equivalent to kW. When \dot{Q} varies with time, the amount of heat transfer during a process is determined by integrating \dot{Q} over the time interval of the process:

$$Q = \int_{t_1}^{t_2} \dot{Q} dt \quad (\text{kJ}) \quad (2-15)$$

When \dot{Q} remains constant during a process, this relation reduces to

$$Q = \dot{Q} \Delta t \quad (\text{kJ}) \quad (2-16)$$

where $\Delta t = t_2 - t_1$ is the time interval during which the process takes place.

Heat can be transferred in three different modes: *conduction*, *convection*, and *radiation*. All modes of heat transfer require the existence of a temperature difference, and all modes are from the high temperature medium to a lower-temperature one.

THE FIRST LAW OF THERMODYNAMICS

- The first law of thermodynamics (the conservation of energy principle) provides a sound basis for studying the relationships among the various forms of energy and energy interactions.
- The first law states that energy can be neither created nor destroyed during a process; it can only change forms.
- The First Law: For all adiabatic processes between two specified states of a closed system, the net work done is the same regardless of the nature of the closed system and the details of the process.

We all know that a rock at some elevation possesses some potential energy, and part of this potential energy is converted to kinetic energy as the rock falls (Fig. 2–37). Experimental data show that the decrease in potential energy ($mg\Delta z$) exactly equals the increase in kinetic energy ($\frac{1}{2}m(v_2^2 - v_1^2)$) when the air resistance is negligible, thus confirming the conservation of energy principle for

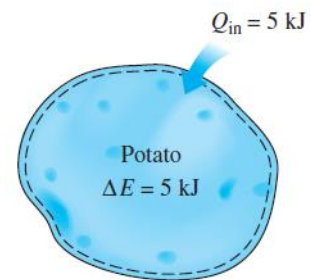
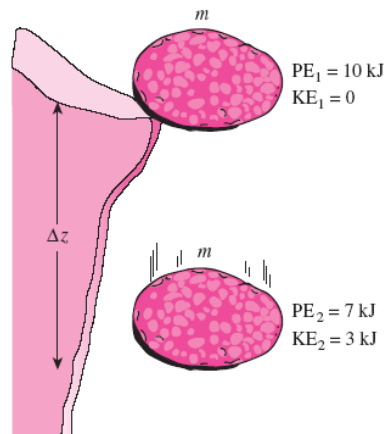


FIGURE 3–40

The increase in the energy of a potato in an oven is equal to the amount of heat transferred to it.

mechanical energy.

Energy cannot be created or destroyed; it can only change forms

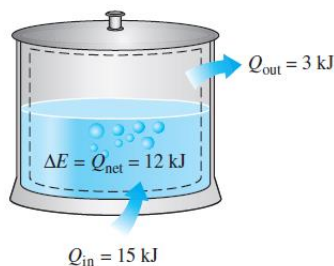


FIGURE 3–41

In the absence of any work interactions, the energy change of a system is equal to the net heat transfer.

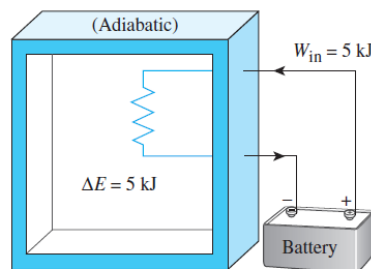


FIGURE 3–42

The work (electrical) done on an adiabatic system is equal to the increase in the energy of the system.

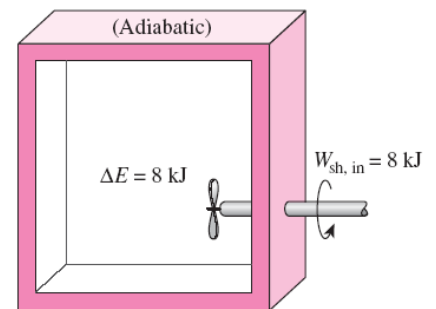


FIGURE 3–43

The work (shaft) done on an adiabatic system is equal to the increase in the energy of the system.

Energy Balance

The net change (increase or decrease) in the total energy of the system during a process is equal to the difference between the total energy entering and the total energy leaving the system during that process.

$$\left(\begin{array}{c} \text{Total energy} \\ \text{entering the system} \end{array} \right) - \left(\begin{array}{c} \text{Total energy} \\ \text{leaving the system} \end{array} \right) = \left(\begin{array}{c} \text{Change in the total} \\ \text{energy of the system} \end{array} \right)$$

or

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}}$$

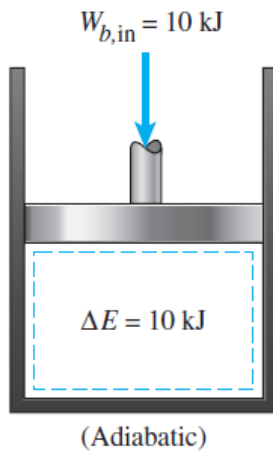


FIGURE 3–44

The work (boundary) done on an adiabatic system is equal to the increase in the energy of the system.

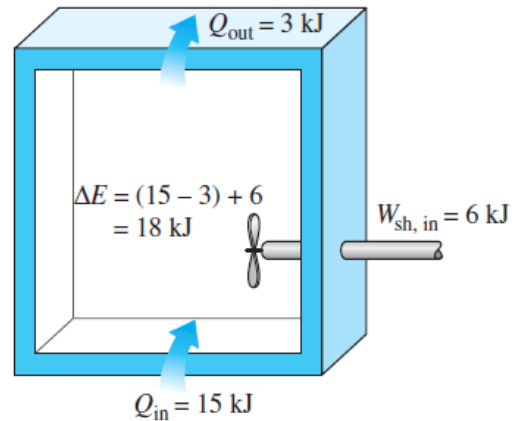


FIGURE 3–45

The energy change of a system during a process is equal to the *net* work and heat transfer between the system and its surroundings.

Energy Change of a System, ΔE_{system}

The determination of the energy change of a system during a process involves the evaluation of the energy of the system at the beginning and at the end of the process, and taking their difference. That is,

$$\text{Energy change} = \text{Energy at final state} - \text{Energy at initial state}$$

or

$$\Delta E_{\text{system}} = E_{\text{final}} - E_{\text{initial}} = E_2 - E_1$$

Note that energy is a property, and the value of a property does not change unless the state of the system changes. Therefore, the energy change of a system is zero if the state of the system does not change during the process.

Also, energy can exist in numerous forms such as internal (sensible, latent, chemical, and nuclear), kinetic, potential, electric, and magnetic, and their sum constitutes the *total energy* E of a system. In the absence of electric, magnetic, and surface tension effects (i.e., for simple compressible systems), the change in the total energy of a system during a process is the sum of the changes in its **internal**, **kinetic**, and **potential** energies and can be expressed as

$$\Delta E = \Delta U + \Delta KE + \Delta PE$$

where

$$\Delta U = m(u_2 - u_1)$$

$$\Delta KE = \frac{1}{2}m(V_2^2 - V_1^2)$$

$$\Delta PE = mg(z_2 - z_1)$$

$$\boxed{Q = W + \Delta KE + \Delta PE + \Delta U}$$

Mechanisms of Energy Transfer, Ein and Eout

Energy can be transferred to or from a system in three forms: *heat*, *work*, and *mass flow*. Energy interactions are recognized at the system boundary as they cross it, and they represent the energy gained or lost by a system during a process. The only two forms of energy interactions associated with a fixed mass or closed system are *heat transfer* and *work*.

Noting that energy can be transferred in the forms of heat, work, and mass, and that the net transfer of a quantity is equal to the difference between the amounts transferred in and out, the energy balance can be written more explicitly as

$$E_{\text{in}} - E_{\text{out}} = (Q_{\text{in}} - Q_{\text{out}}) + (W_{\text{in}} - W_{\text{out}}) + (E_{\text{mass,in}} - E_{\text{mass,out}}) = \Delta E_{\text{system}}$$

Energy balance for any system undergoing any kind of process can be expressed more compactly as

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\text{Net energy transfer by heat, work, and mass}} = \underbrace{\Delta E_{\text{system}}}_{\text{Change in internal, kinetic, potential, etc., energies}} \quad (\text{kJ}) \quad (2-35)$$

or, in the **rate form**, as

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{dE_{\text{system}}/dt}_{\text{Rate of change in internal, kinetic, potential, etc., energies}} \quad (\text{kW}) \quad (2-36)$$

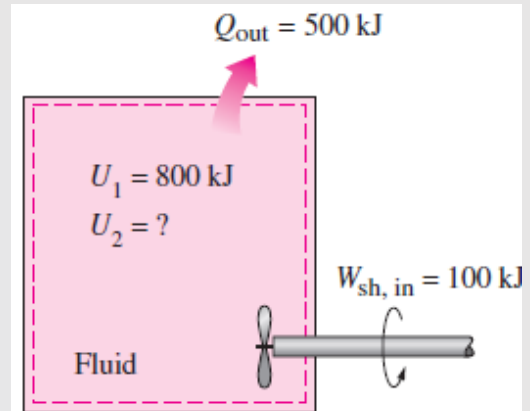
For constant rates, the total quantities during a time interval Δt are related to the quantities per unit time as

$$Q = \dot{Q} \Delta t, \quad W = \dot{W} \Delta t, \quad \text{and} \quad \Delta E = (dE/dt) \Delta t \quad (\text{kJ}) \quad (2-37)$$

Example 3-1

A rigid tank contains a hot fluid that is cooled while being stirred by a paddle wheel. Initially, the internal energy of the fluid is 800 kJ. During the cooling process, the fluid loses 500 kJ of heat, and the paddle wheel does 100 kJ of work on the fluid. Determine the final internal energy of the fluid. Neglect the energy stored in the paddle wheel.

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\text{Net energy transfer by heat, work, and mass}} = \underbrace{\Delta E_{\text{system}}}_{\text{Change in internal, kinetic, potential, etc., energies}}$$
$$W_{\text{sh,in}} - Q_{\text{out}} = \Delta U = U_2 - U_1$$
$$100 \text{ kJ} - 500 \text{ kJ} = U_2 - 800 \text{ kJ}$$
$$U_2 = \mathbf{400 \text{ kJ}}$$



EXAMPLE 3-2

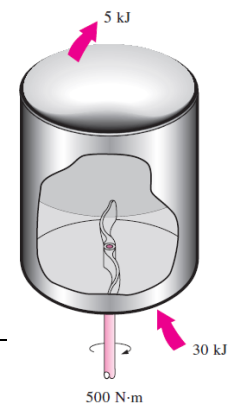
Water is being heated in a closed pan on top of a range while being stirred by a paddle wheel. During the process, 30 kJ of heat is transferred to the water, and 5 kJ of heat is lost to the surrounding air. The paddle-wheel work amounts to 500 N.m. Determine the final energy of the system if its initial energy is 10 kJ.

Assumptions The pan is stationary and thus the changes in kinetic and potential energies are negligible.

Analysis We take the water in the pan as our system. This is a closed system since no mass enters or leaves. Applying the energy balance on this system gives

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\text{Net energy transfer by heat, work, and mass}} = \underbrace{\Delta E_{\text{system}}}_{\text{Change in internal, kinetic, potential, etc., energies}}$$
$$Q_{\text{in}} + W_{\text{sh,in}} - Q_{\text{out}} = \Delta U = U_2 - U_1$$
$$30 \text{ kJ} + 0.5 \text{ kJ} - 5 \text{ kJ} = U_2 - 10 \text{ kJ}$$
$$U_2 = \mathbf{35.5 \text{ kJ}}$$

Therefore, the final internal energy of the system is 35.5 kJ.



EXAMPLE 3-3

A vertical piston–cylinder device contains water and is being heated on top of a range. During the process, 65 kJ of heat is transferred to the water, and heat losses from the side walls amount to 8 kJ. The piston **rises** as a result of evaporation, and 5 kJ of work is done by the vapor. Determine the change in the energy of the water for this process.

Assumptions The pan is stationary and thus the changes in kinetic and potential energies are negligible.

Analysis We take the water in the cylinder as the system. This is a closed system since no mass enters or leaves. Applying the energy balance on this system gives

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\text{Net energy transfer by heat, work, and mass}} = \underbrace{\Delta E_{\text{system}}}_{\text{Change in internal, kinetic, potential, etc. energies}}$$
$$Q_{\text{in}} - W_{\text{out}} - Q_{\text{out}} = \Delta U = U_2 - U_1$$
$$65 \text{ kJ} - 5 \text{ kJ} - 8 \text{ kJ} = \Delta U$$
$$\Delta U = 52 \text{ KJ}$$

٦- الاسئلة البعدية

- 1- Water is being heated in a closed pan on top of a range while being stirred by a paddle wheel. During the process, 40 kJ of heat is transferred to the water, and 7 kJ of heat is lost to the surrounding air. The paddle-wheel work amounts to 700 N.m. Determine the final energy of the system if its initial energy is 12 kJ.

• المصادر الاساسية :

• المصادر المقترحة:

1-An Introduction to Statistical Mechanics and Thermodynamics Robert H. Swendsen, First edition 2012.

• روابط مقترحة ذات صلة:

