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## CLASS SCHEDULE

## MECHANICAL ENGINEERING

| | | |
|---|---|---|
| HMT | MONDAY Live @11AM | YOGESH SIR |
| PRODUCTION | TUESDAY Live @11AM | GAURAV SIR |
| SOM | WEDNESDAY Live @8PM | MUKESH SIR |
| THERMODYNAMICS | THURSDAY Live @11AM | KANISTH SIR |
| ENGINEERING MATHEMATICS | FRIDAY Live @11AM | ANANT SIR |

ISRO | BHEL | DRDO & OTHER PSUs

GATE

# Thermodynamics

# Pure Substance

## MOST EXPECTED QUESTIONS

Live@ 3pm

## PART-2

Kanisth sir

**Assertion (A):** For a mixture of solid, liquid and vapour phases of a pure substance in equilibrium, the number of independent intrinsic properties needed is equal to one.

**Reason (R):** The three phases can coexist only at one particular pressure.

(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**

(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**

(c) **A** is true but **R** is false

(d) **A** is false but **R** is true

[ESE : 2005]

1 → d

$P = 3$

$C = 1$

$F = C - P + 2$

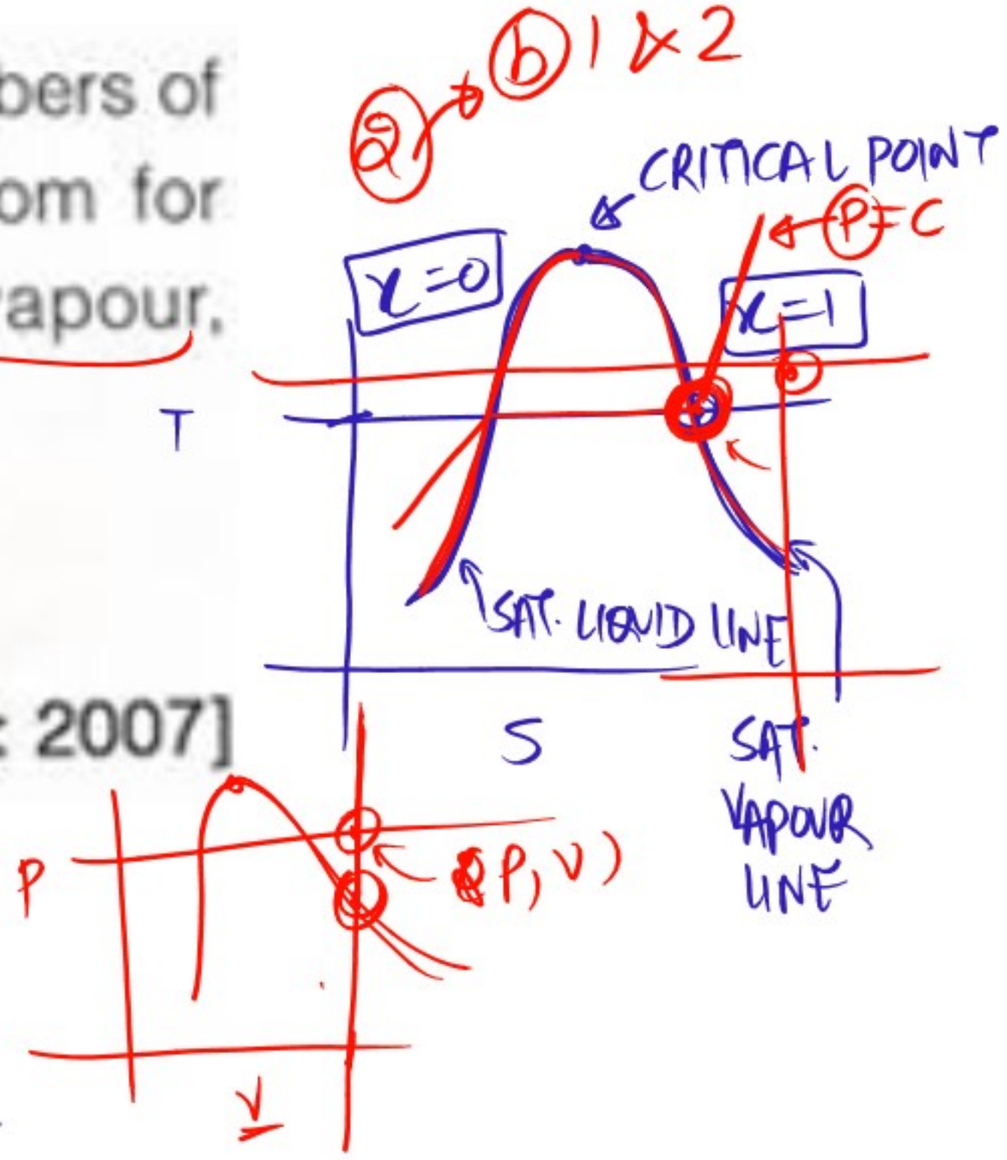
$= 1 - 3 + 2$

$F = 0$

For a pure substance, what are the numbers of the thermodynamic degrees of freedom for saturated vapour and superheated vapour, respectively?

(a) 1 and 1
(b) 1 and 2
(c) 2 and 1
(d) 2 and 2

[ESE : 2007]



Which one of the following statements is correct when saturation pressure of water vapour increases?

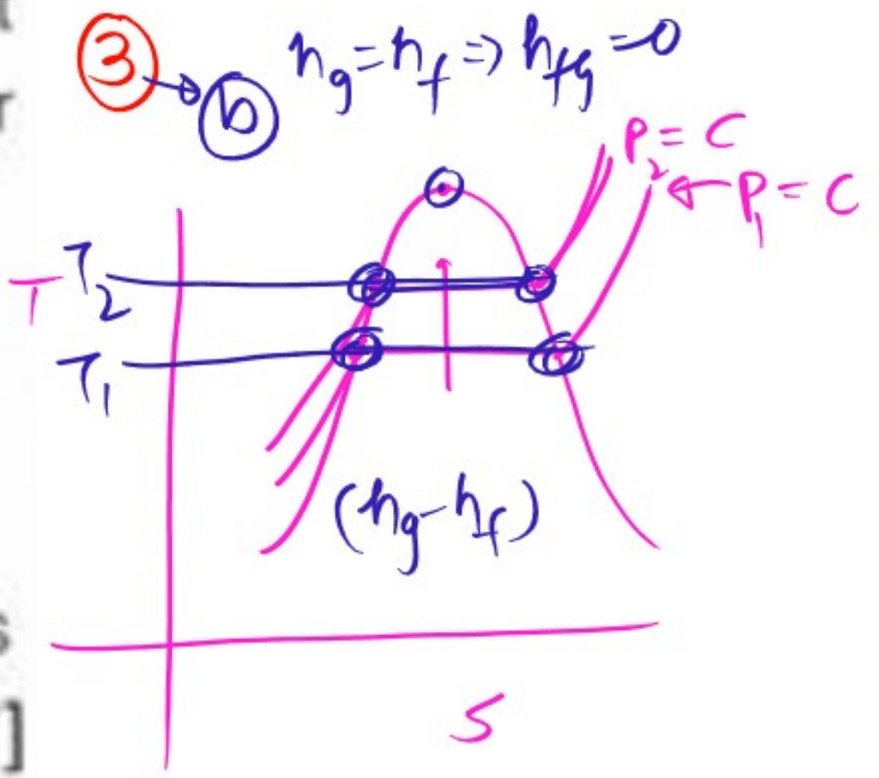
(a) Saturation temperature decreases

(b) Enthalpy of evaporation decreases

(c) Enthalpy of evaporation increases

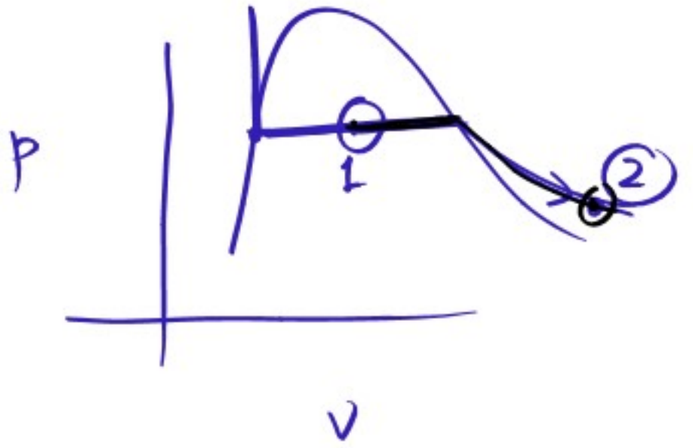
(d) Specific volume change of phase increases

[ESE : 2007]

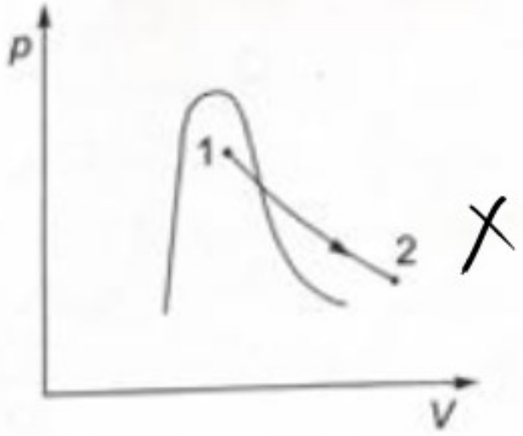


Which $p$–$V$ diagram for steam illustrates correctly the isothermal process undergone by wet steam till it becomes superheated?

④ → ©

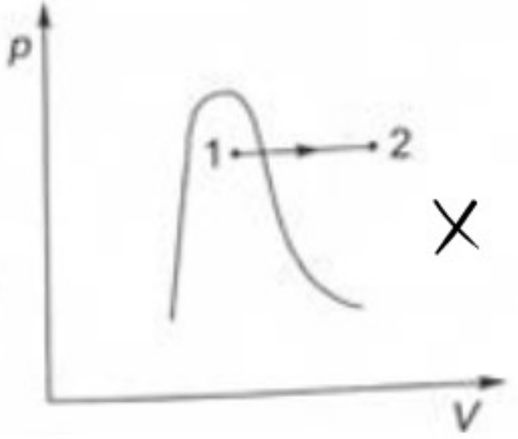



(a)



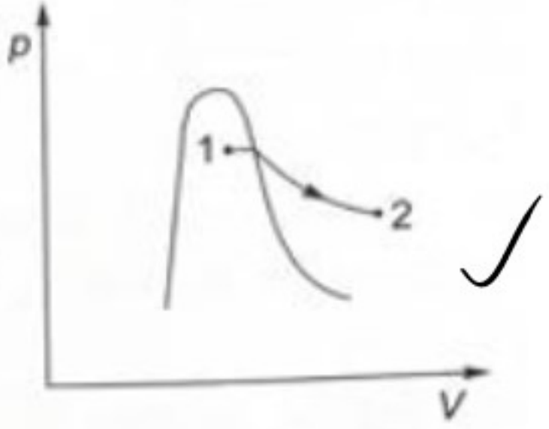

X

(b)



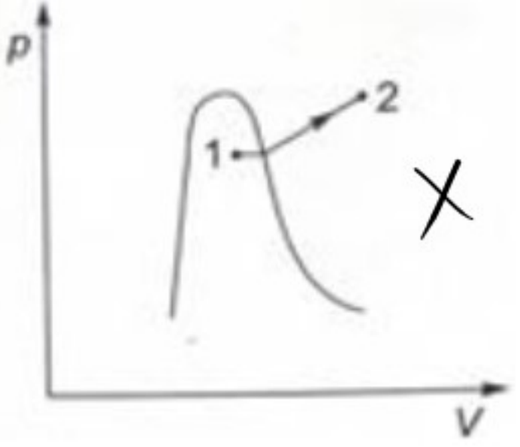

X

(c)




✓

(d)




X

The specific volume of water when heated from 0°C

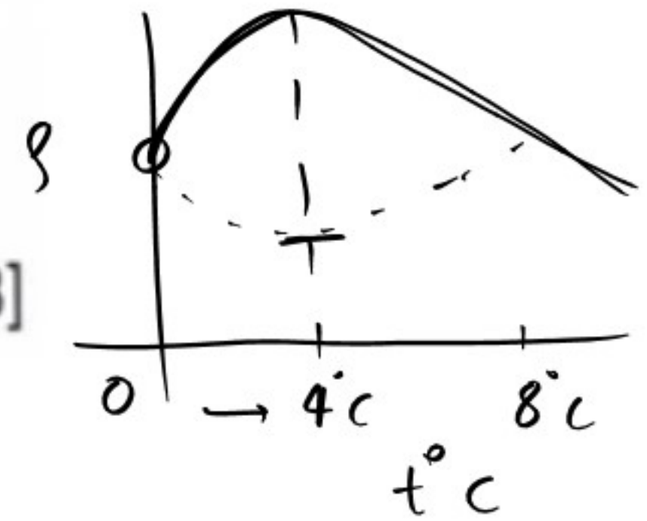
(a) first increases and then decreases

(b) first decreases and then increases

(c) increases steadily

(d) decreases steadily [ESE : 2008]

(5) → (b)




$v = \frac{1}{\rho}$

With increase of pressure, the latent heat of steam

(6)

(a) remains same

(b) increases

(c) decreases ✓

(d) behaves unpredictably [ESE : 2002]

Consider the following statements regarding the throttling process of wet steam:

1. The steam pressure and temperature decrease but enthalpy remains constant.
2. The steam pressure decreases, the temperature increases but enthalpy remains constant.
3. The entropy, specific volume, and dryness fraction increase.
4. The entropy increases but the volume and dryness fraction decrease.

Which of these statements are correct?

(a) 1 and 4 (b) 2 and 3

(c) 1 and 3 (d) 2 and 4

[ESE : 2002]

The internal energy of a gas obeying Van der Waals equation $\left(p+\frac{a}{v^2}\right)(v-b)=RT$ depends on its

(a) temperature

(b) temperature and pressure

(c) temperature and specific volume

(d) pressure and specific volume

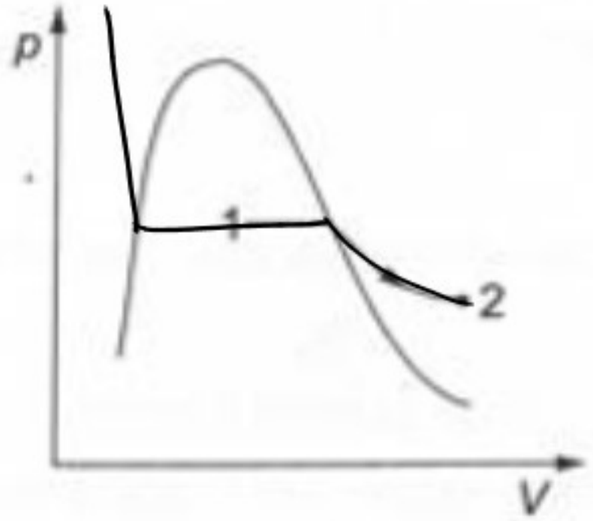
[ESE : 2000]

B — C

REAL GAS

$u = u(T, v)$

The process 1-2 for steam shown in the given figure is




(a) isobaric
(b) isentropic
(c) isenthalpic
(d) isothermal

[ESE : 2000]

(9) → (d)

The value of compressibility factor for an ideal gas may be:

1. Less or more than one
2. Equal to one
3. Zero
4. Less than zero

The correct value (s) is/are given by

(a) 1 and 2 (b) 1 and 4

(c) 3 only (d) 2 only

[ESE : 2002]

10

$PV = 2RT$

$PV = 1 \times RT$

10 → d

Saturated liquid at a high pressure $p_1$ having enthalpy of saturated liquid 1000 kJ/kg is throttled to a lower pressure $p_2$, at pressure $p_2$ enthalpy of saturated liquid and that of the saturated vapour are 800 and 2800 kJ/kg respectively. The dryness fraction of vapour after throttling process is

(a) 0.1 ✓
(b) 0.5
(c) 18/28
(d) 0.8

[ESE : 2003]

(1) → (A)

$h_1 = 1000$ kJ/kg

$P_2$ → $h_f = 800$, $h_g = 2800$ kJ/kg

$h_1 = h_2$

$h_1 = h_f + x(h_g - h_f)$

$1000 = 800 + x(2800 - 800)$

$200/2000 = x \Rightarrow 0.1$

Water has a critical specific volume of 0.003155 $m^3/kg$. A closed and rigid steel tank of volume 0.025 $m^3$ contains a mixture of water and steam at 0.1 MPa. The mass of the mixture is 10 kg. The tank is now slowly heated. The liquid level inside the tank **[1 Mark]**

(A) Will rise ✓

(B) Will fall

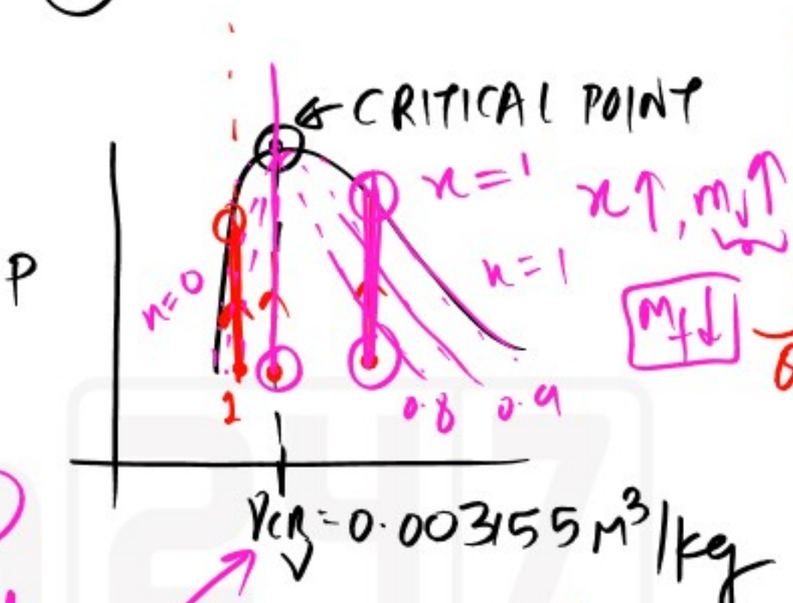
(C) Will remain constant

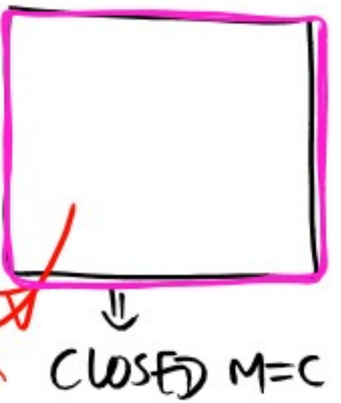
(D) May rise or fall depending on the amount of heat transferred

$\downarrow x = \frac{m_v \downarrow}{m_{total}}$

$m_{total} = \uparrow m_f + m_v \downarrow$

(12)




$v = \frac{V}{M} = \text{const}$

$= \frac{0.025}{10}$

$v = 0.0025$

A pure substance at 8 MPa and $400^0$C is having a specific internal energy of 2864 kJ/kg and a specific volume of 0.03432 $m^3$/kg. Its specific enthalpy (in kJ/kg) is _____. **[1 Mark]**

(13)

$h = u + pv$

$= 2864 + 8000 \times 0.03432$

$\frac{kJ}{kg} \quad \frac{kN}{m^2} \times \frac{m^3}{kg}$

$\frac{kJ}{kg}$

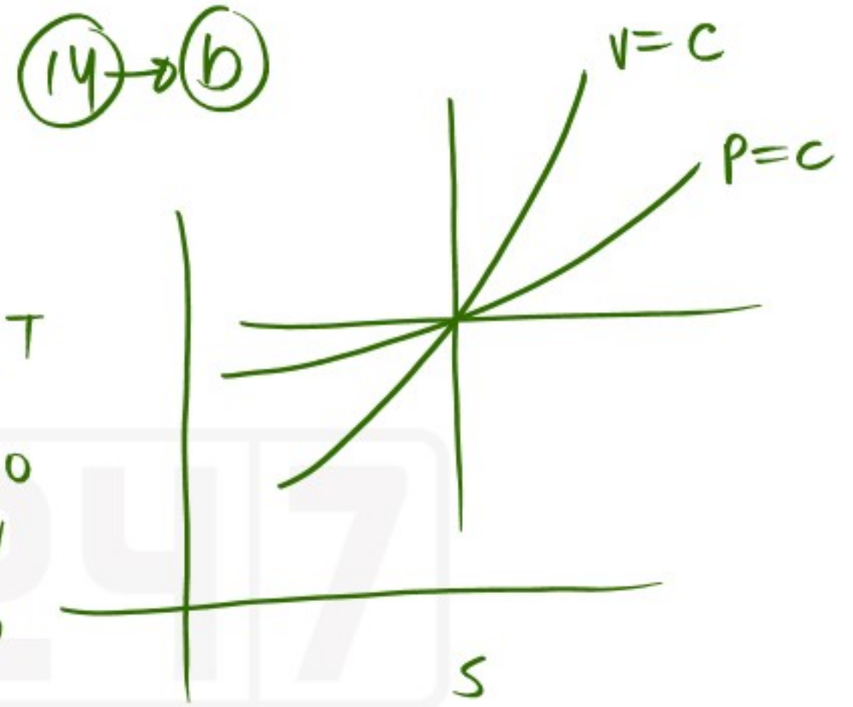
$\Rightarrow 3138.56 \frac{kJ}{kg}$

***

On a *T-S* diagram the slope of constant pressure line ($m_p$) and the slope of constant volume line ($m_v$) can be related by which one of the following relations ?

(a) $m_p = m_v$ (b) $m_v > m_p$

(c) $m_p > m_v$ (d) $m_p \cdot m_v = 1$




$Tds = du + Pdv$

$v \to c \Rightarrow dv = 0$

$Tds = C_v dT$

$\left(\frac{\partial T}{\partial s}\right)_{v=c} = \frac{T}{C_v}$ — (1)

$m_v$

$Tds = dh - vdp$

$P = c \Rightarrow dp = 0$

$Tds = C_p dT \Rightarrow \left(\frac{\partial T}{\partial s}\right)_{P=c} = \frac{T}{C_p}$

$m_p$

$C_p > C_v$

$\frac{1}{C_p} < \frac{1}{C_v}$

$\frac{T}{C_p} < \frac{T}{C_v}$

$m_p < m_v$

A tank of volume $0.05\ m^3$ contains a mixture of saturated water and saturated steam at $200^0C$. The mass of the liquid present is 8 kg. The entropy (in kJ/kgK) of the mixture is _____ (correct of two decimal places) property data for saturated steam and water are :

**[2 Marks]**

At $200^0C$, $p_{sat} = 1.5538\ MPa$,

$v_f = 0.001157\ m^3/kg$,

$v_g = 0.12736\ m^3/kg$,

$s_{fg} = 4.1014\ kJ/kgK$,

$s_f = 2.3309\ kJ/kgK$.

15

$V = 0.05 m^3$

$T = 200^\circ C$

$m_f = 8 kg$

$m = m_f + m_g$ (LIQUID, VAPOUR)

$V = V_f + V_g$

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

$V = mv$

$0.05 = v_f m_f + v_g m_g$

$0.05 = 0.001157 \times 8 + 0.12736 \times m_g$

$m_g = 0.3198$

$s = s_f + x(s_{fg})$

$x = \frac{m_g}{m_{total}}$

$x = \frac{0.3198}{8 + 0.3198} \Rightarrow 0.0384$

$s = 2.3309 + 0.0384(4.1014)$

$= 2.4884 \ kJ/kgK$

Q. The Van der Waals equation of state is

16 → C

$$\left(p+\frac{a}{v^2}\right)(v-b)=RT$$

p pressure, v is specific volume, T is temperature and R is characteristic gas constant. The SI unit of a is [1 Mark]

(A) J/kg-K

(B) m3 /kg

(C) m5 /kg-s2 ✓

(D) Pa/kg

N → $kg \times \frac{M}{S^2}$

UNIT OF (P) = UNIT OF $\left(\frac{a}{v^2}\right)$

$\frac{N}{M^2} = \frac{a}{\left(\frac{M^3}{kg}\right)^2}$ ⇒ $a = \frac{kg \cdot M}{M^3 S^2} \times \frac{M^6}{kg^2} M^5$

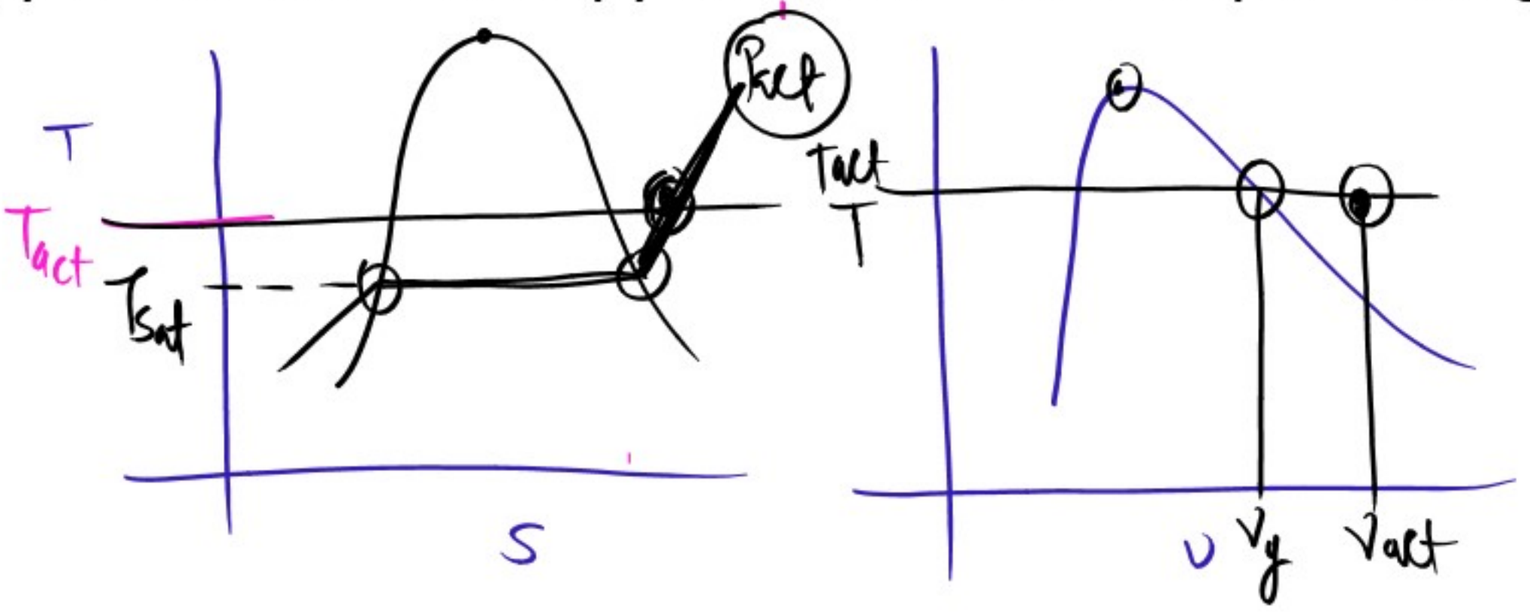
$\frac{M^5}{kg \cdot s^2}$

Q. Which one of the following statements is correct for a superheated vapour? [1 Mark]

1. Its pressure is less than the saturation pressure at a given temperature.
2. Its temperature is less than the saturation temperature at a given pressure. ✗

(C) Its volume is less than the volume of the saturated vapour at a given temperature. ✗

(D) Its enthalpy is less than enthalpy of the saturated vapour at a given pressure. ✗




17 → 9

TUESDAY

3PM

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