

Table of Contents

1. Atmospheric Processes
2. Lapse Rates — DALR, ELR, SALR
3. Inversion
4. Stability and Instability
5. Types of Instability
6. Stability Criteria
7. Tephigram
8. Normand Theorem
9. Practice Q&A
10. Master Reference Tables

1. Atmospheric Processes

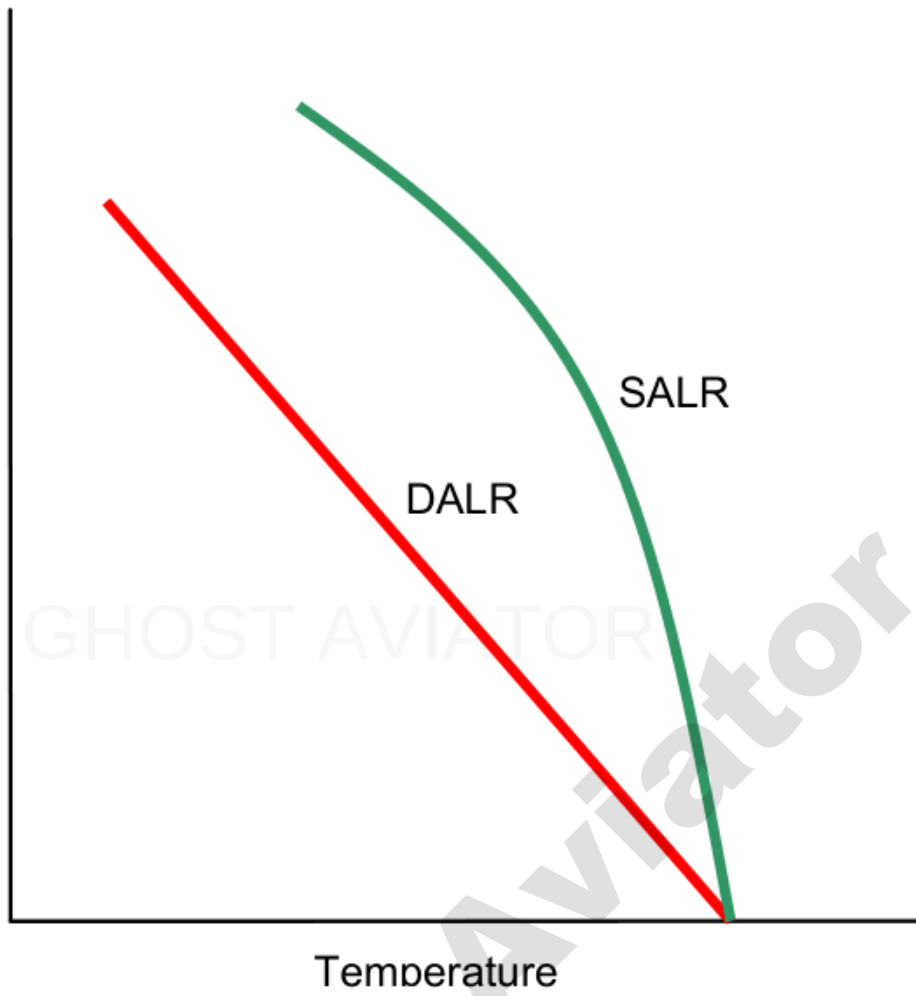
Air is a poor conductor of heat. A small rising or falling parcel of air in atmospheric processes can be regarded as insulated from its surroundings.

Process	Definition	Heat Exchange
Isothermal	Heat is allowed to enter or leave the system — temperature remains the same	Yes (with surroundings)
Adiabatic	No heat enters or leaves the system. (Greek: a = not, diabano = pass through)	No (insulated)

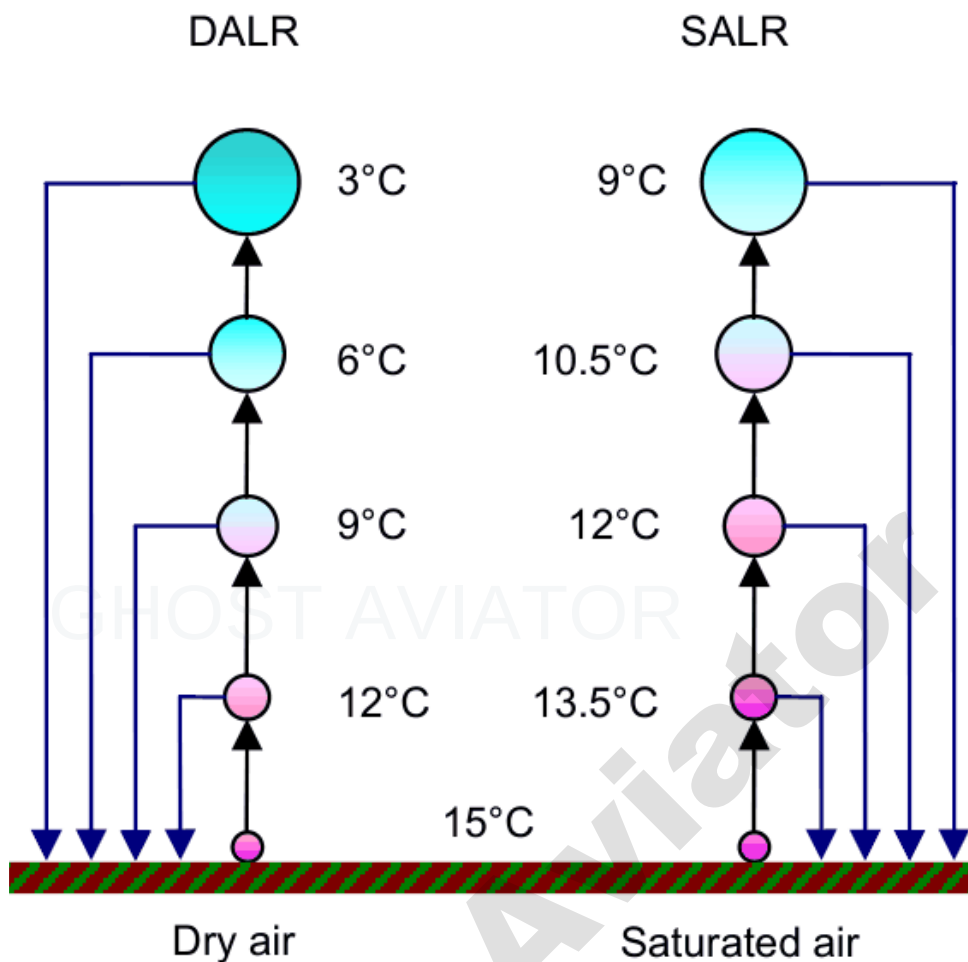
Adiabatic Process explained: If a parcel of air ascends adiabatically, it moves into a region of lower pressure and *expands*. The work done in expanding is at the expense of its internal energy → temperature falls. Conversely, descending air is compressed → temperature rises. Adiabatic processes, to a large extent, determine the vertical distribution of temperature in the atmosphere.

2. Lapse Rates

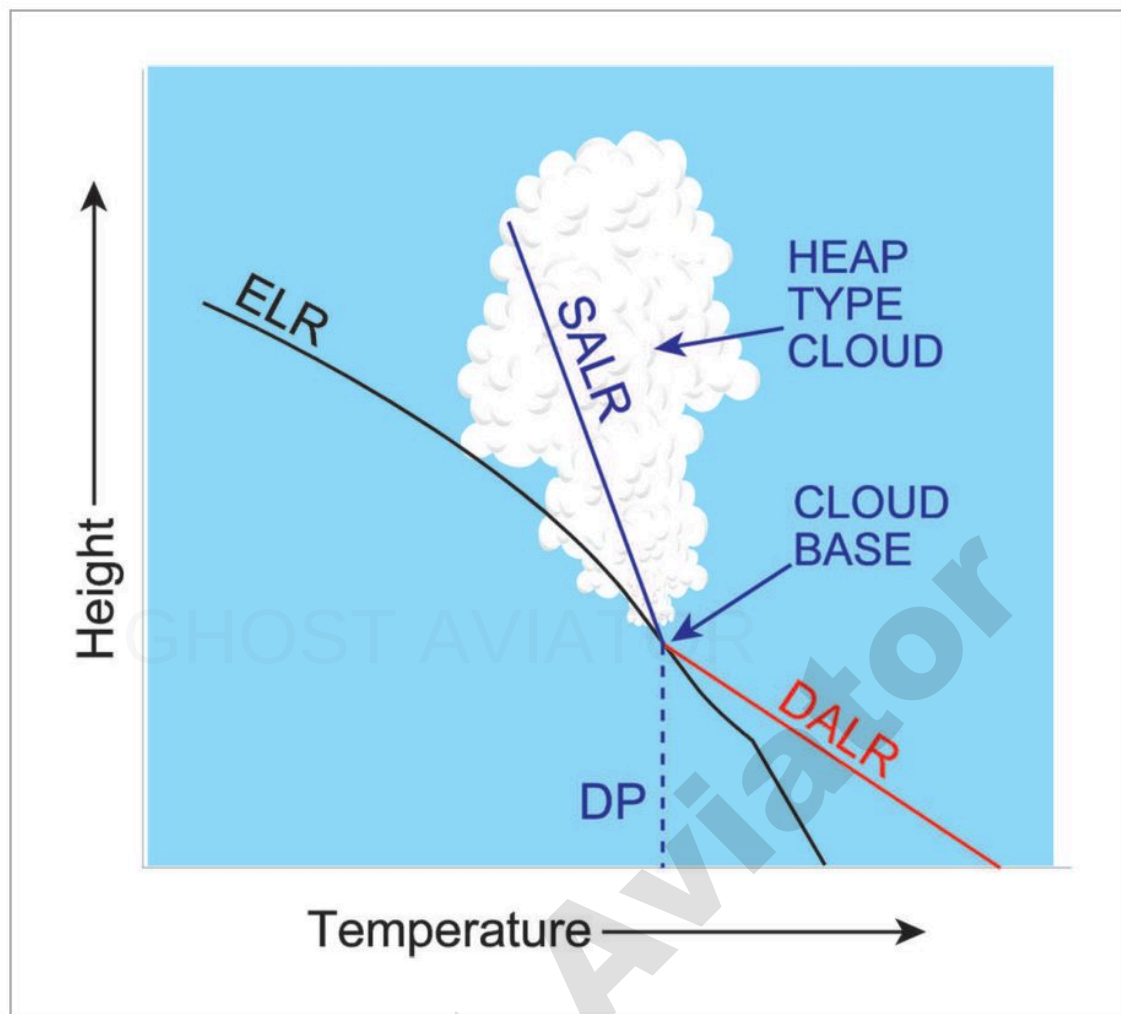
Lapse Rate (LR): Decrease of temperature with height. Taken positive when temperature decreases with height. Average LR in the troposphere is about **6.5°C/km**.



DALR and SALR on a temperature-height graph



Dry and saturated parcel cooling



Environmental lapse rate, DALR and SALR

Three Key Lapse Rates

DALR – Dry Adiabatic Lapse Rate Rate of temperature decrease with height when *unsaturated* air ascends adiabatically. Value = $9.8^{\circ}\text{C}/\text{km}$ = $3^{\circ}\text{C}/1000\text{ ft}$ (In ISA: ELR = $6.5^{\circ}\text{C}/\text{km}$)

SALR – Saturated Adiabatic Lapse Rate When saturated air lifts adiabatically → water vapour condenses → latent heat released → offsets adiabatic cooling. Value $\approx 5^{\circ}\text{C}/\text{km}$ (variable – generally increases as the rising air becomes colder, approaching DALR) At higher levels (low temperatures), very little WV → latent heat small → SALR approaches DALR.

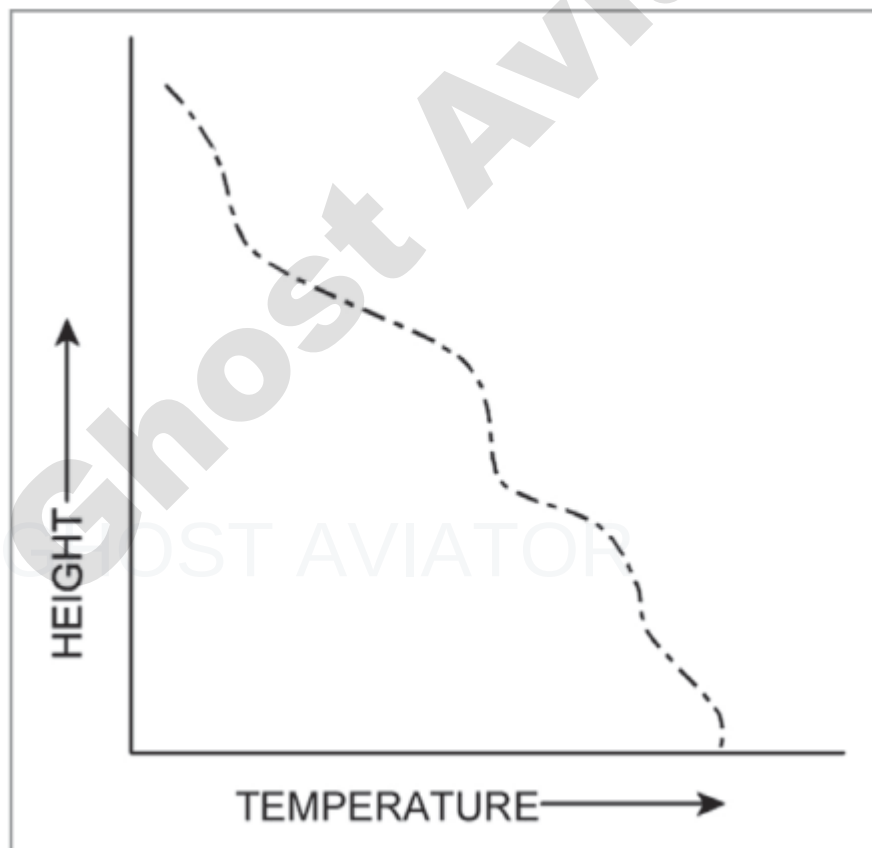
ELR – Environmental Lapse Rate Actual lapse rate existing in the atmosphere. In ISA, ELR = $6.5^{\circ}\text{C}/\text{km}$. In actual atmosphere: can be any value. It may be super-adiabatic (temperature decreases faster than DALR), zero (isothermal), or negative (an inversion).

Lapse Rate	Value	Condition
DALR	9.8°C/km (3°C/1000 ft)	Unsaturated ascending air
SALR	~5°C/km (variable)	Saturated ascending air
ELR (ISA)	6.5°C/km	Actual atmosphere (ISA standard)

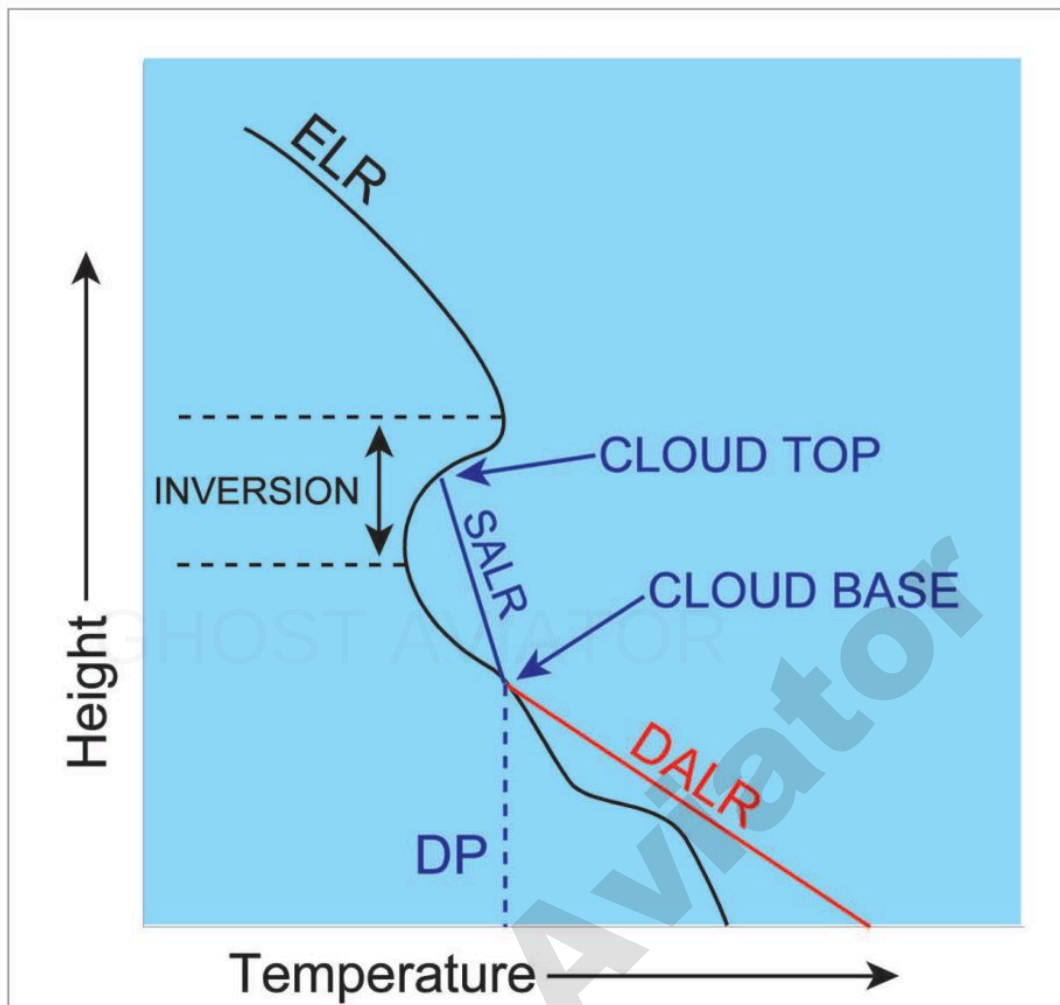
Mnemonic: DALR = Dry = Decreases fastest (9.8°C/km). SALR = Saturated = Slower cooling (latent heat released). ELR = Environment = actual.

3. Inversion

Inversion: Increase of temperature with height (negative lapse rate). Opposite of normal.



Variable environmental lapse rate



Inversion limiting cloud top

Inversion Layer

An atmospheric layer in which there is an inversion of temperature. Vertical motion through such a layer is inhibited due to stability in the layer. An inversion layer near the Earth's surface occurs during cloudless cool nights. Inversion at higher levels is associated with anticyclones and sometimes with the fronts.

Effects of Inversion

Type	Common Occurrence	Aviation Effect
Low level inversion	Common during winters due to nocturnal cooling. Also associated with ridges, high pressure areas and anticyclones.	Smoke, haze, mist, fog stagnate over ground → poor visibility . Often at top of stratified cloud layer.
Higher level inversion	Associated with anticyclones, sometimes fronts	Does not allow surface air to rise and mix with upper winds → smoke/pollution trapped below

Join live classes for guided practice and doubt clearing.

Key Point: Inversion indicates **stability** and **lack of turbulence** in the atmosphere. However, low level inversion causes poor visibility — haze, mist, fog, smoke stagnate — especially **radiation fog**. Inversion is often present at the top of a stratified cloud layer.

4. Stability and Instability

Stable atmosphere analogy: A glass ball placed at centre of a convex glass — displaced and left, it will oscillate and return to original position (like a pendulum). Stratosphere and Thermosphere are **stable** atmospheres.

Unstable atmosphere analogy: A glass ball placed at top of an inverted watch-glass — if displaced will roll down further, will NOT return to original position.

Atmospheric Instability

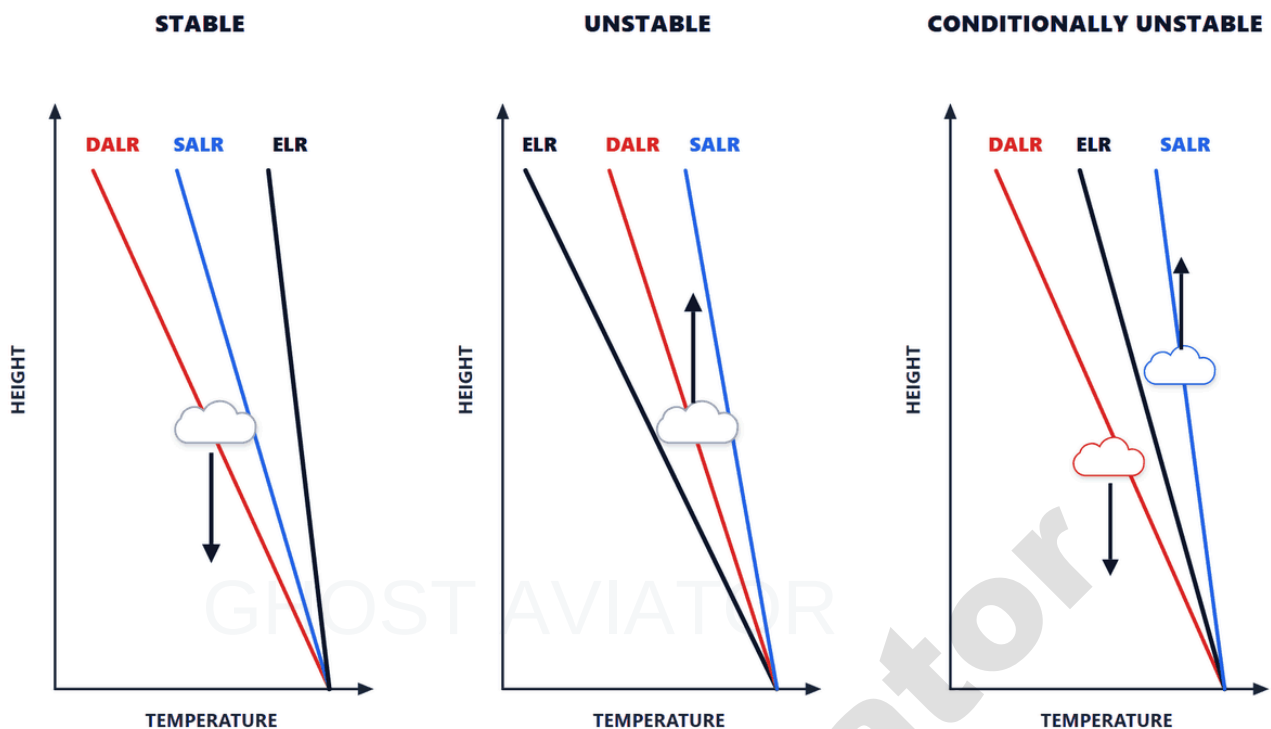
A layer is **stable** if a parcel of air in it, given a small push upwards, sinks back to its original level. It is **neutral** if it continues to move at its new level. It is **unstable** if it continues to move up at its own.

To estimate static stability in a layer, changes in KE of a test parcel at various levels are estimated from the Aerological Diagram (**T-phi gram / Tephigram**).

The atmosphere is stable, neutral or unstable according as the KE of the parcel decreases, remains constant or increases — A fall of temperature with height alone does not establish instability: compare the environmental lapse rate with the dry and saturated adiabatic rates.

5. Types of Instability/Stability

Conditional Instability: State of atmosphere in which **DALR > ELR > SALR**. Atmosphere is unstable for saturated air and stable for unsaturated air.



Stable, unstable and conditionally unstable air

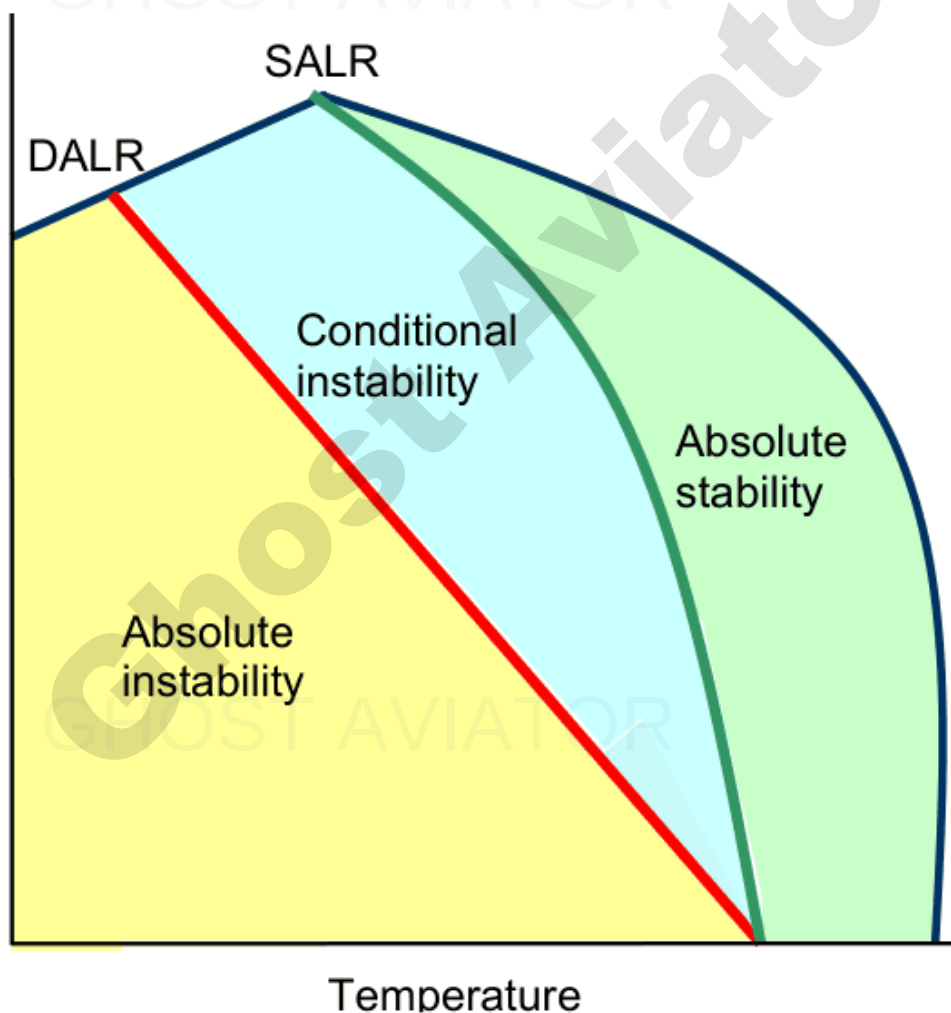
Latent Instability: An atmospheric layer in an initially stable parcel of air that eventually becomes unstable due to forced ascent. The parcel possesses latent (hidden) instability. It is **Real Latent** if force required to lift is much less than energy released when it becomes unstable. It is **Pseudo Latent** if energy required to lift > energy released later.

Potential (Convective) Instability: When a layer as a whole if lifted bodily becomes unstable if latent heat released on lifting produces sufficient temperature difference between bottom and top of layer to steepen LR of lifted layer. For potential instability it is essential that **RH is high in lower levels and low in higher levels**.

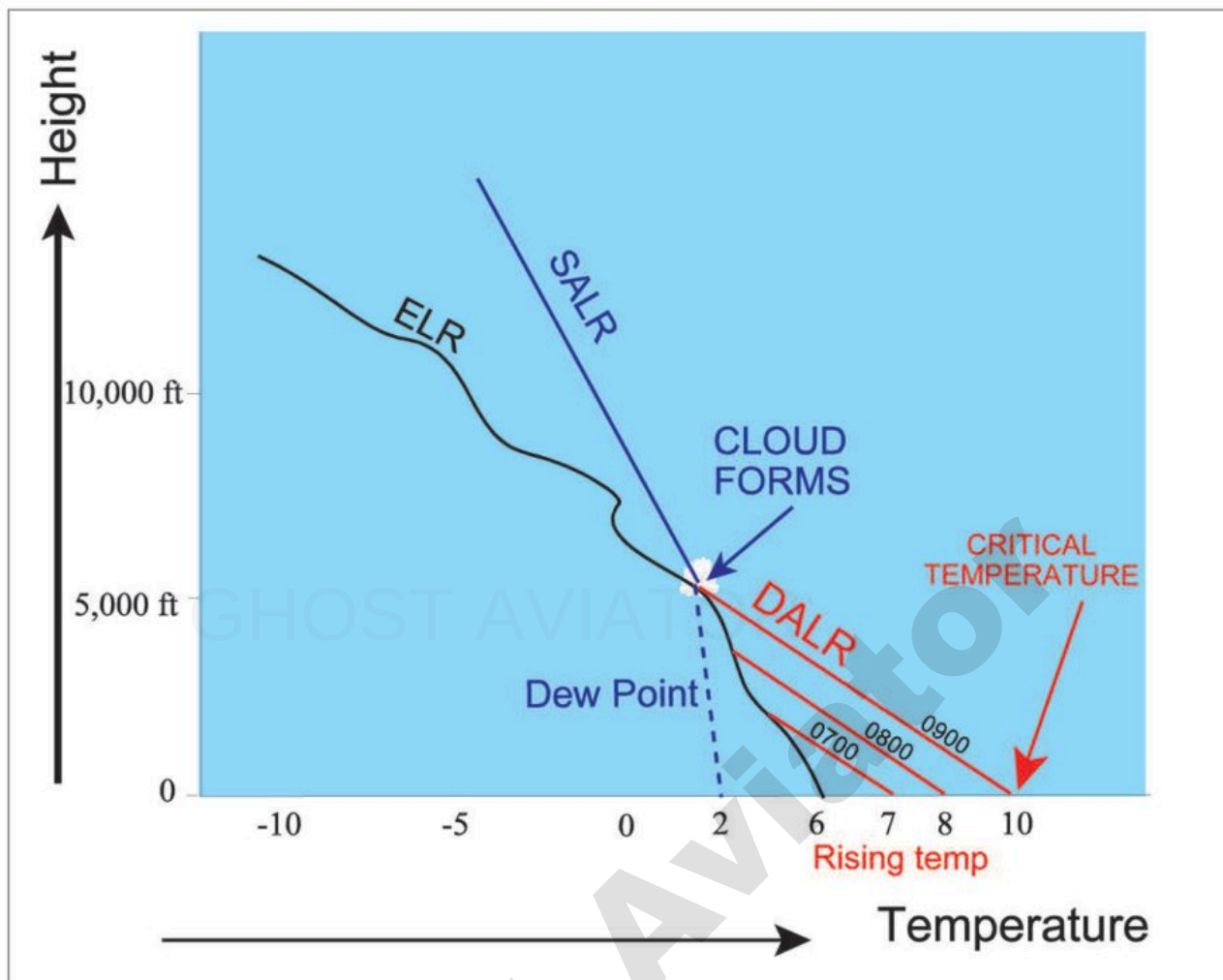
6. Stability Criteria

STABILITY CRITERIA TABLE

Condition	Stability Status	When (ELR relation)
Dry air is	Stable	$DALR > ELR$
Saturated air is	Stable	$SALR > ELR$
Air (Dry or Saturated) is	Absolutely Stable	$SALR > ELR$ (both dry and sat stable)
Air (Dry or Saturated) is	Absolutely Unstable	$ELR > DALR$
Conditional Instability	Unstable for sat; stable for dry	$DALR > ELR > SALR$



Stability regions by ELR



Condensation level and critical temperature

flowchart TD

A[ELR value?] --> B{Compare with SALR and DALR}

B -->|ELR < SALR| C[ABSOLUTELY STABLE

Both dry and sat air stable]

B -->|SALR < ELR < DALR| D[CONDITIONALLY UNSTABLE

Stable for dry, unstable for saturated]

B -->|ELR > DALR| E[ABSOLUTELY UNSTABLE

Both dry and sat air unstable]

C --> F[Fine wx, stratiform clouds]

D --> G[Thunderstorm if forced uplift + moisture]

E --> H[Severe convection, CB, TS]

Key Stability Rule:

DALR = **9.8°C/km** (fixed)

SALR ≈ **5°C/km** (variable)

ELR = actual measured value

If $ELR < SALR \rightarrow$ **Absolutely Stable (AS on both accounts)**

If $SALR < ELR < DALR \rightarrow$ **Conditionally Unstable**

If $ELR > DALR \rightarrow$ **Absolutely Unstable**

Worked Example from Textbook

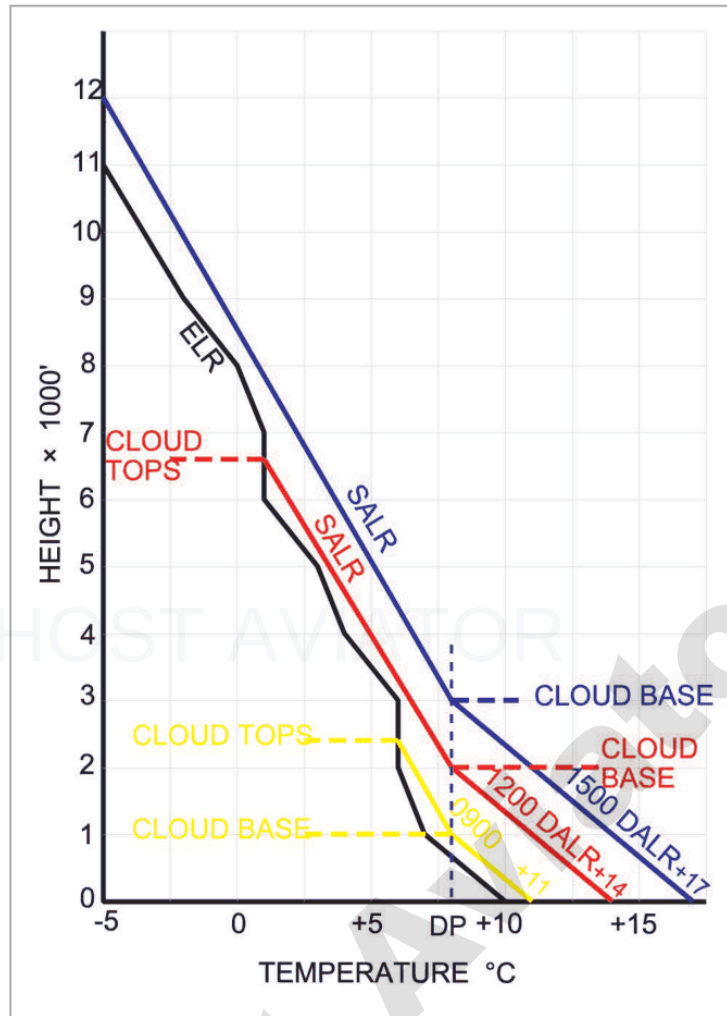
Q: DALR = 9.8°C, ELR = 6.8°C → atmosphere is? Compare: DALR (9.8) > ELR (6.8) > SALR (~5) → DALR > ELR > SALR → **Conditionally Unstable**
Q: SALR = 5.5°C, ELR = 4.5°C → atmosphere is? Compare: SALR (5.5) > ELR (4.5) → both stable → **Absolutely Stable**
Q: Surface temp 35°C, DALR → temp at 2 km? $T \text{ at } 2 \text{ km} = 35 - (9.8 \times 2) = 35 - 19.6 = 15.4^\circ\text{C} \approx 15^\circ\text{C}$

How to Apply Stability Test (T-phi gram)

When a parcel of dry air is lifted, it follows DALR. Saturated air follows SALR. Comparing the temperature of the lifted parcel (as given by DALR/SALR) with the environmental temperature (ELR) at any level AB (Figure 9.1): if parcel temperature is more than environmental → parcel will shoot up = **Unstable**. If colder → it will sink = **Stable**.

7. Tephigram (T-phi Gram)

Tephigram: A thermodynamic diagram on which upper air temperatures, winds and dew point temperatures (as obtained from Radiosondes and Rawin) are plotted at various levels. Used for estimating meteorological parameters viz. Instability-Stability in the atmosphere, Mintra Level, LCL, base and top of cloud, Potential and Latent Instability, wet bulb temperature etc.



Finding cloud base and tops on a temperature-height diagram

Lines on Tephigram (used in India)

Line Type	Represents
Horizontal Lines	Potential Temperature or DALR
Vertical Lines	Temperature
Slanting Lines 45° to DALR	Pressure at different levels
Curved lines slanting left (gradually becoming parallel to DALR at higher levels)	SALR lines
Dashed lines slightly slanting left	Isohygric lines (lines of equal saturation mixing ratio — g/kg)

Separate lines exist for saturation over water and over ice on the Tephigram.

8. Normand Theorem and Normand Point

Normand Theorem: If we draw upwards DALR from dry bulb (TT), SALR from wet bulb (TwTw), and Isohygric from dew point (TdTd) temperatures, the three lines meet at a point called the **Normand Point**. By knowing TT and TdTd, we can calculate TwTw at any level.

LCL (Lifting Condensation Level): The first Normand Point (from the surface) is the **First Normand Point**. This is also called the **Lifting Condensation Level (LCL)** and gives an idea of the height at which cloud may form.

Exam Tip: LCL = level where rising parcel first becomes saturated = cloud base height. Found using Tephigram by intersection of DALR (from TT), SALR (from TwTw) and Isohygric (from TdTd).

9. Practice Q&A

Q1. DALR = 9.8°C, ELR = 6.8°C — atmosphere is (a) stable (b) unstable

✅ Answer: (a) stable

The environmental lapse rate (6.8 °C/km) is less than the dry adiabatic lapse rate (9.8 °C/km). A lifted unsaturated parcel cools faster than its surroundings, becomes heavier and sinks back, so the atmosphere is stable for dry air. (If the air is saturated, the saturated rate of about 5 °C/km is smaller than 6.8, and the same atmosphere is conditionally unstable.)

❌ (b) Unstable would need the environmental lapse rate to exceed the dry adiabatic rate.

💡 ELR less than DALR = stable for dry air. ELR more than SALR but less than DALR = conditionally unstable.

Q2. SALR = 5.5°C, ELR = 4.5°C — atmosphere is (a) unstable (b) stable (c) indifferent

✅ Answer: (b) stable

SALR (5.5) > ELR (4.5): even saturated air is stable → Absolutely Stable atmosphere.

🎯 When SALR > ELR → Absolutely Stable. No convection possible even with moisture.

Q3. DALR > ELR > SALR is (a) conditionally unstable (b) latently stable (c) potentially stable

✅ Answer: (a) conditionally unstable

This is the definition of Conditional Instability: DALR > ELR > SALR. Stable for dry air, unstable for saturated air.

🎯 DALR > ELR > SALR = CONDITIONAL. Think: "conditionally" based on whether air is saturated or not.

Q4. Dry air is unstable when (a) ELR = DALR (b) ELR > DALR (c) ELR < DALR

✓ Answer: (b) $ELR > DALR$

Dry air is unstable when $ELR > DALR$ (Absolutely Unstable). The environment is cooling faster than the parcel → parcel remains warmer than surroundings → keeps rising.

🌀 $ELR > DALR$ = Absolutely Unstable = superadiabatic lapse rate = dangerous convection.

Q5. The saturated air is said to be unstable if (a) $SALR = ELR$ (b) $SALR < ELR$ (c) $SALR > ELR$

✓ Answer: (b) $SALR < ELR$

If $SALR < ELR$, the environment cools faster than the saturated parcel → parcel remains warmer → unstable.

🌀 For BOTH dry and saturated: if $ELR > \text{your lapse rate}$ → unstable. $ELR > SALR$ → saturated air unstable.

Q6. If $ELR = SALR = DALR$ the atmosphere is (a) Stable (b) Indifferent (c) Unstable

✓ Answer: (b) Indifferent (Neutral)

When all three lapse rates are equal, the parcel neither accelerates upward nor downward — neutral/indifferent equilibrium.

🌀 All equal = neutral. Parcel displaced stays at new level without returning or ascending further.

Q7. DALR means (a) Rate at which temperature of unsaturated parcel of air falls with height when made to ascend adiabatically (b) Rate at which temp falls with height (c) Rate at which ascending parcel of saturated air cools

✓ Answer: (a)

$DALR$ = Dry Adiabatic Lapse Rate = rate of cooling of unsaturated air ascending adiabatically = 9.8°C/km .

(b) = ELR definition; (c) = $SALR$ definition.

 D = Dry (unsaturated). A = Adiabatic. LR = Lapse Rate. Value = $9.8^{\circ}\text{C}/\text{km} = 3^{\circ}\text{C}/1000 \text{ ft}$.

Q8. Surface temp 30°C . Assuming DALR, temperature at 2 km is (a) 18°C (b) 10°C (c) 42°C

 Answer: (b) 10°C

$T \text{ at } 2 \text{ km} = 30 - (9.8 \times 2) = 30 - 19.6 \approx 10^{\circ}\text{C}$

 DALR = $9.8^{\circ}\text{C}/\text{km}$. Multiply by height in km and subtract from surface temp.

Q9. An Isothermal atmosphere is (a) Stable (b) Unstable (c) Neutral

 Answer: (a) Stable

Isothermal = ELR = 0. Since DALR (9.8) > ELR (0), dry air is stable. Since SALR (~ 5) > ELR (0), saturated air also stable $\rightarrow$ Absolutely Stable.

 Isothermal $\rightarrow$ ELR = $0 \rightarrow$ less than both DALR and SALR $\rightarrow$ Absolutely Stable.

Q10. If ELR is less than SALR, atmosphere is said to be (a) Absolutely unstable (b) Conditionally unstable (c) Absolutely stable

 Answer: (c) Absolutely stable

ELR < SALR means environment cools slower than even saturated air $\rightarrow$ both dry and saturated air parcels are stable $\rightarrow$ Absolutely Stable.

 ELR < SALR < DALR $\rightarrow$ Absolutely Stable $\rightarrow$ no convection possible $\rightarrow$ stratiform clouds, radiation fog.

Q11. DALR is approximately (a) $5^{\circ}\text{C}/\text{km}$ (b) $15^{\circ}\text{C}/\text{km}$ (c) $10^{\circ}\text{C}/\text{km}$

 Answer: (c) $10^{\circ}\text{C}/\text{km}$ (closest to $9.8^{\circ}\text{C}/\text{km}$)

DALR = $9.8^{\circ}\text{C}/\text{km} \approx 10^{\circ}\text{C}/\text{km}$. In some textbooks/exams rounded to $10^{\circ}\text{C}/\text{km}$.

 DALR $\approx 10^{\circ}\text{C}/\text{km}$ (exact = 9.8). SALR $\approx 5^{\circ}\text{C}/\text{km}$. ELR (ISA) = $6.5^{\circ}\text{C}/\text{km}$.

Q12. SALR at mean sea level is about (a) $10^{\circ}\text{C}/\text{km}$ (b) $5^{\circ}\text{C}/\text{km}$ (c) $5^{\circ}\text{F}/\text{km}$

 Answer: (b) $5^{\circ}\text{C}/\text{km}$

SALR near sea level where temperatures are warm and moisture is abundant is approximately $5^{\circ}\text{C}/\text{km}$. It varies and approaches DALR at high altitudes.

 SALR = $\sim 5^{\circ}\text{C}/\text{km}$ at MSL. Decreases toward DALR as altitude increases and moisture decreases.

Q13. SALR approaches DALR (a) at -15°C (b) at -40°C

 Answer: (b) at -40°C

At higher levels where temperature is below -40°C , very little water vapour is present $\rightarrow$ latent heat released on condensation is negligible $\rightarrow$ SALR approaches DALR ($9.8^{\circ}\text{C}/\text{km}$).

 -40°C = magic temperature. Below -40°C : supercooled water freezes spontaneously; SALR $\rightarrow$ DALR.

Q14. Dry air having a temp of 35°C on surface when forced to rise adiabatically by 1 km would attain a temp of (a) 29°C (b) 25°C (c) 45°C

 Answer: (b) 25°C

$$T = 35 - (9.8 \times 1) = 35 - 9.8 = 25.2^{\circ}\text{C} \approx 25^{\circ}\text{C}$$

 DALR: subtract 9.8°C ($\approx 10^{\circ}\text{C}$) per km ascent.

Q15. Inversion in the atmosphere indicates (a) Stability (b) Instability (c) Neutrality

 Answer: (a) Stability

Inversion = temperature increases with height = ELR is negative = highly stable condition. Vertical

motion is inhibited through an inversion layer.

 Inversion = Stability = Fog/Smog trap = poor visibility but no convection.

Q16. Environmental LR can be more than DALR (a) True (b) False

 Answer: (a) True

ELR can be more than DALR — this is called super-adiabatic lapse rate, creating Absolutely Unstable atmosphere. Common in very hot surface conditions.

 Super-adiabatic ELR ($>9.8^{\circ}\text{C}/\text{km}$) = dangerous convection. Rare but possible on very hot days.

Q18. The process which to a large extent determines the vertical distribution of temperature in atmosphere is (a) Adiabatic (b) Isothermal (c) Isentropic

 Answer: (a) Adiabatic

Adiabatic processes — DALR and SALR — determine vertical temperature distribution in the troposphere. Isothermal processes do not; isentropic is the same as adiabatic in many contexts but adiabatic is the key term here.

 Adiabatic processes = the key to atmospheric temperature distribution = pilot exam staple.

Q19. Rise in temperature with height is (a) Lapse (b) Normal (c) Inversion

 Answer: (c) Inversion

Lapse = fall with height (normal). Rise with height = Inversion (abnormal, negative lapse rate).

 Temperature rises with height = INVERSION. Always exam-worthy.

Q20. Inversion is common in (a) Post Monsoon (b) Monsoon (c) Winters

 Answer: (c) Winters

Low level inversion is common during winters due to nocturnal cooling of the surface, resulting in surface temperatures lower than air above. This traps fog and haze.

 Winter + clear sky + calm winds + night = radiation cooling = INVERSION = RADIATION FOG.

GHOST AVIATOR

Ghost Aviator

GHOST AVIATOR

10. Master Reference Tables

All Numerical Values

Parameter	Value
DALR	9.8°C/km = 3°C/1000 ft
SALR (MSL)	~5°C/km (variable)
ELR (ISA)	6.5°C/km
Average LR in troposphere	6.5°C/km
Temperature at which SALR → DALR	-40°C
Mintra level temperature estimate (100% RH)	-45°C

Stability Criteria Summary

Condition	ELR Relation	Stability
Absolutely Stable	$ELR < SALR < DALR$	Both dry and sat air stable
Conditionally Unstable	$SALR < ELR < DALR$	Dry stable; Saturated unstable
Absolutely Unstable	$ELR > DALR$	Both unstable (super-adiabatic)
Neutral (Dry)	$ELR = DALR$	Dry air neutral
Neutral (Saturated)	$ELR = SALR$	Saturated neutral
Inversion	$ELR < 0$ (negative)	Absolutely Stable
Isothermal	$ELR = 0$	Absolutely Stable

Quick Revision Summary — Chapter 9:

- Three processes: Isothermal (heat exchange), Adiabatic (no heat exchange)
- DALR = **9.8°C/km** (dry/unsaturated). SALR ≈ **5°C/km** (saturated, variable). ELR = actual.
- ELR < SALR → Absolutely Stable | SALR < ELR < DALR → Conditionally Unstable | ELR > DALR → Absolutely Unstable
- Inversion = T rises with height = stability = fog/smog trap = poor visibility
- Conditional Instability: stable for dry, unstable for saturated air
- Potential Instability: RH high in lower levels, low in higher levels
- Tephigram = thermodynamic chart for upper air data analysis
- Normand Point = intersection of DALR (from TT), SALR (from TwTw), Isohygric (from TdTd) = LCL = cloud base
- SALR approaches DALR at **-40°C** (very little WV at high altitude)