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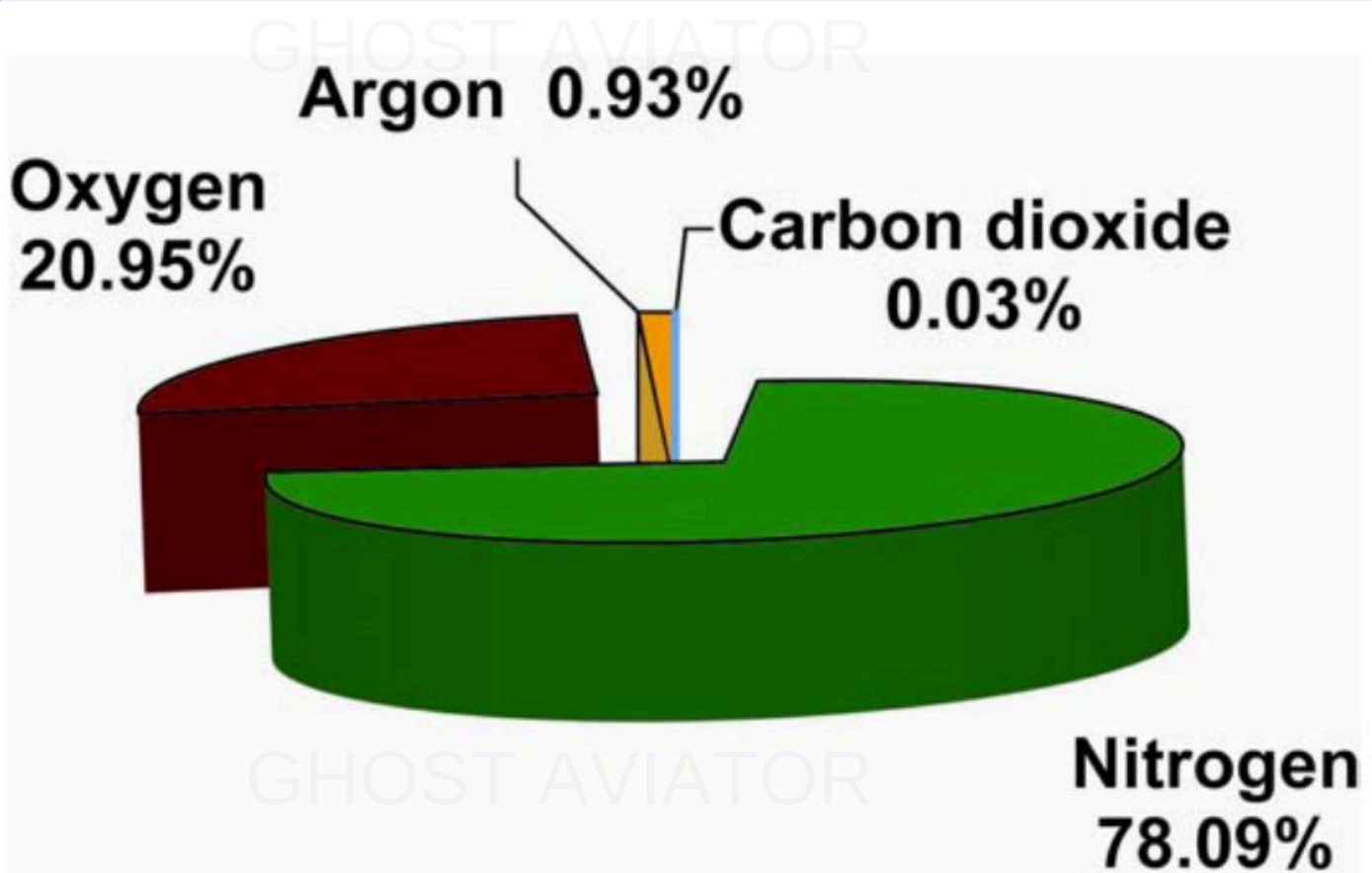
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1. Composition and Structure of the Atmosphere

Definition — Atmosphere

The atmosphere of the earth is an **envelope of homogeneous mixture of gases**, called **Air**. It surrounds the earth and is attached to it due to gravitation. It moves with the earth at the same speed and direction.

- Total thickness: approximately **480 km**
- **80%** of the atmosphere is within **16 km**
- No exact upper boundary — gradually merges with outer space



Composition of dry air near the surface

Characteristics of the Atmosphere

Property	Detail
Weight	Has weight and hence exerts pressure
Compressibility	Compressible and expandable
Shape	Occupies space, has no definite shape
Mobility	Mobile — allows transfer of heat and moisture
Conductivity	Poor conductor of heat and electricity

2. Constituents — Major Gases

Gas	Symbol	% by Volume
Nitrogen	N ₂	78.09%
Oxygen	O ₂	20.95%
Argon	Ar	0.93%
Carbon Dioxide	CO ₂	0.035%

Trace Gases

Neon, Helium, Methane, Krypton, Xenon, Nitrous Oxide, Iodine, H₂, O₃ (0.000007%), Ammonia, Carbon Monoxide, CO₂, SO, Nitrogen Dioxide. The atmosphere also contains water vapour (WV) and solid particles.

★ N₂ : O₂ Ratio — Exam Favourite

By Volume: N₂ : O₂ = 4 : 1

By Weight: N₂ : O₂ = 3 : 1

Mnemonic: "Volume 4, Weight 3 — N before O"

⚠ Supplementary Oxygen Required

Due to rapid reduction of gases with height, **supplementary oxygen is needed above 10,000 ft**.

Join live classes for guided practice and doubt clearing.

Homosphere vs Heterosphere

Layer	Height	Characteristic
Homosphere	Up to ~80 km	Nearly uniform composition; well-mixed
Heterosphere	Above 80 km	Gases separate by molecular weight; composition varies

3. Variable Gases, Greenhouse Gases & Dry/Saturated Air

Variable Gases

The gases like Water Vapour (WV), Carbon Mono Oxide, Sulphur di Oxide, Nitrogen di Oxide, and Methane **vary in amount from place to place**, being concentrated more in industrial areas, cities and water bodies, than in open areas. Though very small in quantity, these gases are very significant for weather and life.

Greenhouse Gases

Greenhouse Effect

Water vapour, CO₂, O₃, Methane and some other gases are **transparent to solar (Short Wave) radiation** but **partially absorb terrestrial (Long Wave) radiation**, and re-radiate it. This keeps the earth warmer than it would have otherwise been.

Greenhouse gases: H₂O, CO₂, O₃, CH₄ (Methane)

Global Warming Warning

Excessive amount of greenhouse gases is causing **Global Warming, which is a serious threat to our life and needs to be limited.**

Dry Air vs Saturated Air

Water in the atmosphere can exist in three states:

- **Solid:** Snow, Ice, Hail
- **Liquid:** Drizzle, Rain, Shower
- **Gas:** Water Vapour (WV)

Concept	Detail
WV concentration	Rapidly decreases with height
Warmer air	Can hold greater amount of WV
Tropics (23½°N to 23½°S)	Air can hold up to 4% WV by volume
Above 30,000 ft	Very low WV due to very low temperatures
Saturated air	The water-vapour pressure equals the saturation vapour pressure at that temperature: 100% RH . The required amount of vapour changes with temperature.
Unsaturated air	RH < 100%. Unsaturated air may still contain water vapour; “dry air” in composition and gas-law calculations means air without water vapour.

4. Carbon Dioxide (CO₂) & Ozone (O₃)

Carbon Dioxide (CO₂)

- Produced by burning of fuel, wood etc.
- Concentration substantial in **industrial areas**; negligible in Polar regions and higher altitudes
- Large amount of CO₂ is dissolved in the oceans
- Plants absorb CO₂, use its carbon as food and release O₂ into atmosphere

Ozone (O₃)

Ozone Properties

- Forms in the **upper atmosphere**
- Absorbs **Ultra Violet (UV) radiation** from the Sun → raises temperature
- The ozone distribution depends on chemical formation, destruction and transport by atmospheric circulation.
- Maximum O₃ concentration: **20–25 km**
- O₃ found between **10–50 km**

✓ Why Ozone Matters for Aviation & Life

Ozone protects us from the ill effects (like skin cancer, sunburn and cataracts) of UV radiation.

Ozone Hole

⚠ Ozone Depletion

In recent times the O₃ layer has **thinned** and large holes have developed mainly over the Polar and other latitudes due to:

- Atmospheric pollution
- Excessive use of **halocarbon refrigerants, solvents, chlorofluoro carbons**
- On reaching Stratosphere they release halogen atoms through **photodissociation** → breaks down O₃ into O₂

Solid Particles (Aerosols)

Particles such as salt from evaporating sea water, dust from arid regions, industrial particles:

- Obscure solar radiation and affect visibility and temperature
- Act as **condensation nuclei** → promote condensation of WV prematurely
- In larger cities/industrial areas: frequent **fog and smog** (mixture of fog and smoke) due to high concentration of particles

5. Vertical Distribution of Air Mass

Height	Fraction of Atmosphere Contained Below
6 km	1/2 (50%)
10 km	3/4 (75%)
35 km	99%

★ Memory Aid

"6-10-35 = Half-3/4-All"

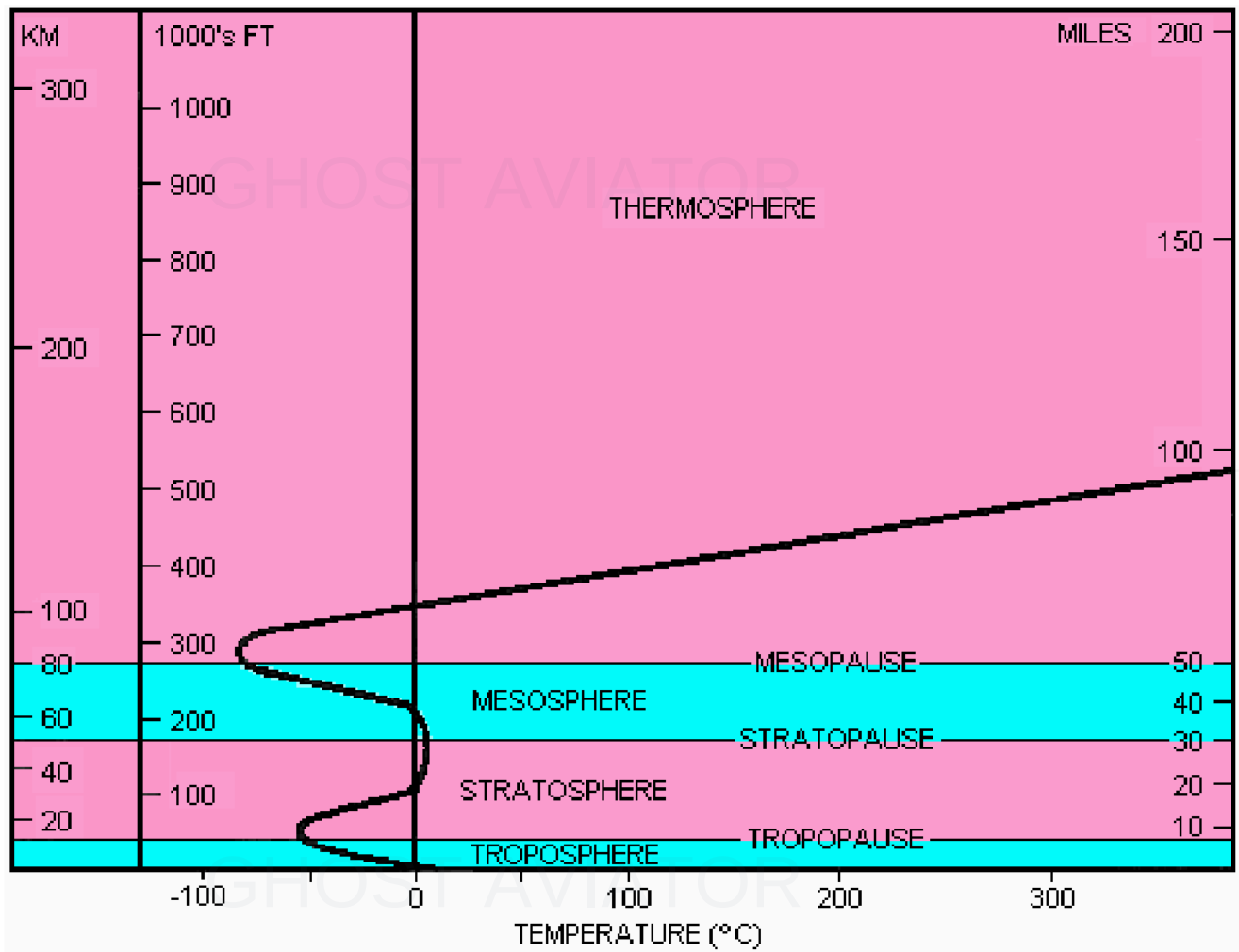
Half the atmosphere below 6 km; ¾ below 10 km; 99% below 35 km.

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6. Thermal Structure of the Atmosphere

How the Atmosphere is Heated

Solar radiation heats the earth and the earth in turn heats up the atmosphere by **conduction, convection, radiation** and release of latent heat by condensation of water vapour. Hence **temperature falls with height**, up to a certain height. **The atmosphere is thus heated from below and not from above.**



Temperature through the layers of the atmosphere

Heat Flow from Earth's Surface

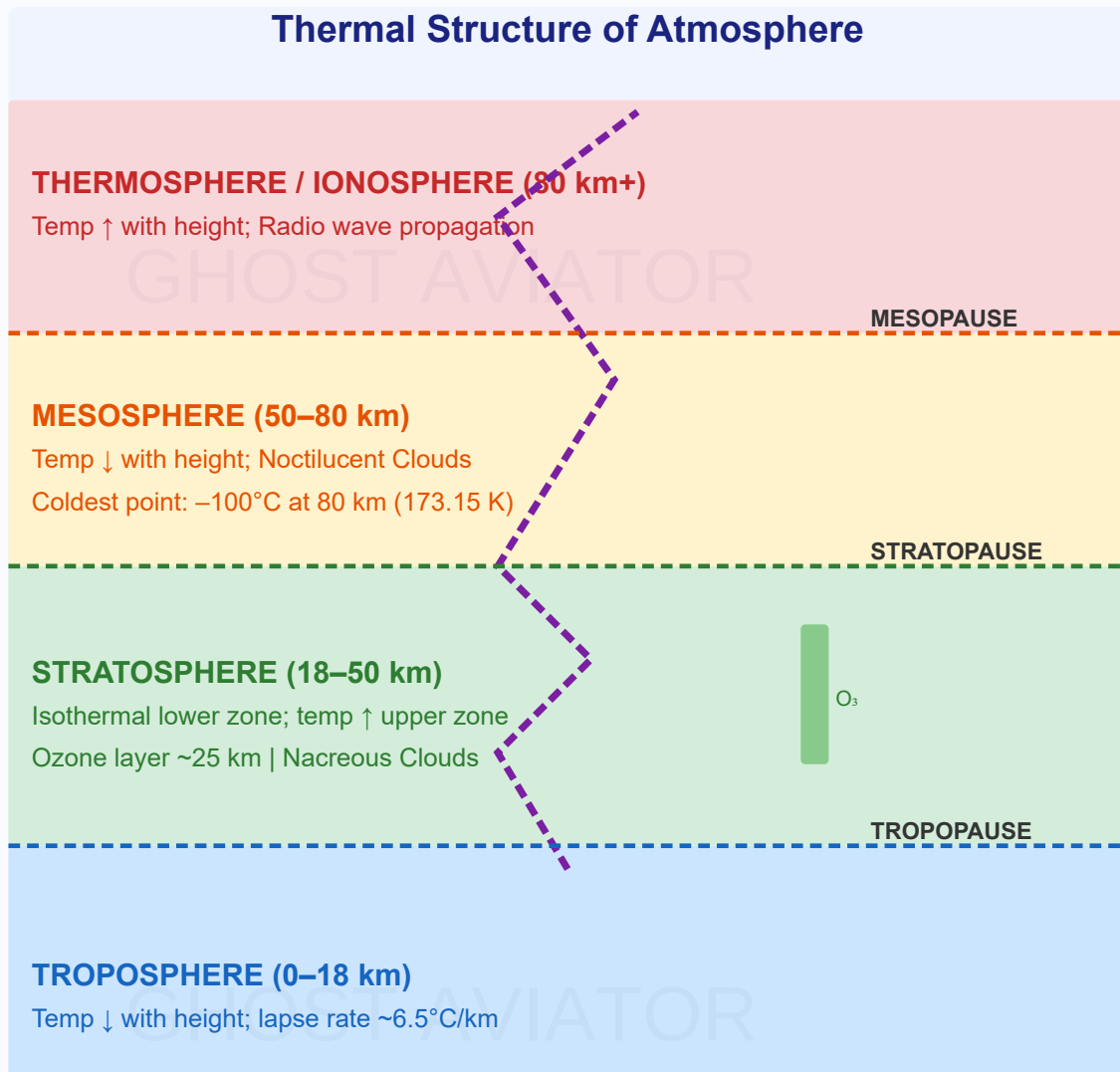
Type of Heat	Mechanism	Percentage
Sensible Heat	Conduction, Convection, Radiation	23%
Latent Heat	Evaporation, Condensation, Sublimation	77%

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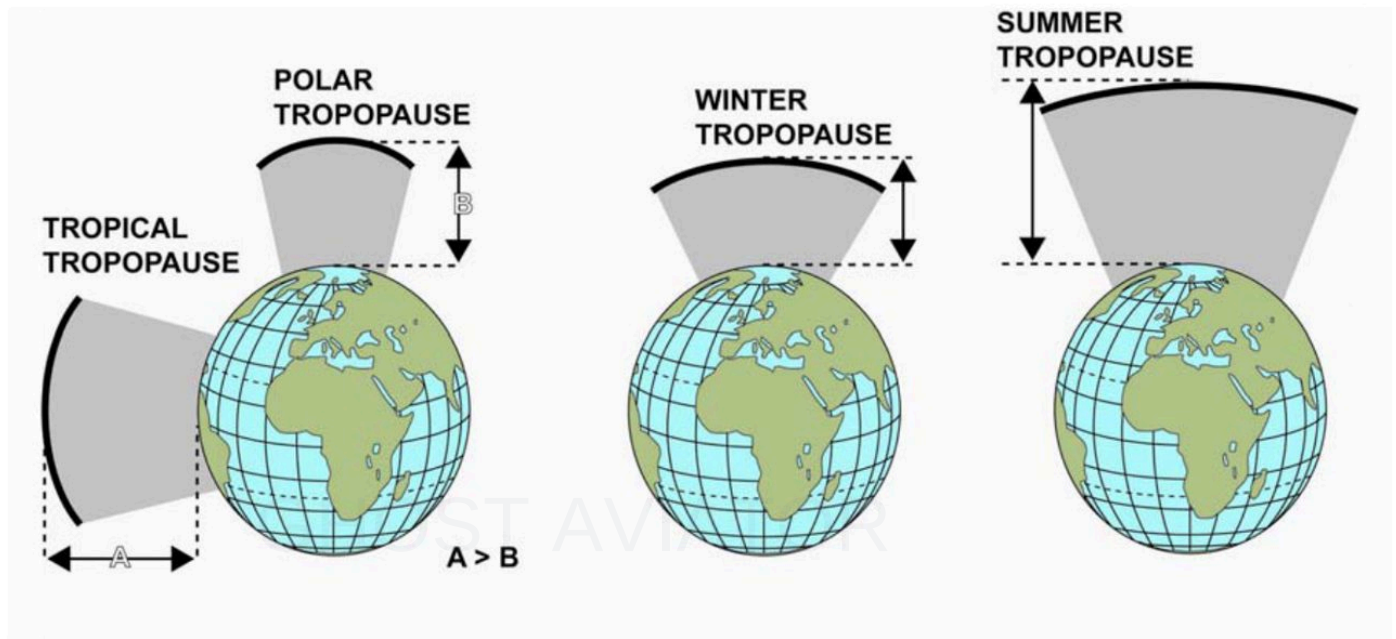
★ Exam Tip

Latent heat transfer is **dominant** at 77%. Sensible heat = 23%. Mnemonic: "*Latent is Larger (77)*"

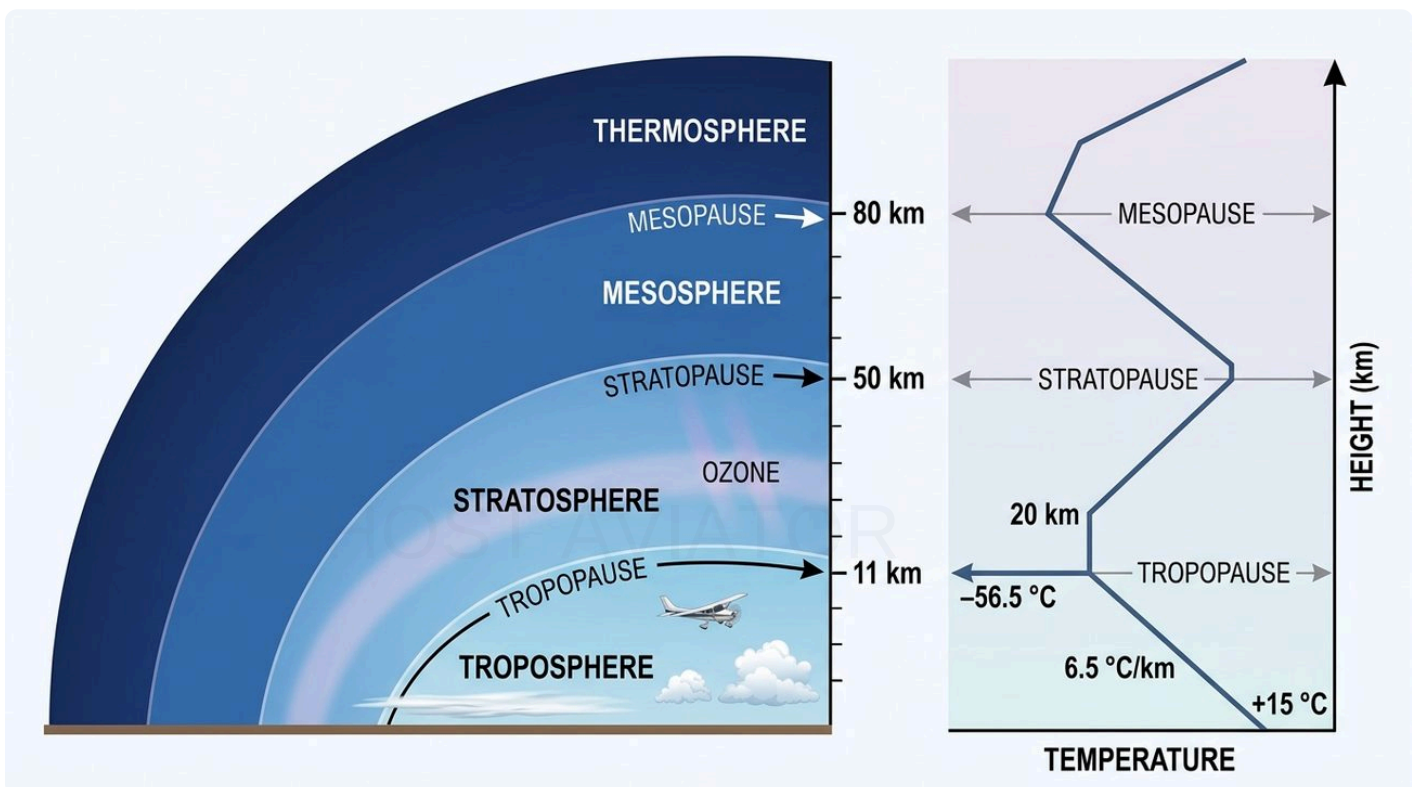
Thermal Structure — Visual Diagram



7. Atmospheric Layers in Detail



Tropopause height is highest over the tropics, lower in winter and higher in summer



The atmosphere in layers, with the temperature profile beside it

A. Troposphere

Troposphere

- Lowest portion of the atmosphere
- Extends from surface to **16–18 km** at equator and **8–10 km** at poles
- Higher height at equator due to **rising hot air convection currents**
- Temperature falls at **$\sim 6.5^{\circ}\text{C}/\text{km}$** — called the **Lapse Rate**
- All kinds of weather occur here; turbulent mixing
- Contains **75%** of atmospheric mass and **99%** of water vapour and aerosols

Sub-Layer	Height Range
Lower Troposphere	Surface to 2.1 km
Mid Troposphere	2.1 km to 7.6 km
Upper Troposphere	7.6 km to Tropopause

B. Tropopause

Tropopause

- Top of the troposphere; marks boundary between Troposphere and Stratosphere
- At tropopause: lapse rate reduces to **$1\text{--}2^{\circ}\text{C}/\text{km}$** or temperature stops falling
- Controlled by: Surface Temperature, Latitude, Season, Land-Sea distribution, Synoptic Situation
- Temperature at equator: **-70° to -75°C**
- Temperature at poles: **-40° to -45°C**
- At lower height in **Winters** than Summers
- **Warmer the surface** → **Higher the tropopause**

Tropopause Breaks/Folds

There are two regions where tropopause **abruptly changes height**, called **breaks/folds**:

- At about **40°** Lat and **60°** Lat
- Break at **40°** Lat is more prominent
- **Jet streams occur at these breaks**

Type	Pressure Level	Latitude Range	Height (India)	Temp (India)	Associated Jet
Polar Tropopause	~300 hPa	Lat. 45°–60° polewards	–	–	Polar Front Jet (southern end)
Middle Tropopause	~200 hPa	Between Polar & Tropical	~11.5 km (winters ~23°N)	–45°C	–
Tropical Tropopause	~100 hPa	Lat. 35°–40°	~11.5 km (winters ~23°N)	–45°C	Subtropical Jet (STJ) at southern end

✓ Importance of Tropopause for Pilots

- Maximum height clouds can reach
- Jet streams and maximum wind speeds occur **just below it**
- **Clear Air Turbulence (CAT)** occurs just below it

C. Stratosphere

▣ Stratosphere (Tropopause to ~50 km)

- Initially (8–10 km above tropopause) **isothermal**
- Temperature then increases slowly and towards the top sharply
- **Inversion produced by absorption of UV radiation from sun by ozone**
- Ozone layer found at height of ~25 km
- Very **dry and stable** region — low humidity, no weather
- Above stormy weather; steady, strong, horizontal winds
- **Nacreous Clouds** (Mother of Pearl Clouds) sometimes seen in higher latitudes in winters

Stratopause: Upper boundary of the Stratosphere.

D. Mesosphere

Mesosphere (Stratopause to ~80 km)

- Extends **50–80 km** from Stratopause
- Lack of solar radiation absorption + weak vertical mixing → temperatures **fall with height**
- **Noctilucent Clouds** seen occasionally in Polar regions

Mesopause: Top of Mesosphere. Temperatures stop falling. Coldest area of atmosphere. Temperature at 80 km = **-100°C** (**173.15 K**). Meteors burn up in this layer.

E. Thermosphere

Thermosphere / Ionosphere (80 km+)

- From Mesopause to end of atmosphere
- Temperatures **increase with height**
- Above **60 km** also called **ionosphere**
- Important for **radio wave propagation**
- Serious interference in radio propagation during solar disturbances

F. Exosphere

Exosphere (outermost layer)

- Outermost layer extending up to **10,000 km** from top of Thermosphere
- Molecules, ozone and atoms escape into space
- Air is very thin — few particles; very active with very high temperature but far apart → very little heat present in this layer

Atmospheric Layers — Process Flowchart

flowchart TD

```
A["🌍 Earth's Surface\n(0 km)"] --> B["TROPOSPHERE\n0-18 km (equator), 8-10 km (poles)\nTemp ↓ at 6.5°C/km\nAll weather here | 75% mass | 99% WV"]
B --> C["TROPOPAUSE\nTemp stops falling\nJet streams & CAT below it"]
C --> D["STRATOSPHERE\n~18-50 km\nOzone at 25 km absorbs UV\nTemp ↑ (inversion)\nStable, dry, no weather"]
D --> E["STRATOPAUSE"]
E --> F["MESOSPHERE\n~50-80 km\nTemp ↓ with height\nNoctilucent clouds (polar)\nMeteors burn here"]
F --> G["MESOPAUSE\n-100°C / 173 K\nColdest point"]
G --> H["THERMOSPHERE / IONOSPHERE\n80 km+\nTemp ↑ with height\nRadio wave propagation"]
H --> I["EXOSPHERE\nTo 10,000 km\nMolecules escape to space"]

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style B fill:#64b5f6
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8. International Standard Atmosphere (ISA)

What is ISA?

A standard average atmosphere specified for various purposes like design and testing of aircraft, evaluation of aircraft performance, calibration of altimeters. The most widely used is the **ICAO ISA (International Standard Atmosphere)**.

ISA Specifications

Parameter	Value
Air Condition	Dry
Temperature at MSL	15°C (288.15 K)
Pressure at MSL	1013.25 hPa
Density at MSL	1225 g/m ³
Acceleration due to gravity	980.665 cm/s ²
Lapse Rate (up to 11 km / 36,090 ft)	6.5°C/km (1.98°C/1000 ft ≈ 2°C/1000 ft)
Temperature 11–20 km (up to 65,617 ft)	-56.5°C (constant / isothermal)
Temperature 20–30 km	Rises at 1°C/km with temp -44.5°C at 32 km (104,987 ft)

ISA Deviation Formula

ISA Deviation = Actual Temperature - ISA Temperature

Worked Example 1:

Actual temp at 2 km = 05°C

ISA temp at 2 km = 15 - (6.5 × 2) = 15 - 13 = 2°C

ISA Deviation = 05 - 02 = +03°C

Worked Example 2:

Pressure at MSL = 1002.25 hPa

ISA Pressure at MSL = 1013.25 hPa

ISA Deviation = 1002.25 - 1013.25 = -11 hPa

Worked Example 3:

Actual temp at 19 km = -60°C

ISA temp at 19 km = -56.5°C (constant 11–20 km)

ISA Deviation = -60 - (-56.5) = -3.5°C → answer -03.5°C

★ Key ISA Numbers to Remember

15-25-56.5-36090

MSL Temp = 15°C | MSL Pressure = 1013.25 hPa | Isothermal at -56.5°C | Isothermal starts at 36,090 ft (11 km)

9. Jet Standard Atmosphere (JSA)

📦 Why JSA?

ISA values are satisfactory for aircraft operating below **30,000 ft**, but NOT above. For space flights and very high altitude flying and engine manufacturing, additional specific values are required. JSA was introduced to meet these requirements.

Parameter	ISA	JSA
MSL Temperature	15°C (288.15 K)	15°C (288.15 K)
Lapse Rate	6.5°C/km (1.98°C/1000 ft)	2°C/1000 ft
Tropopause	Yes (at 11 km)	No Tropopause

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Quick Revision Summary — Chapter 1: Atmosphere

Key Fact	Value
Total atmosphere thickness	~480 km
80% atmosphere within	16 km
N ₂ : O ₂ by Volume	4:1 By Weight: 3:1
Supplementary O ₂ above	10,000 ft
Homosphere up to	~80 km
Max WV (tropics)	4% by volume
Saturated Air RH	100%
Ozone max concentration	20–25 km
Ozone range	10–50 km
Sensible heat	23%
Latent heat	77%
Troposphere height (equator)	16–18 km
Troposphere height (poles)	8–10 km
Lapse rate	~6.5°C/km
WV + aerosols in troposphere	99%
Atmospheric mass in troposphere	75%
Tropopause temp (equator)	–70° to –75°C
Tropopause temp (poles)	–40° to –45°C
Stratosphere to	~50 km
Ozone layer height	~25 km
Mesosphere range	50–80 km
Mesopause temperature	–100°C (173.15 K)

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Ionosphere above	60 km
Exosphere up to	10,000 km
ISA MSL Temp	15°C (288.15 K)
ISA MSL Pressure	1013.25 hPa
ISA MSL Density	1225 g/m ³
ISA Lapse Rate	6.5°C/km up to 11 km
ISA Isothermal zone	−56.5°C, 11–20 km
JSA Lapse Rate	2°C/1000 ft (no tropopause)

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Practice Questions & Answers

Q1

Lowest layer of atmosphere is (a) Troposphere (b) Tropopause (c) Stratosphere

✓ CORRECT ANSWER: (A) TROPOSPHERE

The Troposphere is the lowest layer, starting at earth's surface and extending to the tropopause. All weather occurs here.

DISTRACTOR ANALYSIS

(b) Tropopause is a boundary, not a layer. (c) Stratosphere is above the Troposphere.

📌 INSTRUCTOR'S NOTE

Remember the order: **T-S-M-T-E** = Troposphere, Stratosphere, Mesosphere, Thermosphere, Exosphere from bottom to top.

Q2

Height of Tropopause at equator is (a) 8–10 km (b) 16–18 km (c) 14 km

✓ CORRECT ANSWER: (B) 16–18 KM

At the equator, rising hot air due to convection pushes the tropopause higher — up to 16–18 km.

DISTRACTOR ANALYSIS

(a) 8–10 km is the tropopause height at the poles. (c) 14 km is intermediate but incorrect.

📌 INSTRUCTOR'S NOTE

Equator = Hot = Higher tropopause. Poles = Cold = Lower tropopause. "Hotter higher, colder lower."

Q3

Height of Tropopause at Poles is (a) 12 km (b) 13 km (c) 08 km

✓ CORRECT ANSWER: (C) 08 KM

At the poles, the atmosphere is colder; therefore convective activity is minimal and the tropopause is lower, around 8–10 km.

DISTRACTOR ANALYSIS

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(a) and (b) are too high for polar regions.

 INSTRUCTOR'S NOTE

Polar tropopause ~300 hPa; Tropical tropopause ~100 hPa (lower pressure = higher altitude).

Q4

Higher the surface temperature would be the tropopause. (a) Higher (b) Lower (c) Same

 **CORRECT ANSWER: (A) HIGHER**

Warmer surfaces generate more convective activity, pushing the tropopause to a greater height.

DISTRACTOR ANALYSIS

(b) Lower — incorrect; this is the effect at colder surfaces/poles. (c) Same — temperature definitely affects tropopause height.

 INSTRUCTOR'S NOTE

"Warmer surface = Higher tropopause" — think of hot air balloons rising higher when it's warmer.

Q5

Height of tropopause (a) Is constant (b) Varies with altitude (c) Varies with Latitude

 **CORRECT ANSWER: (C) VARIES WITH LATITUDE**

Tropopause height depends on latitude (equator ~16–18 km; poles ~8 km) and also on season, surface temperature, synoptic situation.

DISTRACTOR ANALYSIS

(a) Is constant — definitely not; it varies significantly. (b) Varies with altitude — altitude is not the controlling factor.

 INSTRUCTOR'S NOTE

Tropopause height is controlled by: Surface Temp, Latitude, Season, Land-Sea distribution, Synoptic situation.

Q6

Above 8 km the lower temperatures are over (a) Equator (b) Mid Latitudes (c) Poles

 **Answer: (a) Equator**

Above the low polar tropopause (about 8 km) the polar air is already in the stratosphere, where temperature stops falling and begins to rise. Over the Equator the troposphere is still 16–18 km deep and keeps cooling, reaching about -75 to -80 °C at its top, against -40 to -50 °C at the Poles. So above 8 km it is colder over the Equator.

✗ (b) Mid-latitudes lie between the two extremes. (c) Poles: above 8 km the polar air is the warmer of the two.

💡 *At the surface the Equator is warmest; at tropopause level the Equator is coldest. The picture turns over at about 8 km.*

Q7

Atmosphere is heated by (a) Solar Radiation (b) Heat from earth surface (c) From above

✓ CORRECT ANSWER: (B) HEAT FROM EARTH SURFACE

The atmosphere is heated from below by the earth's surface (via conduction, convection, radiation and latent heat). The atmosphere is a poor absorber of direct solar radiation.

DISTRACTOR ANALYSIS

(a) Solar radiation heats the EARTH, not directly the lower atmosphere. (c) From above is incorrect — atmosphere is heated from below.

📌 INSTRUCTOR'S NOTE

Remember: **Temperature falls with height** in troposphere **BECAUSE** heating is from below.

Q8

The temperature at 80 km is (a) 173 K (b) 100 K (c) -137°C

✓ CORRECT ANSWER: (A) 173 K (= -100°C)

The text explicitly states: "The temperature at 80 km is about -100°C (173.15 K)." $173\text{ K} \approx -100^{\circ}\text{C}$. This is the Mesopause, the coldest point in the atmosphere.

DISTRACTOR ANALYSIS

(b) $100\text{ K} = -173^{\circ}\text{C}$, far too cold. (c) $-137^{\circ}\text{C} = 136\text{ K}$, not matching the textbook value.

📌 INSTRUCTOR'S NOTE

Mesopause = $-100^{\circ}\text{C} = 173.15\text{ K}$. Mnemonic: "80 km $\rightarrow$ 173 K $\rightarrow$ Meteors burn".

Q9

Join live classes for guided practice and doubt clearing.

CO₂ and H₂O are also called (a) Green House Gases (b) Rare Earth Gases (c) [other]

✅ CORRECT ANSWER: (A) GREEN HOUSE GASES

CO₂ and H₂O (water vapour) along with O₃ and Methane are greenhouse gases — they are transparent to shortwave solar radiation but absorb longwave terrestrial radiation.

DISTRACTOR ANALYSIS

(b) Rare Earth Gases (Noble gases like Argon, Neon, Helium) are a different category entirely.

📌 INSTRUCTOR'S NOTE

Greenhouse gases: **W-C-O-M** = Water vapour, CO₂, O₃, Methane.

Q10

Troposphere is generally (a) Stable (b) Unstable (c) Neutral

✅ CORRECT ANSWER: (B) UNSTABLE

The Troposphere has a lapse rate of ~6.5°C/km. With turbulent mixing, convective activity and all weather occurring here, it is generally unstable.

DISTRACTOR ANALYSIS

(a) Stable — that's the Stratosphere. (c) Neutral — not the defining characteristic.

📌 INSTRUCTOR'S NOTE

Troposphere = Unstable; Stratosphere = Stable. Easy contrast for exams.

Q11

Stratosphere is (a) Unstable (b) Neutral (c) Stable

✅ CORRECT ANSWER: (C) STABLE

The Stratosphere has a temperature inversion (temperature increases with height due to ozone absorbing UV), making it very stable with no convective weather.

DISTRACTOR ANALYSIS

(a) Unstable — that's the Troposphere. (b) Neutral — not the dominant characteristic.

📌 INSTRUCTOR'S NOTE

Stratosphere = "Stratified" = Layered = Stable. Also: no weather, steady winds.

Q12

Tropopause is discontinuous at about (a) 30°lat (b) 40°lat (c) 80°lat

✓ **CORRECT ANSWER: (B) 40°LAT**

The breaks/folds in the tropopause occur at ~40° and ~60° latitude, with the break at 40°lat being more prominent. Jet streams occur at these breaks.

DISTRACTOR ANALYSIS

(a) 30°lat — not a significant break. (c) 80°lat — too poleward, not where the prominent break is.

 INSTRUCTOR'S NOTE

"Break at 40, Fold at 60." Jet streams at these breaks — important for upper-level wind planning.

Q13

Most of atmospheric mass is contained in (a) Troposphere (b) Stratosphere (c) Heterosphere

✓ **CORRECT ANSWER: (A) TROPOSPHERE**

The Troposphere contains 75% of the atmospheric mass and 99% of water vapour and aerosols.

DISTRACTOR ANALYSIS

(b) Stratosphere is relatively thin in mass. (c) Heterosphere is the outer part with very low density.

 INSTRUCTOR'S NOTE

Troposphere = 75% mass, 99% WV & aerosols. Two key numbers.

Q14

Stratosphere extends from Tropopause to (a) 50 km (b) 60 km (c) 40 km

✓ **CORRECT ANSWER: (A) 50 KM**

The Stratosphere extends up to ~50 km from the earth's surface (approximately 30–32 km above the tropopause at equator).

DISTRACTOR ANALYSIS

(b) 60 km is too high — enters Mesosphere region. (c) 40 km is not the correct upper boundary.

 INSTRUCTOR'S NOTE

Layer tops: Tropo ~18, Strato ~50, Meso ~80. Easy: 18–50–80.

Q15

The middle atmosphere layer with temperature inversion and stability is (a) Troposphere (b) Tropopause (c) Stratosphere

✅ CORRECT ANSWER: (C) STRATOSPHERE

The Stratosphere has a temperature inversion (UV absorption by ozone warms upper layers) making it very stable. It lies between the Tropopause and Stratopause.

DISTRACTOR ANALYSIS

(a) Troposphere is unstable with a normal lapse rate. (b) Tropopause is a boundary, not a layer.

📌 INSTRUCTOR'S NOTE

Stratosphere = Stable + Inversion = Ozone = UV absorption. All linked.

Q16

Mother of Pearl clouds occur in (a) Mesosphere (b) Thermosphere (c) Stratosphere

✅ CORRECT ANSWER: (C) STRATOSPHERE

Nacreous Clouds (Mother of Pearl Clouds) are sometimes seen in the Stratosphere in higher latitudes in winters.

DISTRACTOR ANALYSIS

(a) Mesosphere — Noctilucent clouds occur here. (b) Thermosphere — no clouds form here.

📌 INSTRUCTOR'S NOTE

Nacreous = Stratosphere | Noctilucent = Mesosphere. "Na-Stra, Noc-Meso".

Q17

The temperature in ISA at 17 km is (a) -56.5°C (b) -65.5°C (c) -35.5°C

✅ CORRECT ANSWER: (A) -56.5°C

In ISA, from 11 km to 20 km (65,617 ft), temperature is assumed constant at -56.5°C . 17 km falls within this isothermal zone.

DISTRACTOR ANALYSIS

(b) -65.5°C and (c) -35.5°C are both incorrect — no lapse rate change occurs in this zone.

📌 INSTRUCTOR'S NOTE

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ISA isothermal zone: 11 km to 20 km = -56.5°C throughout. Any question with height 11–20 km → answer is -56.5°C .

Q18

By weight, approximate ratio of O_2 to N_2 in the atmosphere is (a) 1:3 (b) 1:4 (c) 1:5

✓ CORRECT ANSWER: (A) 1:3 (I.E., $\text{O}_2 : \text{N}_2 = 1:3$ BY WEIGHT)

$\text{N}_2 : \text{O}_2$ by weight = 3:1, so $\text{O}_2 : \text{N}_2$ by weight = 1:3.

DISTRACTOR ANALYSIS

(b) 1:4 — that is the VOLUME ratio ($\text{O}_2:\text{N}_2 = 1:4$). Don't confuse weight and volume ratios.

📌 INSTRUCTOR'S NOTE

Volume: 4:1 | Weight: 3:1 ($\text{N}_2:\text{O}_2$). Volume ratio is larger because N_2 is less dense per unit volume.

Q19

By volume, the approximate ratio of O_2 to N_2 in the atmosphere is (a) 1:3 (b) 1:4 (c) 1:5

✓ CORRECT ANSWER: (B) 1:4 ($\text{O}_2 : \text{N}_2 = 1:4$ BY VOLUME)

$\text{N}_2 : \text{O}_2$ by volume = 4:1, therefore $\text{O}_2 : \text{N}_2 = 1:4$. $\text{N}_2 = 78.09\%$, $\text{O}_2 = 20.95\%$ — ratio is almost 4:1.

DISTRACTOR ANALYSIS

(a) 1:3 is the weight ratio. (c) 1:5 is incorrect.

📌 INSTRUCTOR'S NOTE

Volume ratio is 4:1 (larger). Weight ratio is 3:1 (smaller). "Volume is Vast (4)."

Q20

By volume, the proportion of CO_2 in the atmosphere is (a) 3% (b) 0.3% (c) 0.03%

✓ CORRECT ANSWER: (C) 0.03% (0.035%)

CO_2 constitutes approximately 0.035% by volume in the atmosphere.

DISTRACTOR ANALYSIS

(a) 3% — vastly overstated. (b) 0.3% — 10 times too high.

📌 INSTRUCTOR'S NOTE

$\text{CO}_2 = 0.035\% \approx 0.03\%$ — tiny amount but significant for greenhouse effect.

Q21

In ISA, the mean sea level temperature is (a) 15°C (b) 10°C (c) 25°C

✅ CORRECT ANSWER: (A) 15°C

ISA MSL temperature = 15°C (288.15 K). This is a fundamental ISA value.

DISTRACTOR ANALYSIS

(b) 10°C — incorrect. (c) 25°C — too warm, not ISA standard.

📌 **INSTRUCTOR'S NOTE**

ISA MSL: Temp = 15°C, Pressure = 1013.25 hPa, Density = 1225 g/m³. Memorise all three together.

Q22

Maximum concentration of ozone is at a height of (a) 10–15 km (b) 20–25 km (c) 30–35 km

✅ CORRECT ANSWER: (B) 20–25 KM

Ozone is found between 10–50 km with maximum concentration at 20–25 km in the lower Stratosphere.

DISTRACTOR ANALYSIS

(a) 10–15 km — lower end of ozone range, not maximum. (c) 30–35 km — past the maximum.

📌 **INSTRUCTOR'S NOTE**

Ozone range: 10–50 km | Max: 20–25 km | Ozone layer: ~25 km. "20-25 is Ozone's favourite zone."

Q23

Additional oxygen is needed while flying above (a) 5000 ft (b) 7000 ft (c) 10000 ft

✅ CORRECT ANSWER: (C) 10000 FT

Due to rapid reduction of gases with height, supplementary oxygen is needed above 10,000 ft.

DISTRACTOR ANALYSIS

(a) 5000 ft and (b) 7000 ft — below the threshold requiring supplemental oxygen.

📌 **INSTRUCTOR'S NOTE**

10,000 ft = critical altitude for supplemental O₂. Also relevant for cabin pressurization regulations.

Q24

CO₂ and H₂O keep the atmosphere (a) Warm (b) Cold (c) Have no effect

✓ CORRECT ANSWER: (A) WARM

CO₂ and H₂O are greenhouse gases that absorb terrestrial longwave radiation and re-radiate it, keeping the earth warmer than it would otherwise be.

DISTRACTOR ANALYSIS

(b) Cold — incorrect, they trap heat. (c) Have no effect — incorrect, they are the primary drivers of the greenhouse effect.

 INSTRUCTOR'S NOTE

Think of greenhouse gases as a "blanket" around the earth, trapping warmth.

Q25

Noctilucent clouds occur in (a) Thermosphere (b) Mesosphere (c) Stratosphere

✓ CORRECT ANSWER: (B) MESOSPHERE

Noctilucent Clouds are seen on rare occasions in the upper Mesosphere, in Polar regions.

DISTRACTOR ANALYSIS

(a) Thermosphere — no clouds form there. (c) Stratosphere — Nacreous/Mother of Pearl clouds occur here, not Noctilucent.

 INSTRUCTOR'S NOTE

Noctilucent = Mesosphere (Polar) | Nacreous = Stratosphere (higher latitudes, winters). Know both!

Q26

Temperature at 2 km is 05°C. What is ISA deviation? Hint: (Actual – ISA) (a) –05°C (b) –02°C (c) 03°C

✓ CORRECT ANSWER: (C) 03°C (I.E. +03°C)

ISA temp at 2 km = $15 - (6.5 \times 2) = 15 - 13 = 2^\circ\text{C}$. ISA Deviation = $5 - 2 = +3^\circ\text{C}$.

DISTRACTOR ANALYSIS

(a) –5°C wrong sign and magnitude. (b) –2°C — wrong direction entirely.

 INSTRUCTOR'S NOTE

ISA Deviation = Actual – ISA. Positive deviation = warmer than ISA. Always compute ISA temp first using lapse rate.

Q27

Pressure at MSL is 1002.25 hPa. Find the ISA deviation. Hint: (Actual – ISA) (a) –11 hPa (b) 10 hPa (c) 12 hPa

✓ CORRECT ANSWER: (A) –11 HPA

ISA MSL Pressure = 1013.25 hPa. Deviation = $1002.25 - 1013.25 = -11$ hPa. Negative means pressure is lower than ISA standard.

DISTRACTOR ANALYSIS

(b) 10 hPa and (c) 12 hPa — wrong sign and magnitude.

📌 INSTRUCTOR'S NOTE

Same formula applies for pressure deviation as temperature deviation. ISA MSL Pressure = 1013.25 hPa.

Q28

In actual atmosphere temp. at 19 km is –60°C. Find the ISA deviation. Hint: (Actual – ISA) (a) –4.5°C (b) –05.5°C (c) –03.5°C

✓ CORRECT ANSWER: (C) –03.5°C

ISA temp at 19 km = –56.5°C (isothermal zone 11–20 km). Deviation = $-60 - (-56.5) = -60 + 56.5 = -3.5^\circ\text{C}$.

DISTRACTOR ANALYSIS

(a) –4.5°C and (b) –5.5°C are arithmetic errors — make sure signs are handled correctly.

📌 INSTRUCTOR'S NOTE

For any altitude between 11–20 km: ISA temp is always –56.5°C. Don't try to apply lapse rate in this zone.

Q29

Nacreous clouds occur in (a) Thermosphere (b) Mesosphere (c) Upper Stratosphere

✓ CORRECT ANSWER: (C) UPPER STRATOSPHERE (STRATOSPHERE)

Nacreous Clouds (Mother of Pearl Clouds) are sometimes seen in the Stratosphere in higher latitudes in winters.

DISTRACTOR ANALYSIS

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(a) Thermosphere — no clouds. (b) Mesosphere — Noctilucent clouds.

 INSTRUCTOR'S NOTE

Nacreous clouds are iridescent and beautiful — found in the stratosphere over polar regions in winter.

Q30

The atmosphere up to 80 km has a nearly similar composition and is called the Homosphere. Its uniform composition is due to (a) Pressure (b) Gravitation of earth (c) Mixing due to turbulence

☒ **CORRECT ANSWER: (C) MIXING DUE TO TURBULENCE**

The atmosphere is generally well mixed up to ~80 km due to turbulent mixing, maintaining a nearly uniform composition.

DISTRACTOR ANALYSIS

(a) Pressure alone doesn't cause uniform mixing. (b) Gravitation causes vertical stratification, not uniform mixing.

 INSTRUCTOR'S NOTE

Homosphere = uniform mixing by turbulence. Heterosphere = no mixing = separation by molecular weight.

Q31

Half of the atmospheric air mass is contained below (a) 20,000 ft (b) 15,000 ft (c) 10,000 ft

☒ Answer: (a) 20,000 ft

Half of the mass of the atmosphere lies below about 5.5–6 km, roughly 18,000–20,000 ft. Of the three options, 20,000 ft is the closest.

☒ (b) 15,000 ft (about 4.6 km) and (c) 10,000 ft (about 3 km) are too low: well over half of the air is still above those levels.

 *Half the air is below about FL180, which is why the 500 hPa level sits near FL180.*

Q32

In jet standard atmosphere the Lapse Rate is (a) 2°C/1000 ft (b) 2°C/km (c) 5°C/km

☒ Answer: (a) 2°C/1000 ft

The Jet Standard Atmosphere assumes a constant lapse rate of 2 °C per 1000 ft and has no tropopause.

✗ (b) 2 °C/km is far too small a lapse rate. (c) 5 °C/km is not a standard rate.

💡 JSA: 2 °C/1000 ft, no tropopause. ISA: 6.5 °C/km (about 2 °C/1000 ft) up to 11 km, then isothermal.

Q33

The rate of fall of temperatures with height, called (a) Isothermal rate (b) Inversion Rate (c) Lapse Rate

✓ CORRECT ANSWER: (C) LAPSE RATE

Lapse rate is the rate at which temperature decreases with increasing altitude, approximately 6.5°C/km in the ISA troposphere.

DISTRACTOR ANALYSIS

(a) Isothermal rate — temperature does NOT change with height (isothermal). (b) Inversion Rate — temperature INCREASES with height (inverse of normal).

📌 INSTRUCTOR'S NOTE

Lapse Rate = normal fall of temperature with height. Inversion = temperature rise with height. Isothermal = constant temperature.

Q34

In actual atmosphere the lapse rate could (a) Assume any value (b) Fall up to 8 km. (c) Rise up to 50 km

✓ CORRECT ANSWER: (A) ASSUME ANY VALUE

In the actual (real) atmosphere — unlike ISA — the lapse rate can assume any value; it can be positive, zero (isothermal), or negative (inversion) depending on atmospheric conditions.

DISTRACTOR ANALYSIS

(b) and (c) describe fixed behaviours. The actual atmosphere is highly variable.

📌 INSTRUCTOR'S NOTE

ISA lapse rate = fixed at 6.5°C/km. ACTUAL lapse rate = variable, can be anything. This distinction is key for stability analysis.

Q35

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Tropical Tropopause extends from the equator to Lat. 35°–40°. Over India it is at (a) 20–21 km (b) 14–15 km (c) 16–16.5 km

✅ Answer: (c) 16–16.5 km

The tropical tropopause lies near the 100 hPa level, roughly 16–16.5 km, and extends from the equator to about 35°–40° latitude. It is the tropopause over most of India in the summer.

❌ (a) 20–21 km is higher than any tropopause. (b) 14–15 km is lower than the ~100 hPa tropical level.

💡 Tropical tropopause: about 100 hPa, 16 km. Polar tropopause: about 300 hPa, 8–10 km.

Q36

Lapse rate in the troposphere is produced by and in the stratosphere by (a) Evaporation; condensation (b) Condensation; solar radiation (c) Terrestrial radiation; solar radiation (d) Solar radiation; convection

✅ CORRECT ANSWER: (C) TERRESTRIAL RADIATION; SOLAR RADIATION

In the Troposphere: cooling with height is due to terrestrial radiation heating from below. In Stratosphere: temperature inversion is due to solar radiation (UV) being absorbed by ozone — causing warming with height.

DISTRACTOR ANALYSIS

Other combinations mix up the mechanisms. Condensation releases latent heat but is not the primary cause of the lapse rate.

📌 INSTRUCTOR'S NOTE

Troposphere heated from Earth (below) → cools upward. Stratosphere heated by ozone absorbing UV (from Sun above) → warms upward.

Q37

Most of the water vapour in the atmosphere is confined up to (a) stratosphere (b) 30,000 ft (c) Mid troposphere (d) lower troposphere

✅ Answer: (b) 30,000 ft

Water vapour is held in the lowest part of the troposphere and falls off quickly with height. Above about 30,000 ft the amount is negligible, so that is the limit up to which it is confined.

❌ (a) The stratosphere holds almost no water vapour. (c) and (d): most of the vapour is in the lower

troposphere, but the level asked for is the upper limit of its presence.

💡 *Water vapour: troposphere only, mostly in the lowest few km, negligible above 30,000 ft.*

Q38

Negative lapse rate of temperature is (a) Isothermal rate (b) Temperature rise with lowering height (c) Temperature rise with height (d) Temperature fall with height

✅ CORRECT ANSWER: (C) TEMPERATURE RISE WITH HEIGHT

A "negative lapse rate" means temperature increases with altitude — this is called an **inversion**. This occurs in the Stratosphere and in inversions within the Troposphere.

DISTRACTOR ANALYSIS

(a) Isothermal = zero lapse rate (no temperature change). (d) Temperature fall with height = positive lapse rate (normal). (b) is phrased incorrectly.

📌 INSTRUCTOR'S NOTE

Positive lapse rate = temp falls with height (normal). Zero lapse rate = isothermal. Negative lapse rate = inversion (temp rises with height).

Q39

In ICAO ISA the atmosphere is assumed to be isothermal (a) in stratosphere (b) 11 to 16 km (c) 11 to 20 km (d) 11 to 32 km

✅ CORRECT ANSWER: (C) 11 TO 20 KM

In ICAO ISA, temperature is assumed constant at -56.5°C from 11 km (36,090 ft) to 20 km (65,617 ft). This is the isothermal (stratospheric) zone.

DISTRACTOR ANALYSIS

(b) 11–16 km — too narrow. (d) 11–32 km — too wide; from 20 km temperature starts rising again. (a) "in stratosphere" is vague and incorrect if taken to mean the whole stratosphere.

📌 INSTRUCTOR'S NOTE

ISA Isothermal: 11–20 km at -56.5°C . After 20 km temp rises. After 32 km another zone begins.

Q40

One of the characteristics of our atmosphere is (a) Poor conductor of heat and electricity (b) Equator is warmer than poles above 10 km (c) Lapse rate is positive in stratosphere (d) Density is constant above 8 km

✓ CORRECT ANSWER: (A) POOR CONDUCTOR OF HEAT AND ELECTRICITY

The atmosphere is a poor conductor of heat and electricity — one of its key characteristics listed at the beginning of the chapter.

DISTRACTOR ANALYSIS

(b) Above 10 km, poles are actually warmer than equator at the tropopause (poles -40 to -45°C vs equator -70 to -75°C). (c) Lapse rate in stratosphere is negative (inversion). (d) Density is NOT constant above 8 km.

📌 INSTRUCTOR'S NOTE

Atmosphere = poor conductor. Counterintuitively, tropopause at POLES is warmer (-40°C) than EQUATOR (-75°C) — despite surface being opposite!

Q41

Heat transfer in the atmosphere is maximum due to (a) convection (b) radiation (c) sensible heat (d) latent heat

✓ CORRECT ANSWER: (D) LATENT HEAT

Latent Heat (Evaporation, Condensation, Sublimation) accounts for 77% of heat transfer from earth to atmosphere — much more than sensible heat at 23%.

DISTRACTOR ANALYSIS

(a) Convection is a mechanism within sensible heat, not the maximum overall. (b) Radiation contributes but is part of the 23%. (c) Sensible heat is only 23%.

📌 INSTRUCTOR'S NOTE

Latent heat = 77% (dominant!). Sensible heat = 23%. "Latent is Larger at 77%."

Q42

The knowledge of the height of tropopause is important for a pilot because (a) weather is mainly confined up to this level (b) clouds rarely reach up to this height due to jetstream (c) stratosphere starts at this height where all solar radiation is absorbed

✓ CORRECT ANSWER: (A) WEATHER IS MAINLY CONFINED UP TO THIS LEVEL

The tropopause is the maximum height clouds can reach. All weather, turbulence, cloud formations are below it. Knowing its height helps pilots plan for weather-free cruising altitudes.

DISTRACTOR ANALYSIS

(b) Clouds do grow to just below tropopause — not because of jet streams. (c) Solar radiation is absorbed by ozone in the stratosphere, not at the tropopause itself.

INSTRUCTOR'S NOTE

Tropopause = weather ceiling. Above it = stable, clear, steady stratospheric winds. CAT and Jet streams just BELOW it.

Q43

In ISA atmosphere the tropopause occurs at a height of (a) 8–10 km (b) 11 km (c) 16–18 km

 CORRECT ANSWER: (B) 11 KM

In ICAO ISA, the tropopause is fixed at **11 km (36,090 ft)**, where the lapse rate stops and isothermal zone begins (-56.5°C).

DISTRACTOR ANALYSIS

(a) 8–10 km = actual polar tropopause. (c) 16–18 km = actual equatorial tropopause. ISA is a standard — fixed at 11 km.

INSTRUCTOR'S NOTE

ISA tropopause = 11 km = 36,090 ft. This is a fixed constant in ISA, unlike the actual variable tropopause.

Q44

Most of the transfer of heat in the atmosphere is due to (a) conduction (b) convection (c) Both A and B (d) latent heat

 CORRECT ANSWER: (D) LATENT HEAT

As stated in the chapter: Latent Heat transfer = 77% (dominant). Sensible heat (including conduction, convection, radiation) = 23%.

DISTRACTOR ANALYSIS

(a) Conduction — atmosphere is a poor conductor. (b) Convection — important but part of 23%. (c) Both — only 23% combined.

INSTRUCTOR'S NOTE

This question is almost identical to Q41. Reinforce: Latent heat dominates atmospheric heat transfer.

Master Reference Tables

1. All Numerical Values — Chapter 1

Parameter	Value	Source
Atmosphere total thickness	~480 km	Composition
80% atmosphere below	16 km	Composition
N ₂ by volume	78.09%	Constituents
O ₂ by volume	20.95%	Constituents
Argon by volume	0.93%	Constituents
CO ₂ by volume	0.035%	Constituents
O ₃ trace concentration	0.000007%	Constituents
N ₂ :O ₂ by Volume	4:1	Ratios
N ₂ :O ₂ by Weight	3:1	Ratios
Supplemental O ₂ required above	10,000 ft	Physiology
Homosphere up to	~80 km	Structure
Max WV (tropics)	4% by volume	WV
WV minimal above	30,000 ft	WV
Tropics latitude band	23½°N to 23½°S	WV
Ozone range	10–50 km	Ozone
Ozone max concentration	20–25 km	Ozone
Ozone layer (Stratosphere)	~25 km	Ozone
Airmass below 6 km	1/2 (50%)	Vertical dist.
Airmass below 10 km	3/4 (75%)	Vertical dist.
Airmass below 35 km	99%	Vertical dist.
Sensible heat transfer	23%	Thermal

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Latent heat transfer	77%	Thermal
Troposphere height (equator)	16–18 km	Layers
Troposphere height (poles)	8–10 km	Layers
ISA Lapse rate	6.5°C/km ($\approx 1.98^\circ\text{C}/1000\text{ ft}$)	Layers
Atmospheric mass in troposphere	75%	Layers
WV+aerosols in troposphere	99%	Layers
Lower Troposphere	Surface – 2.1 km	Layers
Mid Troposphere	2.1 – 7.6 km	Layers
Upper Troposphere	7.6 km – Tropopause	Layers
Tropopause lapse rate	1–2°C/km	Tropopause
Tropopause temp (equator)	–70° to –75°C	Tropopause
Tropopause temp (poles)	–40° to –45°C	Tropopause
Tropopause breaks at	~40° and ~60° Lat	Tropopause
Polar Tropopause pressure	~300 hPa	Tropopause
Tropical Tropopause pressure	~100 hPa	Tropopause
Middle Tropopause pressure	~200 hPa	Tropopause
Stratosphere extent	~18–50 km	Layers
Mesosphere extent	50–80 km	Layers
Mesopause temperature	–100°C (173.15 K)	Layers
Ionosphere above	60 km	Layers
Exosphere extent	Up to 10,000 km	Layers
ISA MSL Temperature	15°C (288.15 K)	ISA
ISA MSL Pressure	1013.25 hPa	ISA
ISA MSL Density	1225 g/m ³	ISA

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ISA gravity	980.665 cm/s ²	ISA
ISA isothermal zone	11–20 km at –56.5°C	ISA
ISA isothermal start	11 km = 36,090 ft	ISA
ISA isothermal end	20 km = 65,617 ft	ISA
ISA temp rise zone (20–30 km)	1°C/km, –44.5°C at 32 km	ISA
JSA Lapse rate	2°C/1000 ft	JSA
JSA valid below	30,000 ft (ISA ok); JSA for above	JSA

2. Mnemonics Summary

Mnemonic	What it Helps Remember
T-S-M-T-E	Atmospheric layers bottom to top: Troposphere, Stratosphere, Mesosphere, Thermosphere, Exosphere
Volume 4, Weight 3	N ₂ :O ₂ ratio by Volume=4:1, by Weight=3:1
Latent is Larger (77%)	Latent heat transfer = 77%, Sensible = 23%
6–10–35 = Half–3/4–All	Vertical air mass distribution
Hotter = Higher (Tropopause)	Warmer surface → higher tropopause
15–1013.25–1225	ISA MSL: Temp, Pressure, Density
11 km = 36,090 ft = –56.5°C	ISA tropopause and isothermal start
Na-Stra, Noc-Meso	Nacreous clouds = Stratosphere; Noctilucent = Mesosphere
W-C-O-M	Greenhouse gases: Water vapour, CO ₂ , O ₃ , Methane
20–25 is Ozone's zone	Maximum ozone concentration at 20–25 km
ISA Dev = Actual – ISA	Formula for ISA deviation (positive = warmer than standard)
Break at 40, Fold at 60	Tropopause discontinuities at ~40° and ~60° latitude

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3. Formula Sheet

Key Formulae — Chapter 1

ISA Temperature at altitude h (km), for $h \leq 11$ km:

$$T(h) = 15 - 6.5 \times h \text{ [}^\circ\text{C]}$$

Example: $h = 5 \text{ km} \rightarrow T = 15 - 32.5 = -17.5^\circ\text{C}$

ISA Deviation:

$$\text{ISA Deviation} = T_{\text{actual}} - T_{\text{ISA}}$$

Positive = warmer than ISA | Negative = colder than ISA

ISA Isothermal zone (11–20 km):

$$T = -56.5^\circ\text{C} \text{ (constant; no lapse rate applies)}$$

Kelvin–Celsius conversion:

$$K = ^\circ\text{C} + 273.15$$

$$-56.5^\circ\text{C} = 216.65 \text{ K} \mid -100^\circ\text{C} = 173.15 \text{ K} \mid 15^\circ\text{C} = 288.15 \text{ K}$$

GHOST AVIATOR