

Human Performance & Limitations · Module A — The Ocean of Air

Altitude & Oxygen

Chapter 3 — The partial pressure of oxygen and the altitude penalty, the four physiological zones of the atmosphere, and the numbers every pilot must know cold.

BOOK

Human Performance & Limitations

AUTHOR

Ghost Aviator

EXAM

DGCA CPL / ATPL — HPL

CHAPTER

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Plate 3.0 — Higher is thinner. As the total pressure falls, so does the oxygen your blood can reach — the altitude penalty.

§ 4

Partial Pressure of Oxygen — Effects of Increasing Altitude

As you climb, the **total barometric pressure** drops, and with it the **partial pressure of oxygen** (pO_2). Because the diffusion of oxygen across the alveolar membrane depends on the pressure gradient, what matters to your blood is not the percentage of O_2 — it is the pO_2 . Here are the standard values the DGCA expects you to know:

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Standard barometric pressure & oxygen availability at altitude

Altitude	Standard Barometric Pressure	O ₂ Available (% of Sea Level)	Pilot Significance
Sea Level (0000 ft)	101 kPa (760 mmHg)	100 %	Normal physiological baseline.
8,000 ft	77 kPa (574 mmHg)	76 %	Cabin pressure is maintained between 6,000 – 8,000 ft.
12,000 ft	66 kPa (496 mmHg)	65 %	Lower edge of the Physiological-Deficient Zone.
18,000 ft	53 kPa (395 mmHg)	52 % (≈ half)	Half the O₂ of sea level.
24,000 ft	41 kPa (311 mmHg)	41 %	Without supplemental O ₂ — incapacitation imminent.
36,000 ft	25 kPa (187 mmHg)	25 % (one-fourth)	Only ¼ of sea-level oxygen.

THREE DEDUCTIONS YOU MUST BE ABLE TO STATE IN THE EXAM

1. The **availability of oxygen and barometric pressure DECREASE** with altitude.
2. The oxygen available is **one-fourth** at **36,000 ft** and **half** at **18,000 ft** of the oxygen available at sea level.
3. **Atmospheric pressure drops faster at lower altitudes** in comparison to the same altitude changes at higher altitudes (the pressure–altitude curve is exponential, not linear).

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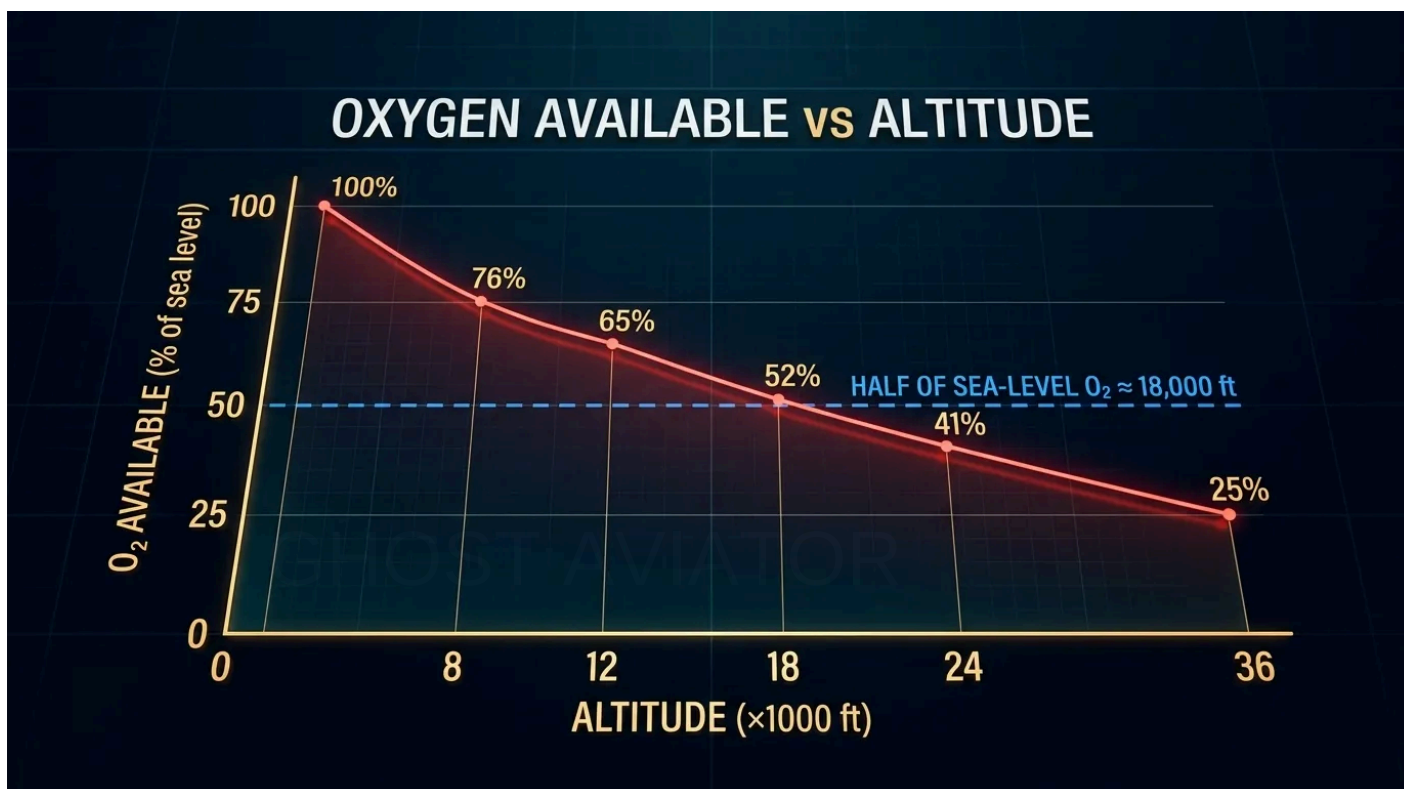


Figure 3.1 — The oxygen available falls non-linearly with altitude: half is gone by 18,000 ft, three-quarters by 36,000 ft.

§ 5 The Physiological Zones of the Atmosphere

The atmosphere is divided — from the pilot's body's point of view — into four functional zones, each demanding a different protective strategy. **You must know the boundaries and the SOP for each.**

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Figure 3.2 — The four physiological zones of the atmosphere and the protection each demands.

5.1 The Physiological Zone

SOP — WITHIN THIS ZONE

Normal healthy human beings used to living near sea level will need **supplementary oxygen to function normally at altitude exceeding 10,000 to 12,000 ft**. Pilots will normally begin breathing supplementary oxygen from **10,000 ft** above sea level.

OXYGEN SUPPLY REGIME BY ALTITUDE

ABOVE 40,000 ft — 100% OXYGEN UNDER PRESSURE

33,700 – 40,000 ft — 100% OXYGEN

10,000 – 33,000 ft — OXYGEN + AIR MIXTURE

UP TO 10,000 ft — AIR ONLY, no supplementary O₂

Figure 3.3 — The oxygen-supply regime by altitude: air only, oxygen+air, 100% oxygen, then oxygen under pressure.

5.2 The Physiological-Deficient Zone

LIMITS & SYMPTOMS — STRICT

Exists from **12,000 ft to 50,000 ft**. **The body is not used to this environment.** The adverse effects include:

- Middle ear and sinus blockage
- Shortness of breath
- Dizziness
- Headache

COMPENSATORY THRESHOLD

At **6,000 – 7,000 ft** altitude the human organism starts with remarkable measures to compensate for the drop in pO₂ when climbing — this is the **threshold for compensatory reactions**. (Hyperventilation, raised heart rate, raised cardiac output, etc. — all later sections.)

CRITICAL-THRESHOLD LIMITS — NON-PRESSURISED FLIGHT

- A pilot climbing in a **non-pressurised aircraft and WITHOUT using supplemental oxygen** will pass the "critical threshold" at approximately **22,000 ft**.
- **Breathing 100 % oxygen** will lift the pilot's physiological safe altitude to approximately **38,000 ft**.

5.3 The Partial Space-Equivalent Zone

DEFINITION & EXTENT

This zone extends from **50,000 ft to 120 nm** (nautical miles). Even 100 % oxygen ceases to be enough at these heights — total pressure becomes the limiting factor.

5.4 The Total Space-Equivalent Zone

DEFINITION

The Total Space-Equivalent Zone extends **outwards from 120 nm**.

MANDATORY LIMITS IN THE UPPER TWO ZONES

- **100 % oxygen does NOT protect from hypoxia** — pressure-breathing required.
- **Sealed cabins and pressure suits are a MUST.**
- Blood and body fluids **BOIL above 63,000 ft** (Armstrong's Line — vapour pressure of body fluids equals ambient pressure).
- **Gravitational changes affect the body** (micro-G adaptation, fluid shift, motion-sickness, etc.).

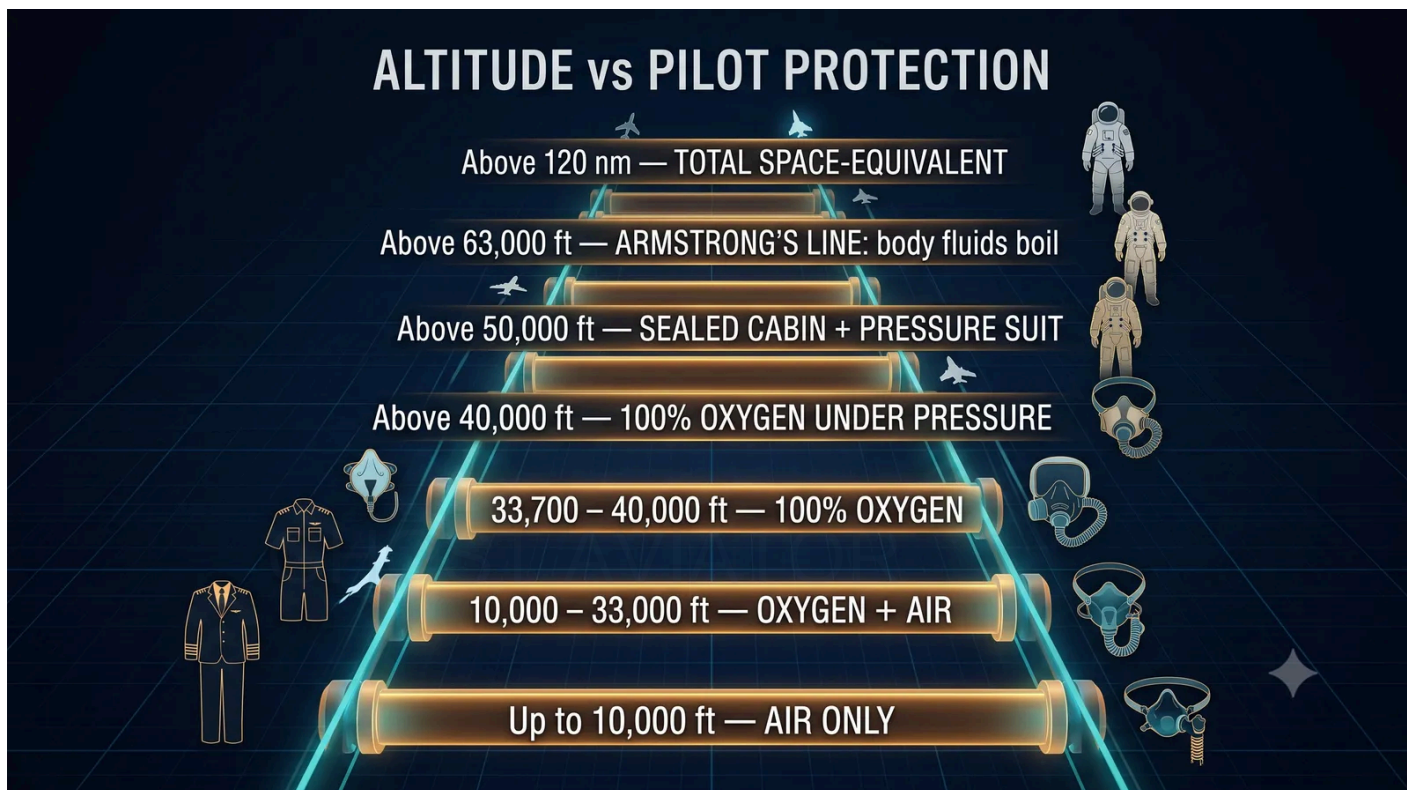


Figure 3.4 — Altitude-versus-protection timeline, from air-only at low level to pressure suits and Armstrong's Line.

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6.1 Numbers you MUST know by heart

Master cheat-sheet — Part 1 numbers

Parameter	Exact Value	Where it comes from
Top of troposphere (average)	13 km / 8.1 mi / 43,000 ft	\$1 Atmospheric layers
Top of stratosphere (over)	100,000 ft	\$1
Troposphere holds	75 % of atmospheric mass	\$1
Nitrogen / Oxygen / Other	78.084 / 20.95 / ~1 %	\$1.2
Water vapour content	1 – 4 % (variable)	\$1.2
ISA sea-level pressure	1013.25 hPa = 760 mmHg = 29.92 inHg = 14.7 psi	\$3.1
ISA lapse rate	1.98 °C / 1000 ft	\$3.1
Tropopause altitude (ISA)	36,090 ft	\$3.1
Isothermal temperature	-56.5 °C	\$3.1
Cabin altitude maintained	6,000 – 8,000 ft	\$4
O ₂ available at 18,000 ft	52 % (half of SL)	\$4
O ₂ available at 36,000 ft	25 % (one-fourth of SL)	\$4
Compensatory reactions begin	6,000 – 7,000 ft	\$5.2
Pilot starts supplementary O ₂	10,000 ft	\$5.1
Physiological-Deficient Zone	12,000 – 50,000 ft	\$5.2
Critical threshold (no O ₂ , unpressurised)	~22,000 ft	\$5.2
Safe altitude on 100% O ₂	~38,000 ft	\$5.2
100% O ₂ Under Pressure (PBA) from	Above 40,000 ft	\$5.1 fig.
Partial Space-Equivalent Zone	50,000 ft – 120 nm	\$5.3
Armstrong's Line (body fluids boil)	63,000 ft	\$5.4
Total Space-Equivalent Zone	Outwards from 120 nm	\$5.4

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6.2 Common DGCA-style probe questions

TRY ANSWERING THESE WITHOUT LOOKING BACK

1. State the percentage composition of nitrogen and oxygen in the atmosphere. *Does it change with altitude?*
2. Give the ISA sea-level values in **five** different units.
3. What is the ISA lapse rate, and up to what altitude does it apply?
4. Why does hypoxia occur with altitude, when the % of O₂ is unchanged? (*Hint: Dalton's Law.*)
5. At what altitude does a pilot normally start using supplementary oxygen?
6. State the four physiological zones with their altitude boundaries.
7. At what altitude does an unpressurised pilot, NOT using supplemental O₂, hit the critical threshold?
8. Why is a pressure suit mandatory above 50,000 ft? Quote Armstrong's Line value.
9. Explain Boyle's Law and give two flight-medical situations where it applies.
10. How does Henry's Law explain both hypoxia *and* decompression sickness?

MNEMONIC — 5 GAS LAWS "Bad Hens Cluck, Geese Dance" → Boyle · Henry · Charles · Graham · Dalton.

MNEMONIC — ZONES (LOW → HIGH) P – P-D – PS – TS → Physiological · Physiological-Deficient · Partial Space-equivalent · Total Space-equivalent. (*Or: "Pilots Probably Prefer Tea" — P, PD, PS, TS.*)

MNEMONIC — HALVING RULE "Half by Eighteen, Quarter by Thirty-Six" → Half of sea-level O₂ at **18,000 ft**; one-quarter at **36,000 ft**.

✦ END OF CHAPTER 3 ✦

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