Flight Physiology

Gas laws, hypoxia and cabin altitude (FP-C); stressors, aircraft safety and CRM (FP-C and CCP-C)

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GAS LAWS

LAW	RULE	EXAMPLE
Boyle	Volume rises as pressure falls	Pneumothorax, ETT cuff, stomach, air splints
Dalton	Total pressure = sum of partial pressures	O_2 stays 21%, PO_2 falls: altitude hypoxia
Fick	Diffusion rises with area and gradient, falls with thicker membrane	Pneumonia, COPD, edema: more hypoxia at altitude
Henry	Dissolved gas follows its partial pressure	Nitrogen bubbles: decompression sickness
Graham	High to low pressure; lighter gases faster	O_2 and CO_2 move between lungs, blood and cells
Charles, Gay-Lussac	Heat raises volume (Charles) or pressure (Gay-Lussac)	Cold: gas shrinks, O_2 cylinder pressure falls

EXAM TIP Exam shortcut: Boyle = volume (trapped gas), Dalton = partial pressure (altitude hypoxia), Fick = sick membrane (pneumonia, COPD), Henry = dissolved gas (the bends).

TRAPPED GAS (BOYLE)

- Expands on climb, shrinks on descent: body gas +38% at an 8,000 ft cabin; dry gas doubles by 18,000 ft
- Ears and sinuses block on descent, mostly below 6,000 ft: swallow, yawn, Valsalva
- Pneumothorax: chest tube with one-way valve before flight; watch for tension
- ETT cuff: manometer on climb and descent (about 20–30 cmH_2O), or saline fill
- PIP rises after climb: rule out ETT obstruction first, then tension pneumothorax
- Stomach: vent an NG or OG tube
- Air splints firm on climb, vacuum splints soften; reverse on descent; recheck pulses

SAFETY Pneumothorax, pneumocephalus, bowel obstruction, gas embolism or decompression sickness: request the lowest safe altitude or a sea-level cabin.

DIVING: DCS AND GAS EMBOLISM

- Symptoms within 48 h of a dive, especially after flying within 24 h of diving: decompression illness until proven otherwise (NASEMSO)
- Oxygen regardless of the SpO_2 to wash out inert gas (NASEMSO); Merck: 100% by close-fitting mask
- Serious DCS: isotonic IV crystalloid without glucose (Merck); alert and mild: oral fluids. NASEMSO: IV access, bolus as indicated
- Arterial gas embolism (breath-hold ascent, or air drawn into a central line): keep flat; Merck supine when unstable, NASEMSO left lateral; no head-down (Merck: not effective; NASEMSO: may worsen cerebral edema); 100% oxygen; recompression before anything nonessential
- Transport: sea-level cabin or the lowest safe altitude (Merck: under 2,000 ft unpressurized) to a hyperbaric-capable hospital

HYPOXIA AND TUC

TYPE	PROBLEM	EXAMPLES
Hypoxic	Too little O_2 reaches the blood	Altitude, airway obstruction, drowning
Hypemic	Blood cannot carry enough O_2	Anemia, blood loss, CO poisoning
Stagnant	Flow too slow	Shock, heart failure, high G, cold
Histotoxic	Cells cannot use O_2	Cyanide, alcohol, narcotics

Insidious onset; euphoria is the most dangerous symptom. Anemia, shock and lung disease lower altitude tolerance.

FAA averages at rest. Exertion shortens it; rapid decompression at 30,000 ft or higher cuts it by a third to a half.

ALTITUDE	TIME OF USEFUL CONSCIOUSNESS
18,000 ft	20–30 min
25,000 ft	3–5 min
30,000 ft	1–2 min
35,000 ft	30–60 sec
40,000 ft	15–20 sec

STRESSES OF TRANSPORT

STRESSOR	EFFECT	MITIGATE
Thermal	About 2 °C colder per 1,000 ft	Warm, insulate, monitor
Dry air	Dehydration, thick secretions	Humidified O_2, fluids
Noise	80–102 dB (helicopter); no auscultation, missed alarms	Ear protection; watch SpO_2, $ETCO_2$, chest rise
Vibration	Fatigue, monitor artifact, loosened tubes	Pad and secure everything
Flicker	Rotor or strobe at 4–20/sec: vertigo, rare seizures	Shade; look away
Fatigue	Slow judgment, errors	Rest, duty limits, IMSAFE check
G forces	Takeoff shifts blood toward the tail; landing, toward the nose	Secure; watch BP. Fixed wing: head forward if high ICP, feet forward if hypovolemic

CABIN ALTITUDE AND OXYGEN

U.S. Standard Atmosphere; volume = 760 ÷ pressure.

ALTITUDE	PRESSURE (MMHG)	DRY GAS VOLUME
Sea level	760	1.0×
6,000 ft	609	1.25×
8,000 ft	565	1.35×
10,000 ft	523	1.45×
18,000 ft	380	2.0×

- Helicopters are unpressurized; pressurized aircraft usually hold a 6,500–8,000 ft cabin (sea-level cabin = lower cruise)
- Decompression: slow >10 sec (most insidious), rapid 1–10 sec, explosive <1 sec (PHAK: <0.5 sec)

EXAM TIP FiO_2 needed = FiO_2 now × pressure now ÷ new pressure. 0.50 at sea level to 8,000 ft: 0.50 × 760 ÷ 565 ≈ 0.67. Over 1.0: fly lower or pressurize. Exam math; titrate to SpO_2 per your program's protocols.

SAFETY Decompression: your own mask first, then the patient's; the pilot descends, ideally below 10,000 ft.

AROUND THE AIRCRAFT

- Approach only when signaled, in the pilot's view
- Front quarter or side approach; never the rear or tail rotor
- Crouch; on a slope, approach from downslope
- Carry equipment low and horizontal; secure loose items
- Stay clear during rotor start-up and slow-down
- Landing zone: about 100 × 100 ft (per program), flat, firm, free of debris and wires; report hazards and wind; never aim lights at the aircraft
- Fire or police secure the zone and keep bystanders back

CREW RESOURCE MANAGEMENT

- CRM: use all people, equipment and information; AMRM adds medical crew, dispatch and managers
- Skills: communication, assertiveness, situational awareness, decisions, teamwork, workload; brief and debrief
- Three to go, one to say no: pilot plus two medical crew; any one can decline; a pilot's decline overrides all
- Patient condition stays out of the go/no-go decision
- Preflight risk analysis: weather, terrain, landing zone, fuel, fatigue, prior turn-downs
- Sterile cockpit: taxi, takeoff, landing, and below 10,000 ft except cruise

EXAM TIP Exam favorites: anyone can say no, nobody pushes to go, and acuity never drives the launch.

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