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1. Causes of Vertical Motion

Definition: Vertical motion in the atmosphere — either upward (ascent) or downward (subsidence) — is driven by several mechanisms. Rising air leads to cooling, condensation and cloud/precipitation formation; sinking air produces warming and clear skies.

Five Main Causes

Cause	Mechanism	Effect
Terrain (Orographic)	Air forced up windward slope; eddies/instability on leeward. Mountain waves on leeward with strong winds.	Nacreous clouds occur in the lower stratosphere in very cold polar conditions
Convection	Surface heating → air rises as thermals. Gliders use thermals.	CU and CB form; strong up/down draughts
Pressure Systems	Low/Cyclone → convergence → ascent; High/Anticyclone → divergence → subsidence	Lows = bad wx; Highs = fine wx
Frontal Zones	Warm front: gradual ascent over wide area; Cold front: sharp/abrupt uplift	WF: steady rain; CF: convection, TS, squally wx
Wind Shear	Vertical wind shear creates strong eddies. CAT at jet stream amplified by mountain waves.	Turbulence, CAT

flowchart TD

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A[Causes of Vertical Motion] --> B[Terrain/Orographic]
A --> C[Convection/Thermals]
A --> D[Pressure Systems]
A --> E[Frontal Zones]
A --> F[Wind Shear]
B --> G[Mountain Waves → Nacreous Clouds]
C --> H[CU & CB formation]
D --> I[Low → Ascent; High → Subsidence]
E --> J[WF: Gradual; CF: Abrupt uplift]
F --> K[CAT amplified near Jet Stream]
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2. Convergence and Divergence

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Convergence: Net horizontal *inflow* of air into a region. Air accumulates → ascent in lower levels → possible subsidence above tropopause (stratosphere acts as stable barrier). Lows, cyclones, depressions and troughs → convergence → bad weather, but better visibility except in precipitation.

Divergence: Net horizontal *outflow* of air from a region. Example: wind to W is **Wly 10 kt** and to E is **Wly 20 kt** → more outflow than inflow = divergence. Anticyclones and ridges → subsidence → fine weather but poor visibility conditions.

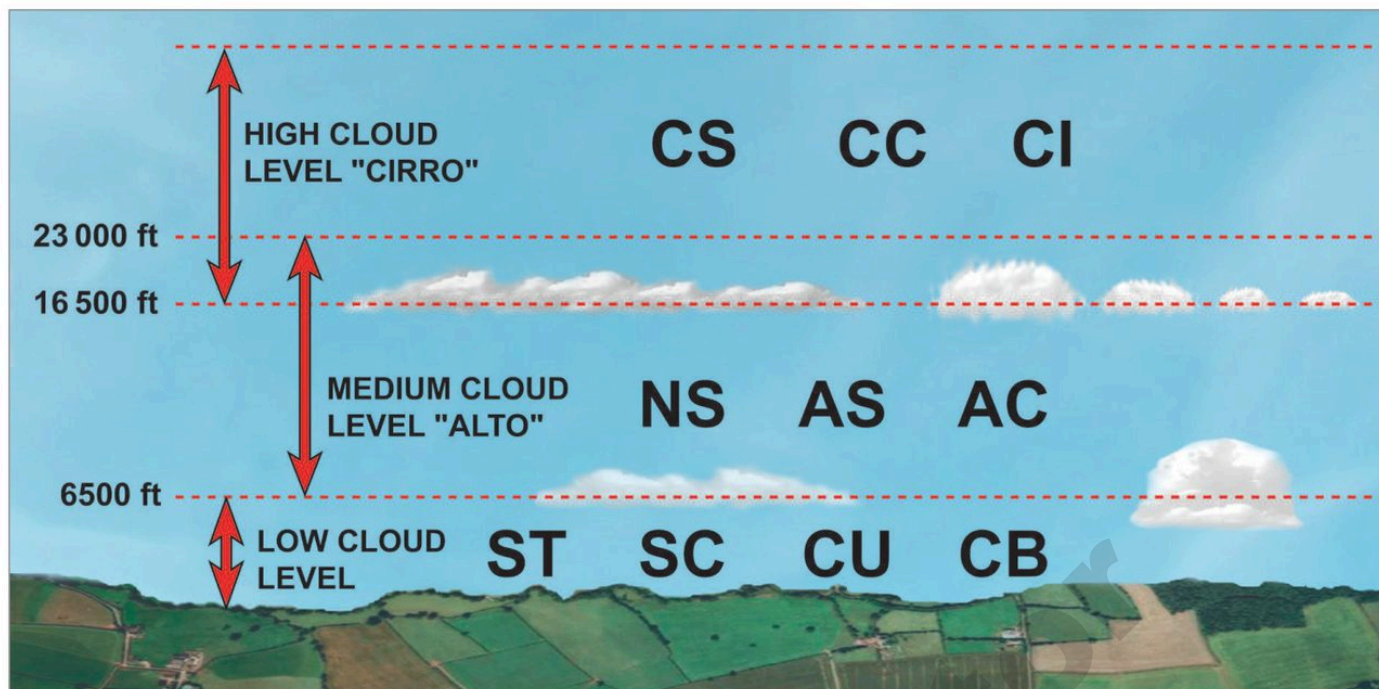
Parameter	Convergence	Divergence
Air flow	Inflow	Outflow
Vertical motion (low level)	Ascent (Convection)	Subsidence
Pressure systems	Lows, Cyclones, Depressions, Troughs	Highs, Anticyclones, Ridges
Weather	Bad weather	Fine weather
Visibility	Better (except in precip)	Poor

Mnemonic: CONvergence = CONDensation (bad wx). DIVergence = DIVE (air dives down) = Subsidence = Fine wx, hazy.

3. Clouds — Classification

Cloud: An aggregate of visible water droplets or ice particles. Clouds form by *adiabatic lifting and cooling* until air saturates. The level at which this occurs is the **Lifting Condensation Level (LCL)**.

Deposition = process by which water vapour directly changes into ice particles.



Cloud classification by height

There are **10 major genera** classified by **Form** (Stratiform, Cumuliform, Cirriform) and **Height** (High, Medium, Low).

Cloud Height by Region

Level	Polar Region	Temperate Region	Tropical Region
High	10,000–25,000 ft (3–8 km)	16,000–45,000 ft (5–13 km)	20,000–60,000 ft (6–18 km)
Medium	6,500–13,000 ft (2–4 km)	6,500–23,000 ft (2–7 km)	6,500–25,000 ft (2–8 km)
Low	up to 6,500 ft (2 km)	up to 6,500 ft (2 km)	up to 6,500 ft (2 km)

4. High Clouds

High clouds in tropics occur at **6–18 km**, consist of **ice crystals**, some may cause precipitation confined to high/medium levels only. Give advance indication of impending weather.



Cirrus



Cirrostratus



Cirrocumulus

Cirrus (CI)

White and fibrous, delicate filaments or patches, narrow bands. Composed of **ice crystals**. Do **not** cause precipitation or ice accretion.

Cirrostratus (CS)

Thin whitish veil of fibrous or smooth appearance. Covers almost whole sky. Produces **Halo** — a coloured circular ring around sun or moon with violet colour inside. When thick may cause any ice fall, remaining confined to high/medium levels. Hardly any ice accretion.

Cirrocumulus (CC)

Thin, white, wave-like very small puffs. Composed of ice crystals. Sky visible in between puffs. Do **not** cause precipitation; hardly any ice accretion.

Memory Aid — High Clouds (3 Cirro): CI CS CC = all ice crystals, no serious precip or icing. CS = produces HALO. CC = mackerel sky.

5. Medium Clouds

In tropics at **2–8 km** . Contain water droplets and ice. Can cause snow and rain.



Altocumulus



Alto cumulus lenticularis and other altocumulus



Altostratus

Altostratus (AC)

White-grey clouds, patches, puffs, rounded masses, rolls, etc. Round masses generally well arranged in long waves, rows or lanes. Sky visible between puffs. **Altostratus Lenticularis** = lens-shaped clouds at crests of mountain waves on leeward side of high mountains. **No precipitation; may cause ice accretion.**

Altostratus (AS)

Uniformly greyish or whitish cloud sheets/layers of fibrous appearance. Totally or partly cover the sky. If thin → see sun through it like *ground glass*. Optical phenomenon **Corona** occurs in AS. **Thick AS: continuous rain or snow. Ice accretion possible below freezing temperatures.**

Warning: Thick Altostratus causes continuous rain or snow. Ice accretion is possible below freezing temperatures in AS.

6. Low Clouds

In tropics below **2 km**. Consist of water droplets or ice crystals.



Stratus



Stratocumulus



Nimbostratus

Stratus (ST)

Grey cloud layer with uniform base. May stretch horizon to horizon. May give **drizzle**, ice prisms or snow grains. ST touching ground = fog. Ragged/patchy ST = **Fracto Stratus**.

Stratocumulus (SC)

Low clouds of large, irregular puffs or rolls, gray or whitish. Regularly arranged. **No serious precipitation.**

Nimbostratus (NS)

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Dark and grey thick cloud layer. Causes **continuous rain or snow**. Thick enough to blot out the sun. Extends both medium and lower levels. **Ice accretion possible below freezing**. **Ice Pallets** fall from thick NS clouds especially in Warm Fronts. Ice pallets are transparent ice particles, spherical/irregular, about less than **5 mm dia**.

Aviation Warning: NS = continuous rain/snow + ice accretion risk below freezing = avoid or be aware during approach/departure.

7. Clouds with Vertical Development



Fair weather cumulus



Cumulonimbus

Cumulus (CU)

Detached clouds, dense with sharp outlines. Base dark, nearly horizontal. Develop vertically as rising mounds, domes or towers. Bulging upper part resembles a cauliflower. Sunlit parts brilliant white. Base sometimes ragged = **Fracto Cumulus**. A well-developed CU with great vertical extent = **Towering Cumulus (TCU)**.

Fair Weather Cumulus

Limited vertical extent. Caused by thermal currents due to surface heating. Occur during daytime only, develop in forenoon, reach max in afternoon, dissipate in evening. **Do not cause precipitation.**

Cumulonimbus (CB)

Heavy and dense cloud of large vertical extent, like mountains or huge towers. Upper portion mostly smooth, fibrous and nearly flattened — spreads out like an **anvil**. Base often very dark. Low ragged cumulus fracto or stratus fractus sometimes present below. **Virga** = shaft of rain or snow falling from distant cloud which vapourises before reaching the ground.

CB causes ALL types of precipitation: RA, SH, GR, SN.

Hail may be experienced under the anvil of a CB.

CB is the most hazardous cloud for aviation and should be avoided.

Flying through active CB cloud should be avoided during TS. Severe turbulence, icing, lightning, hail possible 20–30 nm around a CB.

flowchart LR

CU[Cumulus CU] -->|grows| TCU[Towering Cumulus TCU]

TCU -->|further development| CB[Cumulonimbus CB]

CB --> P1[Rain RA]

CB --> P2[Showers SH]

CB --> P3[Hail GR]

CB --> P4[Snow SN]

CB --> P5[Virga]

CB --> P6[Anvil Top]

8. Very High Level Clouds

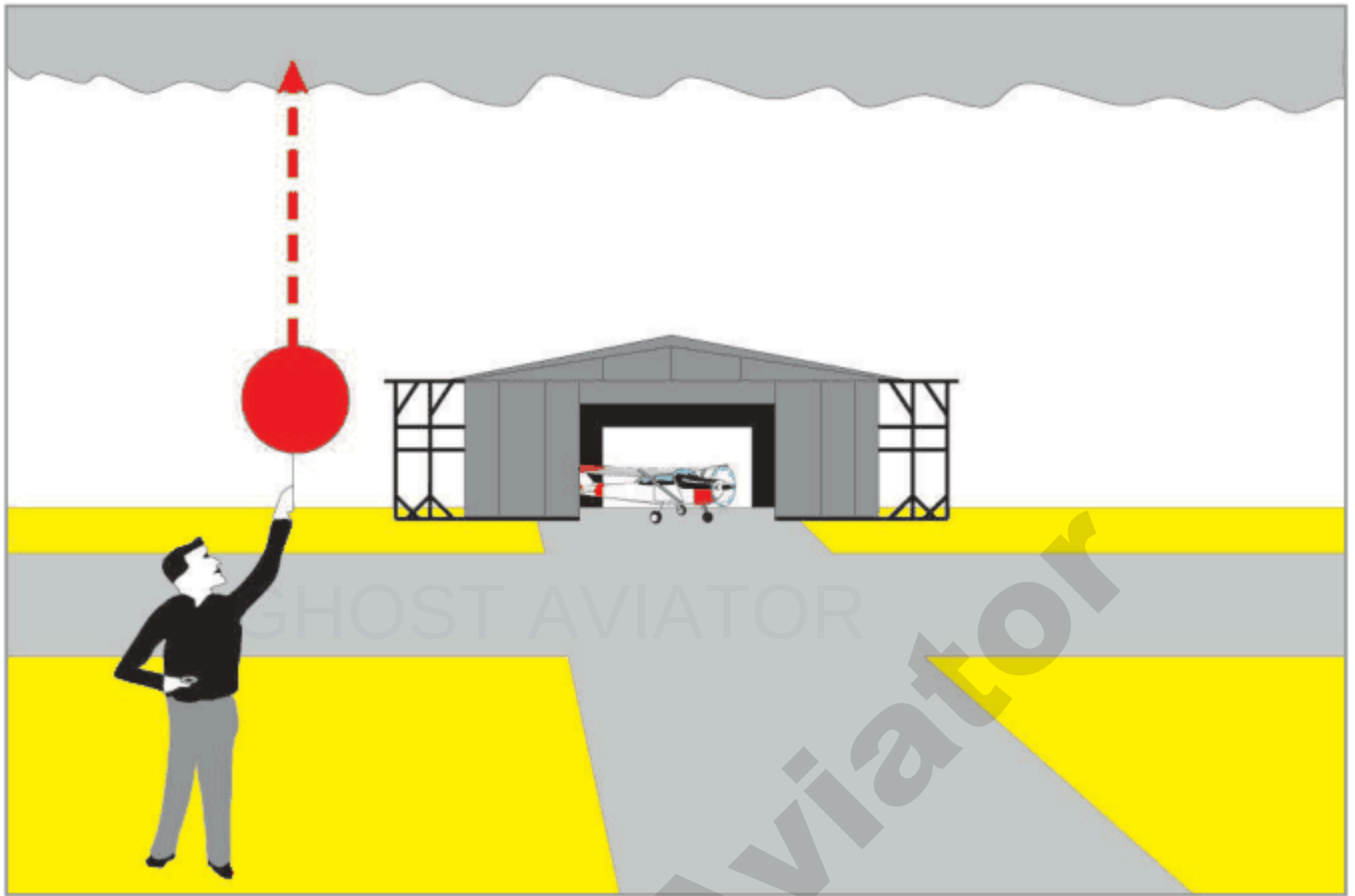
Nacreous Clouds (Mother of Pearl Clouds)

Nacreous clouds are rare polar stratospheric clouds, commonly called mother-of-pearl clouds because of their brilliant iridescent colours. They occur in the lower stratosphere in very cold conditions. They are distinct from noctilucent clouds in the mesosphere.

Noctilucent Clouds

Resemble Cirrus but have bluish, silvery or orange/red colour. Occur in upper Mesosphere between **80–85 km**. Visible soon after sunset or before sunrise between **72°N and 45°N**, mostly around **55°N**, in summers (late May–mid August). Thought to consist of **ice particles** (not meteoric dust, as originally believed).

9. Cloud Base, Amount & Ceiling



Cloud base by balloon



Laser ceilometer



Stratiform cloud seen from an aircraft

Reporting Cloud Base

In METAR, SPECI, TAF and Local Forecast: cloud base reported **from Above Ground Level (AGL)**.
In Area Forecast Charts: cloud base from **Above Mean Sea Level (AMSL)**.

Cloud Amount (Oktas)

Oktas	1–2	3–4	5–7	8/8	Nil	Sky not visible
Term	FEW	SCT (Scattered)	BKN (Broken)	OVC (Overcast)	SKC (Sky clear)	Sky Obscured
Sky Condition	Fine	Fair	Partly cloudy	Cloudy	Fine	Sky Obscured

Cloud Ceiling

Cloud Ceiling: Height, above ground or water surface, of the lowest layer of cloud below **6000 m (20,000 ft)** covering more than half the sky (**5/8 or more**).

Cloud Amount in Imaginary Oktas

For expressing cloud amount, the sky is divided into **eight imaginary parts**. Each part is called one **Oкта**.

Operational Significance: A cloud with a base below **1500 m (5000 ft)** or at or below the highest minimum sector altitude, whichever is greater, is of operational significance.

10. Cloud Species

Species	Description	Applicable Cloud Types
Fibrous	Filament form without tufts or hooks	Ci, CS, CC
Lenticularis	Elongated lens-shaped	AC, SC or CC
Castellaneous	Cumuliform protuberances connected by common base, arranged in lines	CI, CC, AC or CU
Fractus	Ragged	ST or CU
Congestus	Strong sprouting/great vertical development, bulging resembles cauliflower	CU
Calves	Cirrus at top, some protuberances begin to change to fibrous	CB (without distinct anvil)
Capillatus	Distinct anvil. Accompanied by SH, TS, SQ and GR. Produces well defined Virga.	CB

Exam Tip: CB Capillatus = distinct anvil = all precipitation types. CB Calves = developing CB, no distinct anvil yet.

11. Condensation Trails (Contrails)

Condensation trails = visible streaks of condensed water vapour formed in the wake of a moving aircraft.

Type	Description
Wing Tip Trails	Thin, transient, short-lived. Form near wing tips and propeller edges due to aerodynamic reduction of pressure, expansion and consequent adiabatic cooling and condensation.
Exhaust Trails	Form from condensation of moisture from aircraft exhaust at about 9 km and above . Long, persistent, visible. Reveal position and track of aircraft.
Distrails (Dissipation Trails)	Passage of aircraft through a cloud marked by clear lanes. The heat released by aircraft exhaust is sufficient to evaporate the cloud in its wake.

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12. Mintra, Drytra and Maxtra Levels

Mintra (Minimum Trail) Level (ML): Below this level, no condensation trails form. The flight level at which temperature is about **-45°C** gives a good estimate of ML at **100% RH** for jet aircraft.

Drytra Level: When temperatures are very low, contrails form even when RH is **0%**. It is usually about **2 km above the Mintra level**. This is because moisture from the exhaust is sufficient to produce saturation.

Maxtra Level: This level lies in the **stratosphere**, above which no contrails form.

Contrail Layer Summary (bottom to top):

No contrails → Contrails Possible → Contrails Certain (Mintra Level → Drytra Level) → Contrails Possible → No contrails (Maxtra/Sea Level equivalent in stratosphere)

13. Flying in Clouds — Operational Significance

Stratiform Clouds (ST, AS)

Flying is generally smooth. In NS clouds during monsoon with thick AS and NS layers, visibility is reduced due to continuous precipitation. ST clouds reduce visibility and cause difficulty identifying the runway during landings. Ice accretion also occurs in AS and NS clouds above freezing levels.

Cumuliform Clouds (CU, CB)

CC and AC may cause bumpiness. Well developed CU, TCU and CB can cause severe turbulence, downdrafts, gusts, ice accretion, lightning, hail and strong up/down draughts. Flying through CB should be avoided during TS. Hail may be experienced in clear air below the anvil of a CB.

CB Avoidance Rules:

- Avoid flying through active CB
- Avoid flying under CB anvil — hail in clear air possible
- CB causes ALL: RA, SH, GR, SN, TS, severe turbulence, severe icing, lightning
- Operations should be avoided during TS

14. Practice Q&A

Q1. Drizzle occurs from (a) CS (b) ST (c) NS (d) CU

✓ Answer: (b) ST

Explanation: Stratus (ST) gives drizzle, ice prisms or snow grains. It does not give rain.

Distractors: CS (high cloud, no precip); NS (continuous rain, not drizzle specifically); CU (showers, not drizzle).

🎯 **Instructor's Note:** Drizzle = ST. Continuous rain = NS. Showers = CB/TCU.

Q2. Altostratus (AS) is (a) Low cloud of sheet type (b) A medium cloud of sheet type (c) A high cloud of large vertical growth

✓ Answer: (b) A medium cloud of sheet type

AS is a medium-level stratiform cloud. It is a uniformly grey/whitish sheet. In tropics: 2–8 km.

Low cloud = ST/SC/NS. High cloud with vertical growth = CB.

🎯 Alto = medium level prefix. Stratus = sheet. Therefore AS = medium sheet cloud.

Q3. Showers occurs from (a) CU (b) CB (c) AS (d) AC

✓ Answer: (b) CB

Showers (SH) are produced by Cumulonimbus (CB). CB produces RA, SH, GR, SN.

CU: Fair weather, no precip; AS: continuous rain; AC: no precip (or light precip).

🎯 SHowers from SHockers = CB.

Q4. Heavy icing is possible in (a) CI (b) CS (c) ST (d) CB

✓ Answer: (d) CB

CB contains supercooled water droplets, causing heavy icing especially in middle layers. Also rime and clear ice possible.

CI, CS: mainly ice crystals, negligible icing. ST: possible icing at/below freezing.

🎯 CB = ALL hazards including heavy icing.

Q5. To avoid icing in cloudy conditions, a pilot is advised to fly through a cloud which shows optical phenomena (a) Halo (b) Corona (c) With multi-coloured clouds

✓ Answer: (a) Halo

Halo is produced by CS (ice crystals). Ice crystal clouds cause negligible icing. Corona (in AS/AC) indicates supercooled water droplets = moderate icing risk.

Corona = water droplets = icing risk. Multi-coloured = irisations = water droplets = icing risk.

🎯 Halo = ice crystals = safe. Corona = water drops = ICING RISK.

Q6. Dark grey cloud causing continuous rain (a) AS (b) NS (c) SC (d) CB

✓ Answer: (b) NS

Nimbostratus is a dark, grey, thick cloud layer causing continuous rain or snow. Thick enough to blot out the sun.

AS: uniformly grey but lighter, may cause rain; SC: low puffs, no serious precip; CB: showers not continuous.

🎯 NS = Nimbus (rain) + Stratus (layer) = continuous rain from grey blanket.

Q7. A uniform layer of cloud resembling fog but not on the ground (a) AS (b) NS (c) ST

✓ Answer: (c) ST

Stratus is a grey cloud layer with uniform base, resembles fog. When ST touches the ground, it IS fog.

AS: medium level; NS: causes heavy rain; ST: low, fog-like.

🎯 ST touching ground = Fog. ST above ground = Stratus.

Q8. The clouds composed of ice crystals having feathery appearance (a) CI (b) CS (c) AS

✅ Answer: (a) CI

Cirrus clouds are white and fibrous — delicate filaments = feathery appearance. Composed entirely of ice crystals.

CS: thin whitish veil; AS: medium level grey sheet.

🎯 CI = Cirrus = fibrous/feathery = ice crystals. No precip, no icing.

Q9. NS clouds occur (a) At cold front (b) At warm front

✅ Answer: (b) At warm front

At warm fronts, gradual ascent produces AS and NS, giving widespread continuous rain ahead of the surface front.

Cold fronts produce CU and CB (showers and thunderstorms), not NS.

🎯 Warm Front = NS + continuous rain. Cold Front = CB + showers/TS.

Q10. Lenticular clouds indicate presence of (a) Warm Front (b) Cold Front (c) Mountain waves

✅ Answer: (c) Mountain waves

Altostratus Lenticularis form at crests of mountain waves on the leeward side of high mountains. They are stationary despite strong winds.

Fronts produce layered/cumuliform clouds, not lens-shaped stationary clouds.

 Lens-shaped stationary cloud over/downwind of mountain = MOUNTAIN WAVE = severe turbulence possible.

Q11. The lowest level from which condensation trails will not form is (a) Mintra Level (b) Drytra Level (c) Maxtra Level

 Answer: (a) Mintra Level

Mintra (Minimum Trail) Level = lowest level at which contrails can form. Below this = no contrails.

 MINtra = MINimum level for contrails. Drytra = no need for humidity. MAXtra = maximum level, in stratosphere.

Q12. Cloud ceiling is the height of the cloud covering... (a) 3–4 oktas (b) 5/8 or more (c) 8/8

 Answer: (b) 5/8 or more

Cloud ceiling = height of lowest cloud layer below 6000 m covering 5/8 or more of sky (BKN or OVC).

3–4 = SCT (not ceiling); 8/8 = OVC (that IS a ceiling layer but so is BKN).

 Ceiling = BKN (5–7/8) or OVC (8/8) below 20,000 ft.

Q13. AC cloud with cumuliform protuberances indicates (a) Stability (b) Instability (c) Neutrality

 Answer: (b) Instability

Castellaneous AC (ACCaS) with tower-like cumuliform protuberances indicates atmospheric instability at medium levels — a precursor to afternoon thunderstorm development.

 ACCaS = morning sign of afternoon TS. Instability indicator at medium level.

Q14. Hail may be experienced under the anvil of a CB (a) True (b) False

 Answer: (a) True

Hail (GR) can fall in clear air below the anvil of a CB. The anvil spreads out horizontally and can carry hail considerable distances from the storm.

 Never fly under a CB anvil — clear air hail is a serious hazard.

GHOST AVIATOR

Ghost Aviator

GHOST AVIATOR

15. Master Reference Tables

All Numerical Values

Parameter	Value
High clouds — tropics height range	20,000–60,000 ft (6–18 km)
Medium clouds — tropics	2–8 km (6,500–25,000 ft)
Low clouds — all regions	below 2 km (6,500 ft)
Cloud ceiling threshold	6000 m / 20,000 ft
Cloud ceiling coverage threshold	5/8 or more
Exhaust contrail level	9 km and above
Mintra — ML temperature estimate	–45°C @ 100% RH
Drytra — above Mintra by	~2 km
Ice pellets dia	<5 mm
Operationally significant cloud base	below 1500 m (5000 ft)
Noctilucent cloud altitude	80–85 km
Noctilucent cloud latitude	72°N–45°N, mostly 55°N

Cloud Type Quick Reference

Cloud	Level	Composition	Precipitation	Icing	Aviation Hazard
CI	High	Ice crystals	None	Negligible	Low
CS	High	Ice crystals	None	Negligible	Low (Halo visible)
CC	High	Ice crystals	None	Negligible	Low
AC	Medium	Water/ice	None (AC Len = none)	Possible	Low–Moderate
AS	Medium	Water/ice	Continuous rain/snow (thick)	Yes below 0°C	Moderate
ST	Low	Water drops	Drizzle	Possible	Moderate (vis)
SC	Low	Water drops	None serious	Possible	Low
NS	Low–Medium	Water/ice	Continuous rain/snow	Yes below 0°C	High
CU	Vertical	Water drops	None (fair wx)	Possible	Low (bumpiness)
TCU	Vertical	Water/ice	Rain, showers	Yes	High
CB	Vertical	Water/ice/hail	RA, SH, GR, SN	Severe	EXTREME — AVOID

Okta/Cloud Amount Table

Oktas	Term (METAR)	Sky Condition
0	SKC/NSC	Fine
1–2	FEW	Fine
3–4	SCT	Fair
5–7	BKN	Partly cloudy
8	OVC	Cloudy/Overcast
///	Sky Obscured (VV///)	Sky Obscured

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Quick Revision Summary — Chapter 8:

- 5 causes of vertical motion: Terrain, Convection, Pressure, Fronts, Wind Shear
- Convergence = ascent = bad wx; Divergence = subsidence = fine wx
- 10 cloud genera; 3 levels; classified by form and height
- High clouds (3 Ci-): ice crystals, no precip, no icing, CS produces HALO
- Medium (Alto-): AS = continuous rain if thick; AC = no precip; Corona in AS
- Low: ST = drizzle; NS = continuous rain; SC = no serious precip
- CB = ALL hazards — AVOID. Hail under anvil in clear air.
- Cloud base: AGL in METAR/TAF; AMSL in area charts
- Ceiling = BKN/OVC below 20,000 ft; Cloud amount in Oktas (0–8)
- Contrails: Wing tip (short), Exhaust (long, persistent ≥ 9 km), Distrails (clear lanes)
- Mintra (lowest level for contrails) → Drytra (2 km above) → Maxtra (stratosphere)