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CUET · GEOGRAPHY · CLASS XI · CODE 313

Solar Radiation, Heat Balance and Temperature

CUET unit: Solar Radiation, Heat Balance and Temperature

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- The earth receives solar energy (insolation), distributes it through the atmosphere, and maintains a heat balance so the planet neither warms up indefinitely nor cools down.
- Atmospheric heating works through conduction, convection, advection, and terrestrial radiation — foundational for understanding weather and climate topics tested in CUET.
- The heat budget (albedo, absorption, re-radiation) and the concept of normal lapse rate/temperature inversion are high-frequency CUET topics due to their numerical and conceptual dimensions.
- Factors controlling temperature distribution (latitude, altitude, distance from sea, ocean currents) are repeatedly tested through statement-based and match-the-following questions.
- Temperature distribution maps (January and July isotherms) and the concept of the thermal equator are tested through case/map-based MCQs in NTA papers.

📖 Detailed Notes

2.1 Core concepts

- **Insolation defined:** The energy received by the earth from the sun is called incoming solar radiation, or insolation. The earth receives most of its energy in short wavelengths. On average the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere. (NCERT §Solar Radiation, p. 67)
- **Aphelion and Perihelion:** The earth is farthest from the sun (152 million km) on 4th July — called aphelion — and nearest (147 million km) on 3rd January — called perihelion. Annual insolation is slightly more on 3rd January than 4th July, but this variation is masked by land-sea distribution and atmospheric circulation. (NCERT §Solar Radiation, p. 67)
- **Variability of insolation:** Insolation varies due to five factors: (i) rotation of earth on its axis; (ii) angle of inclination of sun's rays; (iii) length of the day; (iv) transparency of the atmosphere; (v) configuration of land in terms of its aspect. The last two have less influence. The earth's axis makes an angle of 66½° with the plane of its orbit,

which has greater influence on insolation at different latitudes. (NCERT §Variability of Insolation, p. 67)

- **Angle of incidence and latitude:** Higher latitudes receive slant rays that cover more area, distributing energy over a larger surface — thus less energy per unit area. Slant rays also pass through greater atmospheric depth, causing more absorption, scattering, and diffusion. (NCERT §Variability of Insolation, p. 68)
- **Passage through atmosphere:** The atmosphere is largely transparent to short-wave solar radiation. Within the troposphere, water vapour, ozone, and other gases absorb near-infrared radiation. Very small suspended particles scatter visible spectrum in all directions — this explains the blue colour of the sky and the red colour at sunrise/sunset. (NCERT §Passage of Solar Radiation through the Atmosphere, p. 68)
- **Spatial distribution of insolation:** Insolation at the surface varies from about 320 Watt/m² in the tropics to about 70 Watt/m² at the poles. Maximum insolation is received over subtropical deserts where cloudiness is least. The equator receives comparatively less insolation than the tropics. At the same latitude, insolation is more over continents than oceans. (NCERT §Spatial Distribution of Insolation, p. 68)
- **Conduction:** When the earth is heated by insolation, it transmits heat to atmospheric layers in long-wave form. The air in contact with land gets heated slowly; heat passes upward layer by layer. This process is called conduction. It is important in heating the lower layers of the atmosphere. (NCERT §Heating and Cooling of Atmosphere, p. 68)
- **Convection:** Air in contact with the earth rises vertically on heating in the form of currents and transmits heat upward. This vertical heating is called convection. Convective transfer is confined only to the troposphere. (NCERT §Heating and Cooling of Atmosphere, p. 68)
- **Advection:** Transfer of heat through horizontal movement of air is called advection. Horizontal movement is relatively more important than vertical movement. In middle latitudes, most diurnal weather variations are caused by advection alone. The 'loo' winds in northern India during summer are an outcome of the advection process. (NCERT §Heating and Cooling of Atmosphere, p. 68)
- **Terrestrial radiation:** The earth, after being heated, radiates energy to the atmosphere in long-wave form — this is terrestrial radiation. Long-wave radiation is absorbed by atmospheric gases, particularly CO_2 and other greenhouse gases, indirectly heating the atmosphere from below. (NCERT §Terrestrial Radiation, p. 68–69)
- **Heat budget of the earth:** Taking insolation at the top of the atmosphere as 100 units: 35 units are reflected back to space (27 by cloud tops, 2 by snow/ice, 6 scattered); 65 units are absorbed (14 by atmosphere, 51 by earth's surface). The earth radiates back 51 units as terrestrial radiation (17 to space directly; 34 absorbed by atmosphere — 6 directly, 9 via convection/turbulence, 19 via latent

heat of condensation). The atmosphere radiates 48 units back to space (14 + 34). Total returning = 17 + 48 = 65 units, balancing the 65 units received. This is the heat budget or heat balance. The reflected 35 units constitute the albedo of the earth. (NCERT §Heat Budget of the Planet Earth, p. 69)

- **Latitudinal variation in net radiation balance:** There is a surplus of net radiation balance between 40° N and 40° S; regions near the poles have a deficit. Surplus heat from tropics is redistributed poleward, preventing tropics from overheating and high latitudes from being permanently frozen. (NCERT §Variation in Net Heat Budget, p. 70)
- **Temperature and factors controlling its distribution:** Temperature is measured in degrees and indicates how hot or cold a place is. Factors controlling temperature: (i) latitude; (ii) altitude; (iii) distance from the sea; (iv) air-mass circulation; (v) warm and cold ocean currents; (vi) local aspects. (NCERT §Temperature / Factors Controlling Temperature Distribution, p. 70)
- **Normal lapse rate:** Temperature generally decreases with increasing height at a rate of 6.5°C per 1,000 m — this is the normal lapse rate. (NCERT §The altitude, p. 70)
- **Distribution of temperature — January:** Isotherms generally run parallel to latitude but deviate more in January (especially in northern hemisphere). Over the North Atlantic, warm Gulf Stream and North Atlantic Drift push isotherms northward. Over Siberia, mean January temperature along 60° E longitude is –20°C at both 80°N and 50°N. The southern hemisphere shows more regular, latitude-parallel isotherms due to dominant ocean influence. (NCERT §Distribution of Temperature, p. 71)
- **Distribution of temperature — July:** Isotherms are generally parallel to latitudes. Equatorial oceans record >27°C; subtropical continental Asia (30°N) records >30°C on land. The isotherm of 10°C runs along 40°N and 40°S. The highest annual range of temperature (>60°C) is found over north-eastern Eurasia (continentality effect). The least annual range (3°C) is found between 20°S and 15°N. (NCERT §Distribution of Temperature, p. 71–73)
- **Inversion of temperature:** Normally temperature decreases with altitude (normal lapse rate). When this is reversed — temperature increasing with altitude — it is called inversion of temperature. Ideal conditions: long winter night, clear skies, still air. Earth radiates heat and becomes cooler than the air above by early morning. Inversion promotes atmospheric stability; smoke and dust collect beneath the inversion layer, causing dense morning fogs in winter. In hills and mountains, cold dense air flows downslope under gravity and pools in valley bottoms — this is called air drainage, which protects plants from frost. Over polar areas, temperature inversion is normal throughout the year. (NCERT §Inversion of Temperature, p. 73)
- **Solar constant:** The standardised value of solar radiation reaching the top of the atmosphere on a surface held perpendicular to the rays — 1.94 calories per sq. cm per minute — is referred to as the solar constant. Though called a "constant" it actually fluctuates by about 0.1 per cent over the eleven-year sunspot cycle, but for

school-level computation NCERT treats it as fixed. The figure underpins every numerical exercise on insolation and is also the basis for the 100 units used in the heat-budget calculation (NCERT §Solar Radiation, p. 67).

- **Land–sea contrast in heating and cooling:** Land surfaces heat and cool roughly three times faster than water surfaces of equal area. This is because (i) water is transparent so insolation penetrates several metres and warms a thicker column; (ii) the specific heat of water is much higher than that of soil; and (iii) convection currents and waves continuously redistribute oceanic heat. The contrast explains why coastal stations show a lower diurnal and annual range than interior continental stations — a point NCERT illustrates through the very low range (3°C) of equatorial maritime belts versus the >60°C range of northeastern Eurasia (NCERT §Distribution of Temperature, p. 71–73).
- **Ocean currents and continental coasts:** The Gulf Stream and the North Atlantic Drift carry warm tropical water poleward along the eastern coast of North America and the western coast of Europe, pulling the 0°C January isotherm well north of the Arctic Circle in Norway. The Labrador and Kuroshio currents likewise distort isotherms over the North Atlantic and North Pacific. NCERT uses these deviations to demonstrate that latitude alone cannot explain temperature distribution — the joint effect of currents, winds and land–sea distribution must be invoked.
- **Air-mass circulation as a temperature control:** Polar air masses carry cold conditions southward in winter (cold waves over north India); tropical maritime air masses bring warm humid conditions over coastal India in summer. NCERT explicitly lists air-mass circulation among the six controls of temperature distribution (NCERT p. 70), making it a frequent statement-based test point.

2.2 Definitions to memorise

Term	Definition	Page
Insolation	Incoming solar radiation received by the earth from the sun	67
Aphelion	Position of earth when it is farthest from the sun (152 million km) — 4th July	67
Perihelion	Position of earth when it is nearest to the sun (147 million km) — 3rd January	67
Albedo	The percentage of visible light (solar radiation) reflected back to space by the earth; reflected amount = 35 units out of 100	69
Conduction	Transfer of heat between two bodies in contact from warmer to cooler until temperatures equalise	68
Convection	Vertical transfer of heat in the atmosphere through rising air currents; confined to troposphere	68
Advection	Transfer of heat through horizontal movement of air; dominant in middle latitudes	68

Term	Definition	Page
Terrestrial radiation	Long-wave radiation emitted by the earth's surface back to the atmosphere	68–69
Heat budget / Heat balance	The equilibrium between insolation received (65 units) and energy radiated back to space (65 units) by the earth-atmosphere system	69
Normal lapse rate	The rate of decrease of temperature with increasing altitude — 6.5°C per 1,000 m	70
Isotherm	Lines on a map joining places of equal temperature	71
Inversion of temperature	A condition where temperature increases with altitude, reversing the normal lapse rate	73
Air drainage	Downslope flow of cold dense air in hills and mountains under gravity, pooling in valleys; protects plants from frost	73
Thermal equator	The belt of highest temperatures on Earth, which shifts northward in July	71–72
Solar constant	The standard value (1.94 cal/sq cm/min) of solar radiation received perpendicular to a surface at the top of the atmosphere	67
Scattering	Process by which small atmospheric particles disperse the visible spectrum of solar radiation in all directions; explains the blue sky and red sunsets	68
Diffuse radiation	Solar radiation reaching the surface after being scattered by atmospheric particles, as opposed to direct beam radiation	68
Greenhouse effect	The warming caused when atmospheric gases (chiefly CO_2 and water vapour) absorb long-wave terrestrial radiation and re-radiate part of it back to the surface	69
Latent heat of condensation	Heat released to the atmosphere when water vapour condenses; accounts for 19 of the 34 units transferred from the earth's surface to the atmosphere	69
Convective transfer	Vertical movement of heat through rising warm air and sinking cool air, confined to the troposphere	68
Net radiation balance	Difference between incoming solar radiation absorbed and outgoing terrestrial radiation emitted; positive between 40°N–40°S, negative beyond	70
Loo	Hot, dry advective wind that blows over the northern plains of India in summer; a textbook example of horizontal heat transfer	68
Diurnal range of temperature	Difference between the maximum and minimum temperature recorded at a place in a day	70
Annual range of temperature	Difference between the highest mean monthly temperature and the lowest mean monthly temperature in a year	73

2.3 Diagrams / processes to remember

- **Figure 8.1 — Summer Solstice (p. 68):** Shows the inclination of earth's axis at 66½°, position of Tropics of Cancer and Capricorn, and angle of sun's rays at different latitudes (47° at Tropic of Cancer, 90° at equator, 43° at Tropic of Capricorn). Key for understanding insolation variation.
- **Figure 8.2 — Heat budget of the earth (p. 69):** Two-panel diagram showing the fate of 100 units of incoming solar radiation — what is reflected, scattered, absorbed, and re-radiated. Must be memorised with the exact unit values (35 reflected, 14 absorbed by atmosphere, 51 by earth; then the 51 split into 17 direct to space and 34 to atmosphere; atmosphere finally radiates 48 to space).
- **Figure 8.3 — Latitudinal variation in net radiation balance (p. 70):** Graph showing surplus net radiation between 40°N and 40°S and deficit at higher latitudes. Illustrates why heat transfer from tropics to poles is necessary.
- **Figures 8.4(a) and 8.4(b) — Temperature distribution January and July (pp. 71–72):** World maps showing isotherms. Note deviation of isotherms over continents vs. oceans, position of thermal equator, and differences between hemispheres.
- **Figure 8.5 — Range of temperature between January and July (p. 72):** Shows highest range (>60°C) over north-eastern Eurasia and least range (3°C) in equatorial belt.
- **Process sequence to memorise for the heat budget:** (i) 100 units arrive at the top of the atmosphere → (ii) 35 units (albedo) reflected back without heating earth — 27 from cloud tops, 2 from snow/ice, 6 scattered → (iii) 14 absorbed by atmosphere directly + 51 by earth's surface = 65 absorbed → (iv) the 51 surface units leave as terrestrial radiation: 17 escape directly to space + 34 absorbed by atmosphere (6 direct long-wave, 9 by convection/turbulence, 19 by latent heat of condensation) → (v) atmosphere finally returns 48 units to space, balancing 17 + 48 = 65 outgoing against 65 incoming. Memorise the breakdown of 34 — it is a favourite three-statement NTA trap.

2.5 Key data table (NCERT figures to memorise)

#	Quantity	Value	NCERT page
1	Solar constant at top of atmosphere	1.94 cal/sq cm/min	67
2	Earth–sun distance at aphelion (4 July)	152 million km	67
3	Earth–sun distance at perihelion (3 January)	147 million km	67
4	Earth's axial tilt with orbital plane	66½°	67
5	Surface insolation at tropics	~320 W/m²	68

#	Quantity	Value	NCERT page
6	Surface insolation at poles	~70 W/m²	68
7	Albedo (reflected fraction of insolation)	35 of 100 units	69
8	Units absorbed by atmosphere directly	14 of 100	69
9	Units absorbed by earth's surface	51 of 100	69
10	Units returned to space (earth direct + atmosphere)	17 + 48 = 65	69
11	Normal lapse rate	6.5°C per 1,000 m	70
12	Mean January temperature at Verkhoyansk (Siberia, 80°N) along 60°E	–20°C	71
13	Mean July equatorial ocean temperature	>27°C	71
14	Maximum mean July land temperature (Asia, 30°N)	>30°C	71
15	Highest annual range of temperature (NE Eurasia)	>60°C	72
16	Least annual range of temperature (20°S–15°N)	3°C	72

2.4 Common confusions / NTA trap points

- **Aphelion vs. Perihelion and temperature:** Students confuse perihelion (3rd January, nearest to sun) with being warmer for the northern hemisphere — but northern hemisphere winter falls in January because of axial tilt, not earth-sun distance. The perihelion effect on insolation is masked by land-sea distribution and atmospheric circulation.
- **Heat budget numbers:** A very common NTA trap is testing exact unit values. Remember: 35 reflected (not absorbed), 51 absorbed by earth's surface (not 65), 14 absorbed by atmosphere directly, and 17 units from terrestrial radiation go directly to space.
- **Main source of atmospheric heating:** The atmosphere is mainly heated by long-wave terrestrial radiation from below — NOT directly by short-wave solar radiation (which largely passes through). NTA regularly offers "short-wave solar radiation" as a distractor.
- **Normal lapse rate value:** The rate is 6.5°C per 1,000 m — students often confuse this with 1°C per 165 m (an older figure) or mix it with the adiabatic lapse rate.
- **Maximum insolation location:** Maximum insolation is received over subtropical deserts (not the equator or tropics). The equator receives less than the subtropics due to higher cloud cover. This is a classic NTA distractor pairing.
- **Conduction vs convection vs advection (vector trick):** Conduction = molecular contact (no bulk motion); convection = bulk vertical motion; advection = bulk

horizontal motion. NTA disguises this by changing the direction word — "horizontal convection" or "vertical advection" — neither exists in NCERT terminology.

- **Albedo of 35 vs 35%:** Both expressions describe the same quantity but NTA sometimes presents "0.35" as a decimal — students reject the decimal as wrong. Confirm any equivalent fractional/decimal version.
- **Insolation units in W/m² vs cal/sq cm/min:** NCERT uses cal/sq cm/min for the solar constant at the top of the atmosphere but switches to W/m² (320 in tropics, 70 at poles) for surface insolation. Watch the unit when selecting numerical options.
- **Land cools faster than water:** Within a 24-hour cycle, land surfaces lose heat faster after sunset and cool more quickly than nearby seas. The reverse statement — "water cools faster than land at night" — appears as a tempting distractor in assertion-reason items.
- **Air drainage ≠ katabatic wind in scope:** NCERT uses "air drainage" specifically for the localised down-valley flow that protects orchards from frost. Wider Class-XI vocabulary uses "katabatic" for the same kind of flow; mark whichever term NCERT prints in the stem.

🎯 Practice MCQs

📊 PYQ Alignment

> This chapter features regularly in CUET Geography papers, typically contributing 1–2 MCQs per year, with questions focused on the heat budget unit values (albedo, absorbed/reflected radiation), the mechanisms of atmospheric heating (conduction vs. convection vs. advection), the normal lapse rate value, and factors controlling temperature distribution — particularly the contrast between latitude, altitude, and distance from sea effects. For solved PYQs in this topic, refer to the **CUET PYQ archive at** `/pyq/geography`.