Gravity

Exploration gravity surveys measure variations in gravitational acceleration caused by subsurface density contrasts. What is the typical unit used to express these small variations?

A) m/s^2
B) mGal (1 mGal = 10^{-5} m/s^2)
C) nT (nanoTesla)
D) kg/m^3

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✓ **Correct answer: B** Gravity anomalies in exploration are of the order of a few milligals (mGal). The mGal is defined as 10^{-5} m/s^2, which makes it convenient to express the tiny deviations from average gravity caused by geological structures.

The Bouguer anomaly over a large sedimentary basin is typically negative. What is the physical reason for this?

A) Sedimentary basins are always located near the equator, where gravity is lower.
B) The Bouguer correction over-corrects for the rock column, producing an artefact.
C) Sediments are less dense than the average crustal material they replace, so gravity is slightly weaker above a basin.
D) The free-air correction is not applied over oceanic basins.

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✓ **Correct answer: C** The Bouguer anomaly reflects lateral density contrasts. Sediments typically have densities of 2000–2400 kg/m³, lower than the average crustal value of ~2670 kg/m³. The deficit of mass produces a weaker gravitational pull, yielding a negative anomaly. This is a real geological signal, not an artefact of the correction process.

You are performing a gravity survey and notice that the measured gravity at a fixed base station drifts by about 0.05 mGal over four hours. What is the most likely cause, and how is it corrected?

A) The instrument is malfunctioning and must be replaced.
B) This is the Bouguer effect and is corrected using the density of the crust.
C) This reflects real geological variation and should be kept in the data.
D) This is caused by tidal deformation of the Earth

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✓ **Correct answer: D** A slowly varying drift of a few tenths of a mGal at a fixed station is caused by tidal attraction from the Moon and Sun (which can change gravity by ±0.2–0.3 mGal during a day). You can remove it by looping back to the base station at regular intervals, recording the apparent change, and interpolating a drift correction across all measurements.

Non-uniqueness is a fundamental limitation of potential field methods. Which statement correctly describes this problem and its practical consequence?

A) Non-uniqueness means that the same density body always produces the same surface anomaly regardless of its depth.

A) Many different subsurface density distributions can produce exactly the same surface gravity anomaly

C) Non-uniqueness is only a problem in magnetic surveys, not in gravity surveys.

D) Non-uniqueness can be completely eliminated by increasing the number of gravity stations.

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✓ **Correct answer: B** A given surface potential field is consistent with an infinite family of source distributions. In practice, this means that forward modelling produces a model consistent with the data but not the unique model. Thus, a gravity profile alone cannot uniquely determine depth, density, and geometry simultaneously.

EXERCISE: Computing the Bouguer anomaly

During a gravity survey in a mountainous region, the following values are recorded at a field station:

- Observed gravity: $g_{obs} = 9.780450\ m/s^2$
- Normal (theoretical) gravity at the station latitude: $g_n = 9.781200\ m/s^2$
- Station elevation: $h = 620$ m above sea level
- Assumed rock density: $\rho = 2670\ kg/m^3$ (standard Bouguer density)

Free-air gradient = 0.3086 mGal/m (gravity decreases with height)

Tasks:

(a) Apply the free-air correction and compute the free-air anomaly.

(b) Apply the Bouguer correction to the free-air anomaly and compute the simple Bouguer anomaly.

(c) Interpret the sign of the resulting Bouguer anomaly: what does it suggest about the subsurface?

EXERCISE: Computing the Bouguer anomaly

Step 1: Convert everything to mGal

Step 2: Compute the free-air correction

Step 3: Compute the Bouguer correction

Step 4: Interpret the sign

EXERCISE: Computing the Bouguer anomaly

Step 1: Convert everything to mGal

$g\_obs = 9.780450 \text{ m/s}^2 = 978045.0 \text{ mGal}$

$g\_n = 9.781200 \text{ m/s}^2 = 978120.0 \text{ mGal}$

Step 2: Compute the free-air correction

$\delta g\_FA = +0.3086 \text{ mGal/m} \times 620 \text{ m} = +191.332 \text{ mGal}$

Free-air anomaly: $\Delta g\_FA = 978045.0 - 978120.0 + 191.332 = +116.3 \text{ mGal}$

Step 3: Compute the Bouguer correction

$2\pi G\rho = 0.1119 \text{ mGal/m} \times 620 \text{ m} = 69.375 \text{ mGal}$

$\Delta gB = +116.3 - 69.375 = +46.925 \text{ mGal}$

EXERCISE: Computing the Bouguer anomaly

Step 4: Interpret the sign:

A positive Bouguer anomaly of +46.9 mGal indicates that there is denser-than-average material in the subsurface beneath this station. A persistent positive value may suggest that a dense mafic or ultramafic body exists at depth. This single value is insufficient to determine which explanation is correct. Comparison with regional Bouguer anomaly maps and seismic data would be needed.

Summary of results:

Free-air correction: +191.3 mGal

Free-air anomaly: +116.3 mGal

Bouguer correction: −69.4 mGal

Simple Bouguer anomaly: +46.9 mGal

Why free-air correction is added and Bouguer correction is subtracted?

Free-air correction (added): Free-air correction compensates for being too far from Earth's center, so we add gravity.

Bouguer correction (subtracted): Bouguer correction compensates for extra rock pulling downward, so we remove gravity.

Magnetic

In Singapore, the total intensity of Earth's magnetic field is approximately F = 42,500 nT and the inclination is I = 14°. What does an inclination of 14° mean physically?

A) The field points 14° east of geographic north.

B) The field vector is directed 14° below the horizontal plane.

C) The field has rotated 14° from its position 100 years ago.

D) The field intensity decreases by 14 nT per kilometre of depth.

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✓ **Correct answer: B** Inclination (also called magnetic dip) is the angle between the horizontal plane and the total field vector, measured positive downward in the Northern Hemisphere. Singapore's low inclination of ~14° reflects the city's proximity to the magnetic equator, where the field is nearly horizontal.

A magnetic survey detects a symmetric positive anomaly directly above a magnetised body. At which magnetic inclination would you expect such a perfectly symmetric peak to occur?

A) I = 0° (magnetic equator)

B) I = 45°

C) I = 90° (magnetic pole)

D) The shape of the anomaly does not depend on inclination.

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C) I = 90° (magnetic pole)

D) The shape of the anomaly does not depend on inclination.

✓ **Correct answer: C** The shape of a magnetic anomaly depends strongly on the local inclination. At I = 90° (directly at the magnetic pole), the ambient field is vertical and a uniformly magnetised body produces a symmetric positive anomaly centred directly above it. At lower inclinations the anomaly becomes asymmetric, developing a negative lobe on the equatorward side. At I = 0° the body produces a negative central anomaly flanked by positive side lobes.

Remanent magnetisation can complicate the interpretation of magnetic anomalies. Which of the following correctly describes remanent magnetisation?

A) Remanent magnetisation is acquired when a rock forms (e.g., when lava cools) and persists independently of the present-day field, potentially pointing in a different direction.
B) Remanent magnetisation is proportional to the current Earth field and disappears when the field is removed.
C) Remanent magnetisation only occurs in sedimentary rocks.
D) Remanent magnetisation is always stronger than induced magnetisation in crustal rocks.

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✓ **Correct answer: A** When magma cools, magnetic minerals (primarily magnetite) lock in the direction of the ambient field at that geological moment.