1. Fill in the blank.
   a. ___________________ minerals have a positive magnetic susceptibility but carry no remanence.
   b. Ground surveys that use fluxgate magnetometers generally measure the ___________________ component of Earth’s magnetic field.
   c. Vertical derivatives of potential field data accent gradients along the __________ of shallow tabular bodies.
   d. The proportionality constant relating the induced magnetization a body acquires when placed in Earth’s magnetic field is know as ________________________.
   e. Low pass filtering of potential field data produces a map where __________ (longer, shorter) wavelengths are preserved.
   f. The presence of linear magnetic anomalies on the ocean floor suggest that the Konigsberger ratio (Q) of the ocean floor basalts is (greater than, less than) one.
   g. The angle between the horizontal component (H_o) and geographic North is termed the ____________________.
   h. The magnetic field one Earth radius above the magnetic equator is __________ (8x, 4x, 2x, \(1/2x\), \(1/4x\), \(1/8x\)) the value of the field at the magnetic equator.
   i. 1 nanotesla = ___ gammas = ___ gauss = ___ Teslas = ___ webers/m\(^2\)
   j. This type of remanent magnetization is acquired during crystal growth at room temperatures in the presence of a magnetic field ____________________.
   k. Magnetic permeability of free space (\(\mu_o\)) in the cgs system is equal to __________.
   l. In these materials the spin magnetic moments of unpaired electrons between neighboring atoms are magnetically coupled, moments are anti-parallel and unequal ________________________.
   m. This technique starts by assuming a simple shape for the source of a potential field anomaly and computes the effect of the model at ground surface modifying the model until the computed anomaly matches the observed:________________.
   n. The phenomena of ground state splitting of electron energy levels in the presence of a magnetic field is known as the ____________________________.
   o. Optically pumped or alkali-vapor magnetometers measure this component of Earth's magnetic field ____________________________.
p. A slow, progressive, temporal change in declination and inclination of Earth’s magnetic field is called ________________________________.

q. Gradiometer magnetometers employing proton precession sensing heads most commonly measure the ________________________________.

2. What is the name given to the phenomenon shown in the figure below and what is the cause of this phenomenon?

![Graph of Magnetic Field vs Time](image)

3. Alkali-vapor and proton precession magnetometers are said to be scalar magnetometers while fluxgate magnetometers are said to be vector magnetometers. Why?
4. The magnetic anomalies shown below result from a magnetometer surveys over an east/west lava tunnel on one of the islands of the Galapagos which is near the equator. Determine the depth to the center and radius of the tunnel. Earth’s total field intensity is 36,000 gammas and the susceptibility of the basalt is 0.012 cgs units. Is the ΔZ anomaly correct? Explain.
5. Earth’s geomagnetic poles are presently located at 79.3°N, 71.5°W and 79.3°S, 108.5°E while the magnetic dip poles are located at 79.0°N, 105.1°W and 64.7°S, 138.6°E. Why? Start your discussion by defining what geomagnetic and magnetic dip poles are.

6. Assuming that the magnetic moment of the Earth is $8 \times 10^{22}$ Am$^2$, its radius 6370 km, and that its magnetic field conforms to a geocentric axial dipole model (i.e. a dipole positioned at the Earth’s center and aligned along the rotation axis), calculate the geomagnetic elements (3 vectors and 2 angles) that describe the Earth’s magnetic field at 30°N and 30°S latitudes. Start by defining what the 3 vectors and 2 angles are.
7. Tell me about the magnetic anomalies shown below. In your discussion include shape, possible sources both geometric and geologic, induction verses remanence, etc.
8. The diagram below depicts a buried sphere magnetized by induction in the Northern Hemisphere. Inclination of the field is 60°. Indicate clearly on the figure below along horizontal black line (i.e. ground surface) the following:

(a) The North and South directions on this diagram?

(b) The location where the horizontal field (ΔH) anomaly would be zero and where the anomaly’s positive and negative maximums would be.

(c) Draw the vertical field (ΔZ) anomaly on the diagram below using the ground surface for the zero anomaly line.

(d) Which anomaly (ΔZ or ΔH) would look most like the total field anomaly at this location?

(e) If this body were located in the Southern Hemisphere would the anomaly (total field) maximum be located south of the body’s center or north?
9. The figure below is part of the aeromagnetic anomaly map of the Upper Peninsula of Michigan. The prominent anomaly shown in the center of this map (north-northwest of Traverse Island) occurs over the Jacobsville Sandstone. What might be the cause of this anomaly and how might you determine the thickness of the Jacobsville in this area? Given details in your discussion.
10. The figure shown below is a residual gravity map obtained from a survey made near Noranda, Quebec. The anomaly pattern is associated with a massive body of base metal sulfide (mainly pyrite) which has displaced volcanic rocks of middle Precambrian age. Integrating over the gravity anomaly gives a value of $8.1 \times 10^5$ gu-m$^2$. If the average density of core samples taken from the ore is 4600 kg/m$^3$, and for the volcanic rock the density is 2700 kg/m$^3$, what is the total mass of the sulfide deposit?
Equation Sheet

\[ F = Gm_1m_2/r^2; \quad g = Gm/r^2; \]

\[ G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg-sec}^2; \quad GM = 3.986005 \times 10^{14} \text{ m}^3/\text{sec}^2; \quad R_{\text{ave}} = 6.371,000 \text{ m} \]

\[ g_{\text{th}} = 9780318.46(1+0.005278895 \sin^2 \lambda +0.000023462 \sin^4 \lambda) \text{ gu} \]

\[ \Delta g_z = 4G\pi R^3 \Delta \rho z/3(x^2 + z^2)^{3/2} \text{ (sphere)}; \quad \Delta g_z = 2G\pi R^2 \Delta \rho z/(x^2 + z^2) \text{ (horizontal cylinder)} \]

\[ \Delta g_z = G\pi R^2 \Delta \rho/(x^2 + z^2)^{1/2} \text{ (thin vertical cylinder)}; \quad \Delta g_z = 2\pi G\Delta pt \text{ (infinite sheet)} \]

\[ \Delta g_z = 2\pi G\Delta \rho (L - S_1 + S_2) \text{ (vertical cylinder)}; \quad \Delta g_z = G\Delta \rho \omega t \text{ (short vertical cylinder)} \]

\[ \Delta g_z = 2G\Delta pt \ln (r_2/r_1) \text{ (thin vertical sheet)}; \]

\[ \Delta g_z = 2G\Delta \rho \{[-(xsini +z_1cosi)(sini \ln(r_2/r_1) + cosi (\theta_2 - \theta_1)) +z_2\theta_2 - z_1\theta_1} \text{ (step discontinuity)} \]

\[ \Delta g_z = 2G\Delta \rho (z_2\theta_2 - z_1\theta_1 -x\ln(r_2/r_1)) \text{ (thick vertical step)} \]

\[ \Delta g_z = 2G\Delta pt (\pi/2 - \tan^{-1}(x/z)) \text{ (thin step discontinuity)} \]

\[ z = 1.305x_{1/2} =0.65w_{1/2}; \quad z = x_{1/2} = 0.5w_{1/2} \]

\[ \int \int g_z \text{dxdy} = 2\pi G\Delta M; \quad \Delta M = \Sigma \Delta g_z \Delta x\Delta y/2\pi G; \quad M_T = (\rho_{\text{ore}}/\Delta \rho) \Delta M \]

\[ B_r = 2(\mu_0m/4\pi r^3) \cos \rho = 2(\mu_0m/4\pi r^3) \sin \lambda; \quad B_\theta = (\mu_0m/4\pi r^3) \sin \rho = (\mu_0m/4\pi r^3) \cos \lambda \]

\[ |\mathbf{B}| = \sqrt{B_r^2 + B_\theta^2} = (\mu_0m/4\pi r^3)(4 \cos^2 \rho + \sin^2 \rho)^{1/2} \]

\[ \tan I = 2 \cot \rho = 2 \tan \lambda \]

\[ B = \mu_0H + \mu_0J_l; \quad B = \mu H \quad \mu = \mu_0\mu_r \quad \mu_r = 1 + k \]

\[ \mu_0 = 4\pi \times 10^{-7} \text{ webers/Am} \]

\[ X^2 + Y^2 + Z^2 = T^2 \quad X^2 + Y^2 = H^2 \]

\[ H = T \cos I; \quad Z = T \sin I; \quad Z = H \tan I \]
\[ \tan D = \frac{Y}{X}; \quad X = H \cos D; \quad Y = H \sin D \]

2D Dipping Sheet
\[ \Delta H = 2k\sin \delta [(Z_o \sin \delta - H_o \sin \alpha \cos \delta) \ln(r_2/r_3/r_4) - (Z_o \cos \delta + H_o \sin \alpha \sin \delta)(\theta_1 - \theta_2 - \theta_3 + \theta_4)] \]
\[ \Delta Z = 2k\sin \delta [(H_o \sin \alpha \sin \delta + Z_o \cos \delta) \ln(r_2/r_3/r_4) - (H_o \sin \alpha \cos \delta - Z_o \sin \delta)(\theta_1 - \theta_2 - \theta_3 + \theta_4)] \]
\[ \Delta T = \Delta H \cos \beta \cos I_o + \Delta Z \sin I_o \]

Isolated Pole
\[ \Delta H = -C_m \frac{m x}{r^3} \]
\[ \Delta Z = C_m \frac{m z}{r^3} \]
\[ \Delta T = C_m \frac{m [z \sin I_o - x \cos I_o]}{r^3} \]

Line of Dipoles
\[ \Delta H = 2 C_m \frac{m [(x^2 - z^2) \cos I_o \sin \alpha - 2xz \sin I_o]}{r^4} \]
\[ \Delta Z = 2 C_m \frac{m [(z^2 - x^2) \sin I_o - 2xz \cos I_o \sin \alpha]}{r^4} \]
\[ \Delta T = 2 C_m \frac{m [(x^2 - z^2)(\cos^2 I_o \sin \alpha \cos \beta - \sin^2 I_o) - 4xz \sin I_o \cos I_o \sin \alpha]}{r^4} \]

Isolated Dipole
\[ \Delta H = C_m \frac{m [(3x^2 - r^2) \cos I_o - 3xz \sin I_o]}{r^5} \]
\[ \Delta Z = C_m \frac{m [(3z^2 - r^2) \sin I_o - 3xz \cos I_o]}{r^5} \]
\[ \Delta T = C_m \frac{m [3(x \cos I_o - z \sin I_o)^2 - r^2]}{r^5} \]

Half-width Rules - Vertical field

- Dipole: \( z = 2x_{1/2} \)
- Pole: \( z = 1.3x_{1/2} \)
- Line of poles: \( z = x_{1/2} \)
- Line of dipoles: \( z = 2x_{1/2} \)

Half width rules - Horizontal Field

- Dipole: \( z = 2.5x_{1/2} \)
- Pole: \( z = 1.3x_{1/2} \)
- Line of poles: \( z = x_{1/2} \)
- Line of dipoles: \( z = 2x_{1/2} \)