Guide to: Magnetic fields created by moving charged particles and by electrical currents.

Applications: Fields near wires, solenoids, coils. Measure currents by magnetic-field deflection of coil placed in permanent magnet field. Planets and stars have magnetic fields due to currents inside.

Basic idea: An extension of Coulomb's law to determine fields caused by ***moving*** charges.
Biot-Savart law is analog of Coulomb's law, Ampere's law is analog of Gauss' law.

Derivations: 1) Formulas can be derived for: magnetic field as a function of distance from a long straight wire; magnetic field at the center of a current-carrying loop; both from Biot-Savart.

2) For a solenoid (many current loops in series) one finds that the addition (superposition) of their fields leads to near-constant (uniform) magnetic field inside the solenoid. Ampere's law allows to calculate the strength of the field as a function of current and solenoid length (assumed to be much larger than the diameter).

Equations: Biot-Savart law for single moving charge and for segment of current-carrying wire:

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\ \vec{v}\times\vec{r}}{r^3} = \frac{\mu_0}{4\pi}\frac{I\ \Delta\vec{s}\times\vec{r}}{r^3}$$

The latter requires Calculus to sum $\Delta\vec{s}$ over finite wire length.

Field strength as a function of distance from a current-carrying wire: $B = \frac{\mu_0}{2\pi}\frac{I}{d}$

Field strength at the center of a loop of radius R (multiply by N for more turns): $B = \frac{\mu_0\ I}{2R}$

Field strength inside N-turn solenoid of length L>>R: $B = \frac{\mu_0\ N\ I}{L}$

Problems: 20.1-6; 20.68-87; (Ampere law problems are done using the formulas we derived from Biot-Savart)
Use of the Biot-Savart law to derive magnetic field formulas is really PHYS2020 material
Challenge: adding the fields from multiple wires requires superposition. This is vector addition, even though the formula gives the magnitude of the field. Watch out! Use magnetic field line drawings to get the idea.