The BIG PICTURE
We will study two main topics in physics this semester.
• Heat is a form of energy. Objects contain energy in the disordered motion and vibration of their molecules. Because heat never flows (by itself) from a cold object to a hot one, there are limits on how well we can convert heat energy into organized energy such as work.

• Forces between particles are mediated by *fields.* Fields can have both energy and momentum. We will study fields by focusing on electric and magnetic fields: how electric charges create them and respond to them.

Chapter 17 Goals
Know:
Heat is energy transferred because of a temperature difference
Do all objects expand on heating? Why do most?
$\beta = 3\alpha$
Three mechanisms of heat transfer
All gases extrapolate to P=0 at T = 0 K.
0°C = 273 K (approximately.)

Do:
Convert °F, °C, K *without given formulas.*
Mixing ice and water, find composition and final temperature.
Accurately sketch temperature vs. heat added through phase transitions, and derive unknowns.

Challenge:
How fast does a lake freeze solid?

Chapter 18 Goals
Know:
What is an ideal gas?
What is an equation of state? Ideal gas law? Does it apply when not at equil'm?
What is molar mass?
In an ideal gas, the translational kinetic energy $\propto$ T (*in Kelvin!*)
Heat capacity C_v of a monatomic ideal gas. Is diatomic higher or lower?
Heat capacity of a monatomic solid
What is the triple point? Critical point?

Do:
Apply pV=nRT, numerically *and* "relationally"
Find heat needed to raise temperature of gas *at constant volume.*

Challenge:
Find the air pressure at elevation in an isothermal ideal gas.

Chapter 19 Goals
Know:
Internal energy is a state variable. Q,W are process variables.
The internal energy of an ideal gas depends *<u>only</u>* on temperature!

$\Delta U = Q - W = nC_v\Delta T$ for ideal gas
$W = \int p dV$
Meaning of adiabatic, isothermal, isobaric, isochoric
Why is $C_p = C_v + R$?

Do:
Find W for any easily integrable path
Find ΔU, Q, W for paths where you can find Q or W easily

Challenge:
Find the frequency of oscillation of a piston for isothermal or adiabatic oscillations. (19.69)

Chapter 20 Goals
Know:
What is a "reversible" process? Is there such a thing in the real world?
What is a Carnot cycle? What direction is the loop for an engine?
No engine can exceed Carnot e, because heat does not flow spontaneously from cold to hot.
What is a refrigerator?
Entropy is a state variable. It is a measure of microscopic disorder.

Do:
Determine whether a cycle is an engine or fridge, and find efficiency or coef of performance.
Find the entropy change in a process, either at constant T or given constant heat capacity. For an irreversible process, choose a reversible path to the same endpoint.

Challenge! (hard)
A brick of mass m is placed on top of a frictionless piston on a perfectly insulated cylinder of 1 mole of monatomic ideal gas. The piston oscillates about its new, lower position, and eventually comes to rest. Did the entropy increase? By how much? (To do this problem, you need to calculate the work done ON the gas by the brick. That's *not* $-\int p dV$. See me if you are interested!)

Chapter 21 Goals
Know:
Coulomb's law (you don't need to memorize constant k though.)
Definition of electric field
What is linear and areal charge density?
What is charging by induction? How do insulators and conductors respond to E fields?
What is r hat?
E field in a conductor = 0 (if charges at rest).
E fields "penetrate" insulators
Arrows ≠ vectors. They represent vectors.
Areal density of field lines ∝ field strength. Field lines can't cross.

Do:
Find the force or field from two charges (vector addition)
Write down linear & areal charge densities for uniform charge distributions
Write down integrals for components of electric field from a charge distribution
Find points of zero field (if any) from two charges
Apply superposition to rank fields if directions are changed

Recognize incorrectly drawn field lines
Use superposition to find field from infinite planes of charge.

Challenge:
Consider a charged line (charge density λ) bent into the parabola $y = x^2$.
Find the electric field at the point x=0, y=2. You'll need to know that an infinitesimal segment of the line $dl = \sqrt{(dx^2 + dy^2)}$.

Chapter 22 Goals
Know:
Definition of flux, Gauss's Law
Implications of Gauss's Law for charge on conductors

Do:
Write down vector area for a flat surface tilted at a specified angle to xy, yz, or xz planes.
Find flux from a uniform field through a flat surface
Find flux from a non-uniform field through a surface in xy, yz, or xz planes (Double integral in Cartesian coordinates.)
Find flux from a non-uniform field through a cylinder along z axis. (I'll give you dA in cylindrical coordinates.)
Find E field in any symmetric charge arrangement using Gauss's law.
Find E fields from (for example) a charged insulating plane and a charged insulating wire using superposition.
Predict charges on surfaces of conducting shells with various total charge and point charges inside.

Challenge:
Problems 22.61 and 22.62 are excellent!

Chapter 23 Goals
Know:
Definition of conservative fields
Relationship between work and potential energy
Definition of electric potential
Where $V = 0$ is an arbitrary choice!
Equipotentials are perpendicular to E
Closer equipotentials = stronger field
Field is "downhill" direction

Do:
Find potential energy of simple arrangements of charges and final kinetic energies and velocities if released
Find the change in potential using a line integral in simple cases (i.e. along x or y axes, or r)
Find places where $V = 0$ from two charges
Find electric field from potential using gradient (in simple cases, see Test Your Understanding 23.5)
Find potential from a charge distribution (e.g. rod or ring) by integration.

Chapter 24 Goals
Know:

We treat all capacitors as having equal and opposite charges on two conductors, but you could add equal charge $+Q_{ex}$ to each plate and the potential difference would not change.
Memorize how to find equivalent cap for caps in series and parallel.
Memorize what series and parallel *mean:* parallel = same ΔV; series = same Q.
Understand that "field energy" IS electrical potential energy
$F = -dU/dx$
What is a "dielectric"? What does it do to the field in a capacitor? To the capacitance? To U?
Why are dielectrics are pulled into capacitors?
A capacitor is like a spring. Relate F, U, k, x to V, U, C^{-1}, Q.

Do:
Find equivalent capacitance in a network (ex. 24.6)
Find the force on capacitor plates (24.27)
Find the capacitance of plate, cylinder, or spherical capacitors using Gauss's law and line integral for V.

Challenge: 24.76 is a fun problem. What does your answer mean? In other words, what happens if you start the plate at the unstable equilibrium position?

Chapter 25 Goals
Know:
Usually, a constant force gives constant acceleration. But for current, constant force (electric field) gives constant velocity. Why?
What is the direction of current flow?
How does resistance of a metal depend on temperature? If it decreased with temperature, why would incandescent light bulbs explode / melt?
Memorize the power in any circuit element $P = IV$
Memorize Ohm's law – a material property
Current is like water flow – the same at every place in the pipe!
Potential drop around a loop = 0.
Direction of fields in a circuit and battery; relative magnitudes of fields in wires, resistors
What are ammeters / voltmeters and how are they attached to a circuit

Do:
Find the resistance of a cylinder or cone (25.65) given resistivity
Find current in a loop given resistances and EMFs.

Challenge: Tolman-Stewart experiment and electron inertia, 25.85

Chapter 26 Goals
Know:
Effective resistances for parallel and series resistors
Kirchoff's rules; Qualitative behavior of RC circuits; time constant

Do:
Solve for effective resistance in a network
Apply Kirchoff's rules to find current in a two-loop circuit with resistors & EMFs
Predict light bulb brightness in series, parallel etc.

Challenge: How does a theremin work? See 26.90.

Chapter 27 Goals
Know:
ONLY MOVING charges feel magnetic fields.
Magnetic force does not increase kinetic energy.
Magnetic field lines are loops; the magnetic flux through a closed surface is zero.
What current loops feel in uniform and non-uniform fields
What is the Hall effect?

Do:
Use right hand rule to find forces on moving charges, or on a wire.
Find the radius of circular motion for a moving charge in a magnetic field.
Infer the direction of a magnetic field from forces on moving charges (e.g. 27.55)
Find the sign of charge carriers from the Hall effect.

Chapter 28 Goals
Know:
ONLY MOVING charges create magnetic fields.
What direction of currents in wires give attraction? Repulsion?
Magnetic forces are NOT "equal and opposite"… momentum is NOT conserved!
Memorize what ferromagnetic, paramagnetic, and diamagnetic mean.

Do:
Given Biot-Savart law, find the magnetic field from a moving charge or current element.
Find total field from wires when integration is simple.
Use RHR and understanding of cross products to find the magnetic field direction for charges, wires, loops, soloids, etc.
Given Ampere's law, use it to find magnetic fields in symmetric situations, including an infinite current sheet or inside a wire
Use vector superposition to find magnetic field from multiple sources
Given the formula for force on a finite current segment, find net force (or torque) on a rectangular loop near a wire

Challenge: Problem 28.87 looks fun!

Chapter 29 Goals
Know:
A changing magnetic flux induces an emf around a loop.
Induced electric fields are non-conservative and cannot be represented with a potential
There need NOT be a B field at a place where there is an induced E field
How eddy currents brake

Do:
Find the direction and magnitude of induced emf, for simple changing fields or changing areas.
Find the E field for the emf, if there is one.
Find motional emf for a bar moving in a magnetic field
Find the force required to change the area of a loop in a magnetic field, using energy conservation

Challenge: Problem 29.77.

Chapter 30 Goals
Know:
The direction of the induce E field, conservative E field, voltage drop, and emf in an inductor with changing current
Current in an inductor, voltage across a capacitor cannot jump.
At long times, inductor is a short, a capacitor is an open circuit
Time constant in LR circuit is L/R. Why does a smaller resistor give a longer τ?
Behavior of current and energy in an LC circuit.

Do:
Apply Kirchoff's loop law to loops with inductors and changing current… assign correct direction of voltage drop.
Find the behavior of circuits containing inductors and capacitors at short and long times after switches have been opened/closed.

Chapter 31 Goals
Know:
What's a phasor? How do you set it on "stun"?
V=IX (I'll give you $X_L = \omega L$, $X_C = \omega/C$, V_C lags, V_L leads.)
What is a transformer and how does it work

Do:
Draw a phasor diagram to represent an LRC series circuit, find overall phase of response.

Chapter 32 Goals
Know:
Electromagnetic waves are a consequence of induction, and can be derived and understood from Maxwell's equations.
The E and B fields are perpendicular, and perpendicular to the propagation direction
Waves carry energy and momentum.
In free space, all EM waves travel at the same speed, regardless of wave shape.

Do:
Given the definition of Poynting vector, find the direction of propagation of a wave and the power per unit area.