Test 2 Summary

Coverage: Chapters 6 to 9
Lectures 11 to 20

Work and Energy

Work requires a force applied over a distance
\[ W = Fd \] (Units: Joules)

Work done against gravity leads to Grav. Pot. Energy
\[ U = mgh \] (h = height)

Kinetic energy is energy of motion
\[ K = \frac{1}{2}mv^2 \]

Thermo Law 1: Total Energy is conserved

Power = rate of doing work
\[ P = Fv \] (Units: Watts)

Efficiency = useful work/power
input work/power

Thermal energy is energy of internal motion, etc. within a substance (e.g. steam)

\[ \Rightarrow \] Temperature measures thermal energy per molecule

Absolute temp used: \[ K = ^\circ C + 273 \] Kelvin
Thermo Law 2: thermal processes have one-way nature
- heat flows from hot to cold
- molecules mix but don't un-mix
- entropy increases

Heat Engine transfers thermal energy into work, drawing heat from hot source, exhausting wasted heat to cold dump

\[ \text{Conservation of energy:} \quad Q_h = W + Q_c \]

\[ \text{efficiency} = \frac{W}{Q_h} = 1 - \frac{Q_c}{Q_h} \]

\[ \text{max efficiency possible} = 1 - \frac{T_c}{T_h} \]

Thermal energy transfers three ways:
- conduction
- convection
- radiation

(Read lecture notes about various engines and gas/electric hybrids)
Electricity and Magnetism

Maxwell's Equations describe relation between electric charge/current and electric (E) and magnetic (B) fields.

Fields are lines of force.
Density of field lines $\alpha$ strength of force.

Electric field points in direction of force on a positive "test" charge (not the charge that makes the electric field!)

Maxwell:
- There are no magnetic charges
- Electric field is produced by (electric) charges
- A changing E field generates a B field (Lenz's Law)
- Current (moving charge) generates a B field (Ampère's Law)
- A changing B field generates an E field (Faraday's Law)

(A) = "Ampère's Law" (F) = "Faraday's Law"

Static Electric Field from charge $q$ (units: Coulomb (C))

$$E = \left(9 \times 10^9 \frac{N m^2}{C^2}\right) \frac{q}{r^2} \text{ units: } \frac{N}{C} = \frac{V}{m}$$

$\Rightarrow$ Force $F = g \cdot E = \left(9 \times 10^9 \frac{N m^2}{C^2}\right) \frac{q \cdot q}{r^2}$
Change is conserved, even when it vanishes!
e.g. electron/positron annihilation $e^- + e^+ \rightarrow \gamma + \gamma$
zero net charge light

Electric force between nucleus (protons + neutrons) and electrons $\rightarrow$ Planetary Atomic Model
problems: * any electron orbit is allowed
* electrons would radiate energy away

Voltage is electrical potential energy per charge
$V$ units $J/c = \text{Volt (V)}$

Current is flow of charge
$I$ units $C/s = \text{Amp (A)}$

Ohm's Law defines Resistance $V = IR$
$R$ units $V/A = \text{Ohm (Ω)}$

Faraday's Law
- changing $B$ induces $E$
- moving $B$ induces $E$

Main law of Physics governing modern life!
Waves: medium + restoring force + inertia

Two main types:
- Transverse waves: displacement ⊥ wave direction
- Longitudinal waves: displacement ∥ wave direction

Wave Eqn: \( \omega = f \lambda \)  \( f = \frac{1}{T} \) units: Hertz (Hz)

Two or more waves interfere:
- "Constructive" when peaks add: \( n + m = \lambda \)
- "Destructive" when peaks cancel: \( n - m = 0 \)

Doppler effect when source or "listener" are moving with respect to medium each other
EM waves

Travel in vacuum (Michelson-Morley 1887)
Predicted by Maxwell's Equations

Hertz Experiment

\[
\text{transmitter antenna} \rightarrow \text{EM waves} \rightarrow \text{receiver antenna}
\]

Spark closes circuit $\Rightarrow$ current

antenna gets voltage from EM wave $\Rightarrow$ spark at gap

\[
c = f \lambda \quad f \approx 10^9 \text{ Hz} \quad \Rightarrow \quad \lambda \approx 30 \text{ cm}
\]

EM Wave spectrum - huge range!

Light $\lambda = 400-750$ nm is visible

$\lambda < 400$ nm is ultraviolet, UV

$\lambda > 750$ nm is infrared, IR

Solar Constant $= 1.4 \text{ kW/m}^2$ incident on earth

$= 770 \text{ W/m}^2$ incident on surface

$= 200 \text{ W/m}^2$ average in North America

$\Rightarrow$ size of solar panels required for given power and efficiency
10 lectures, 10 problems

1. work, grav. pot., kinetic energy

2. power, efficiency

3. thermal energy, temp, heat, 2nd Law, heat engine

4. thermal energy transfer, engines, hybrids

5. Maxwells, no mag, charge, fields

6. Fields, electric force, charge conservation, planetary model

7. Current & Voltage, Ohm's Law, Faraday's Law

8. Waves, transverse/longitudinal

9. Wave kinematics $v=f\lambda$, interference, Doppler, Radio

10. EM waves, spectrum, visible/uv/ir, solar energy