Annotated SAT Physics Equation Sheet

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1 Mechanics $(36 - 42\%)$

1.1 Kinematics

Constant motion:

$$\Delta d = v_{avg} \cdot t$$

Changing motion:

$$v_f = v_i + at$$

$$\Delta d = v_i t + \frac{1}{2}at^2$$

$$v_f^2 = v_i^2 + 2a\Delta d$$

1.2 Newton's Laws/Forces

- Newton's Law: $\Sigma F = ma$
- Simple Gravity: $F_g = mg$
- Friction: $F_f = \mu \cdot F_N$
- Spring: $F_s = kx$ (cannot use in W)

1.3 Work/Energy

1.3.1 Energy Conservation

$$E_i = E_f \implies PE_i + KE_i = PE_f + KE_f$$

**must also consider energy "loss" due to heat, friction, etc.

1.3.2 Work

- Definition: F applied parallel to Δd

$$W = Fd\cos\theta$$

- Net work done on system: $W_{net} = \Delta E$
- Work-KE theorem: $W = \Delta KE$

1.3.3 Types of Energy

- Gravity Potential: $PE = mgh$
- Kinetic: $KE = \frac{1}{2}mv^2$
- Spring Potential: $PE_s = \frac{1}{2}kx^2$

1.3.4 Power

$$P = \frac{W}{t} = \frac{\Delta E}{t} = F \cdot v$$

1.4 Impulse-Momentum

1.4.1 Momentum

- Definition: $p = mv$
- Conservation: true if all system forces internal

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

1.4.2 Impulse

$$J = \Delta p = m\Delta v = F_{net} \cdot \Delta t$$

1.5 Graphs

1.5.1 Motion

$$\Delta d \underset{area}{\overset{slope}{\rightleftarrows}} v \underset{area}{\overset{slope}{\rightleftarrows}} a$$

1.5.2 Energy/Momentum

- $W =$ area under F vs. Δd
- $J =$ area under F vs. Δt

1.6 Gravity & UCM

1.6.1 Gravity

$$F_G = \frac{Gm_1m_2}{r^2}$$

1.6.2 UCM

- Period: $T =$ time for one revolution
- Frequency: $f =$ revolutions per second [Hz]

$$f = \frac{1}{T} \iff T = \frac{1}{f}$$

- Rotational speed:

$$v = \frac{2\pi r}{T}$$

- Centripetal acceleration:

$$a_c = \frac{v^2}{r} \implies F_c = \frac{mv^2}{r}$$

1.6.3 UCM + Gravity

- Orbital speed:

$$v = \sqrt{\frac{GM}{r}}$$

1.6.4 Kepler's Laws**

1. Planets move in elliptical orbits w/sun at focus
2. Any line joining planet to sun sweeps out equal areas in equal times
3. $T^2 = kr^3$

1.7 SHM**

- Period of spring:

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

- Period of pendulum:

$$T_p = 2\pi\sqrt{\frac{l}{g}}$$

2 Waves and Optics $(15 - 19\%)$

2.1 Mechanical Waves

2.1.1 Motion

$$v = \lambda f = \frac{d}{t}$$

2.1.2 Interactions

- Reflection: wave bounces
- Refraction: wave changes medium
- Diffraction: wave bends around obstacle
- Interference: wave overlaps another wave
- f constant, v and λ change with medium

2.1.3 Harmonics

- Two fixed/Two free ends:

$$\lambda_n = \frac{2L}{n} \text{ , } n = 1, 2, 3, ...$$

- One fixed/one free end:

$$\lambda_n = \frac{4L}{n} \text{ , } n = 1, 3, 5...$$

- Harmonics: $f_n = nf_1$

2.2 Electromagnetic Waves

2.3 Basics

- Properties:

$$c = \lambda f \text{ ; all light waves travel at } c$$

$$n = \frac{c}{v} \text{ ; speed of light in medium} < c$$

- Law of Reflection: $\theta_i = \theta_r$
- Snell's Law: $n_i \sin\theta_i = n_r \sin\theta_r$

2.4 Lens/Mirror Equations

**d_i negative if diverging

- Magnification:

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

- Focal equation:

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

2.5 Lens/Mirror Images

Location	Converging: convex lens () + concave mirror)(	Diverging: concave lens)(+ convex mirror ()
$d_o > 2f$	SIR	SUV
$d_o = 2f$	TIR	SUV
$f < d_o < 2f$	LIR	SUV
$d_o = f$	No image	SUV
$0 < d_o < f$	LUV	SUV

3 E & M $(18 - 24\%)$

3.1 Electrostatics

3.1.1 Charge

- Charge is quantized: $Q = Ne$
- $e = 1.6 \times 10^{-19}$ C [Coulombs]

3.1.2 Force

- Coulomb's Law: like charges repel, opposites attract

$$F_E = \frac{kq_1q_2}{r^2}$$

3.1.3 Electric Field

- Definition: direction a (+) would go if placed in the field; measured in [N/C]

$$E = \frac{F_E}{q} = \frac{kQ}{r^2}$$

- Field lines point $(+) \to (-)$

3.1.4 Electric Potential/Voltage

- Definition: measured in Volts [V]

$$V = \frac{W}{q} = \frac{kQ}{r}$$

3.2 Circuits

$$I = \frac{\Delta Q}{\Delta t}$$

3.2.1 Kirchhoff's Rules

1. Loop Rule: $\Sigma V_{gains} = \Sigma V_{drops}$
    - Battery voltage = sum of voltages in loop connected to battery
2. Junction Rule: $\Sigma I_{in} = \Sigma I_{out}$
    - Current that enters junction must split between paths

3.2.2 Resistors

- Ohm's Law: $V = IR$; $R = \frac{\rho l}{A}$
- Power: $P = IV = I^2R = \frac{V^2}{R}$
- Series:
    - $R_{tot} >$ any R

$$R_{tot} = R_1 + R_2 + R_3 + ...$$

    - I same
    - V adds up
- Parallel:
    - $R_{tot} <$ any R

$$\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

    - V same
    - I adds up

3.2.3 Capacitors**

- Definition: $C = \frac{Q}{V}$; $C = \frac{\epsilon_0 A}{d}$
- Energy: $E = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{1}{2}QV$
- Series:
    - $C_{tot} <$ any C

$$\frac{1}{C_{tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$$

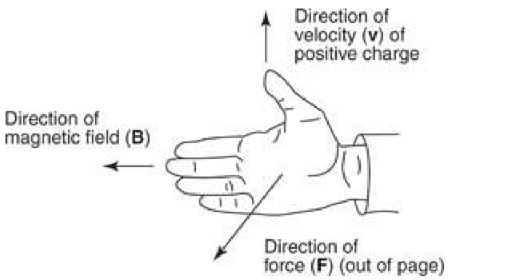
    - Q same
    - V adds up
- Parallel:
    - $C_{tot} >$ any C

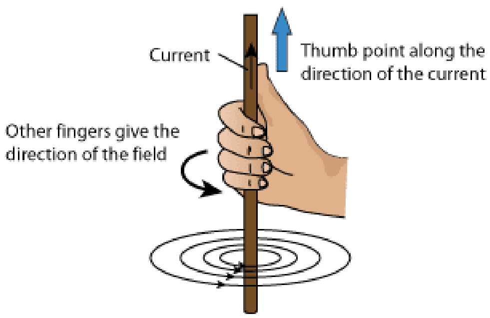
$$C_{tot} = C_1 + C_2 + C_3 + ...$$

    - V same
    - Q adds up

3.3 Magnetism

3.3.1 Right Hand Rule(s)





Right Hand Grip Rule

3.3.2 Magnetic Force

- Charged particle: $F_B = qvB\sin\theta$
- Current-carrying wire: $F_B = BIL\sin\theta$
- Use right hand rule to determine direction; F_B, v, and B all mutually perpendicular

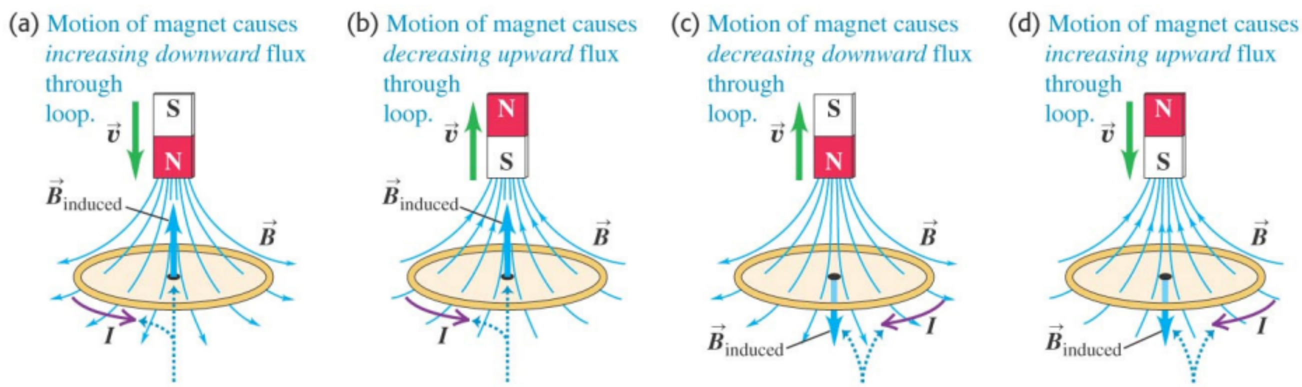
3.3.3 B Field

- Current-carrying wire:

$$B = \frac{\mu_0 I}{2\pi r}$$

3.3.4 Magnetic Flux**

- Lenz's Law: induced B and I act to oppose change
- Equation: $\Phi = BA\cos\theta$



4 Thermodynamics $(6 - 11\%)$

4.1 Ideal Gas

$$PV = nRT$$

$$\frac{V_i}{T_i} = \frac{V_f}{T_f}$$

$$P_i V_i = P_f V_f$$

4.2 Laws**

0. Heat flows hot $\rightarrow$ cold

1. Internal energy (U) changes if heat (Q) added or work (W) done

$$\Delta U = \Delta Q + \Delta W$$

2. No machine can be 100% efficient ($0 < e \leq 1$)

$$\text{efficiency} = e = \frac{Q_{in} - Q_{out}}{Q_{in}} = \frac{Q_{hot} - Q_{cold}}{Q_{cold}}$$

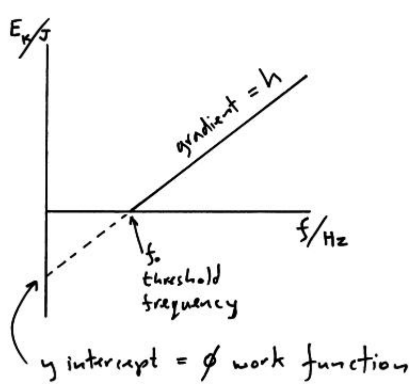
3. Can't get to absolute zero

5 Modern $(6 - 11\%)$

5.1 Quantization

$$E = hf$$

5.2 Photoelectric Effect



- Work function: minimum energy required for effect to occur

$$W = hf_t \text{ where } f_t = \text{threshold frequency}$$

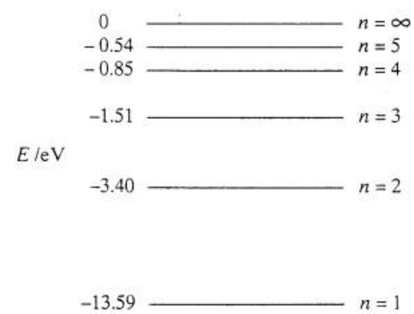
- Energy of photoelectrons:

$$KE = E - W = hf - hf_t$$

5.3 Hydrogen atom

- Orbital energy:

$$E_n = \frac{E_1}{n^2}$$



5.4 DeBroglie Wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

5.5 Mass-Energy Equivalence**

$$E = mc^2$$

5.6 Relativity**

- Length contracts

$$d' = \frac{d}{\sqrt{1 - v^2/c^2}}$$

- Time dilates

$$t' = t \cdot \sqrt{1 - v^2/c^2}$$