AP Physics 2012 – 2013 Ms Thoma

Please refer to the College Board AP Physics website for detailed information:

http://apcentral.collegeboard.com/apc/public/repository/ap-physics-course-description.pdf

Coarse Goals

1. Read, understand, and interpret physical information — verbal, mathematical, and graphical
2. Describe and explain the sequence of steps in the analysis of a particular physical phenomenon or problem; that is,
   a. describe the idealized model to be used in the analysis, including simplifying assumptions where necessary;
   b. state the concepts or definitions that are applicable;
   c. specify relevant limitations on applications of these principles;
   d. carry out and describe the steps of the analysis, verbally, or mathematically;
   e. interpret the results or conclusions, including discussion of particular cases of special interest
3. Use basic mathematical reasoning — arithmetic, algebraic, geometric, trigonometric, where appropriate — in a physical situation or problem
4. Perform experiments and interpret the results of observations, including making an assessment of experimental uncertainties
5. **Labs:** Laboratory experience is an important part of AP Physics. Students will be expected to design experiments; observe and measure real phenomenon; organize, display and critically analyze data; determine uncertainties from measurement; draw inferences from observations and data; communicate results
6. All students will take the AP Physics B exam in May.

This course provides a systematic development of the main principles of physics, emphasizing problem solving and helping students develop a deep understanding of physics concepts . It is assumed that students are familiar with algebra and trigonometry. In most colleges, this is a one-year terminal course including a laboratory component and is not the usual preparation for more advanced physics and engineering courses. AP Physics B provides a foundation in physics for students in the life sciences, pre-medicine, and some applied sciences, as well as other fields not directly related to science .

Content Outline for AP Physics B Exam :

I. Newtonian Mechanics	**35%**
A . Kinematics (including vectors)	7%
B . Newton's three laws of motion, including centripetal force	9%
C . Work, energy, power	5%
D . Systems of particles, linear momentum, collisions	4%
E . Uniform Circular motion, torque, and rotation	4%
F . Oscillations and gravitation	6%
II . Fluid Mechanics and Thermal Physics	**15%**
A . Fluid Mechanics	6%
B . Temperature and heat	2%
C . Kinetic theory and thermodynamics	7%
III . Electricity and Magnetism	**25%**
A . Electrostatics	5%
B . Conductors, capacitors, dielectrics	4%
C . Electric circuits	7%
D . Magnetostatics	4%
E . Electromagnetism	5%
IV **. Waves and Optics . . . .**	**15%**
A . Wave motion (including sound)	5%
B . Physical optics	5%
C . Geometric optics	5%
V . Atomic and Nuclear Physics	**10%**
A . Atomic physics and quantum effects	7%
B . Nuclear physics	3%

VII **Laboratory and experimental situations:** AP exam will include one or more questions or parts of questions posed in a laboratory or experimental setting . Each content area may include lab questions to assess content and experimental skills.

AP EXAM

The **AP Physics B exam** takes three hours, is divided into two sections : -

Section I: multiple choice is 70 questions, 90 minutes, NO calculators are permitted; 50% of total score
Multiple choice questions include single and multiple step computations, variable manipulation; graphical analysis; diagram-based questions; and "reverse multiple choice" questions [*all of the following are true EXCEPT..]*
Scoring: 1 point for correct answer, deduct ¼ point for incorrect answer. O points for skipped item.
If you can eliminate some choices , try to guess. Multiple choice answers are scanned.

Section II: free response is 6 to 8 questions, 90 minutes; graphing calculators permitted; 50% of total score
These are multipart questions labeled with "suggested" times for answering.
Scoring: Most of the credit is awarded for setting up the problems and explaining your reasoning. Each question is scored 10 or 15 points by human scorers.

AP Physics course objectives are detailed on pages 17-37 in AP Physics Course Description
http://apcentral.collegeboard.com/apc/public/repository/ap-physics-course-description.pdf

Correlation of AP Topics to chapter in Giancoli Physics:

Content area I: Newtonian Mechanics	
A. Kinematics	**Chapter 2**: sections 2.1 to 2 .8
	Chapter 3: sections 3. 1 to 3.8
B. Newton's laws of motion	**Chapter 4** sections 4.1 to 4.9
C. Work, energy and power	**Chapter 6** Sections 6.1 to 6.10
D. Systems of particle; linear momentum	**Chapter 7** Sections: 7. 1 to 7.7
E. Circular motion and Rotation	**Chapter 5** sections 5.1 to 5.4
	Chapter 8 sections 8.1 to 8.9
	Chapter 9 sections 9.1 to 9.3
	Chapter 11 : sections 11.1 to 11.3
F. Oscillations and Gravitation	**Chapter 11**: sections 11.1 to 11.6
	Chapter 5: sections 5.6 to 5.9
Content area II. Fluid Mechanics and Thermal Physics	
A. Fluid Mechanics	**Chapter 10**, sections 10.1 to 10.8
B. Temperature and Heat	**Chapter 14** ; sect 14.1 to 14.3;14.7 to14.9
	Chapter 13; sections 13.4to 13.5
C. Kinetic Theory and Thermodynamics	**Chapter 13**; sect 13.1 to 13.3; 13.7-13.11
	Chapter 15: sect 15.1, 15.2,15.4,15.5 to 15.9
Content Area III: Electricity and Magnetism Electrostatics	
A. Electrostatics	**Chapter 16** sections 16.1 to 16.9
B. Conductors, capacitors, dielectrics	**Chapter 17** sections 17.1 to 17.7
C. Electric Circuits	**Chapter 18** sect 18.1 to 18.4, 18.6 to18.8
	Chapter 19 sections 19.1 to 19.7; 19.10
D. Magnetostatics	**Chapter 20** sections 20.1 to 20.6
E. Electromagnetism	**Chapter 21** sections 21.1 to 21.7, 21.9
Content Area IV: Waves and Optics	
A. Wave motion	**Chapter 11** sect 11.6 to 11.9, 11.11 to 11.13
	Chapter 12 sect 12.1 to 12.5; 12.7 to 12.9
A. Physical optics	**Chapter 24** sections 24.1 to 24.8, 24.10
	Chapter 22 sections 22.5
B. Geometric Optics	**Chapter 23** sections 23.1 to 23.11
Content Area V Atomic and Nuclear Physics	
A. Atomic physics and quantum effects	**Chapter 27** sect 27.1 to 27.6; 27.8 to 27.11
	Chapter 28 sections 28.1 to 28.7
A. Nuclear Physics	**Chapter 26** section 26. 10
	Chapter 30 sections 30.1 to 30.9
	Chapter 31 sections 31.1 to 31.3

Notes: Only sections indicated will be covered in this course.

MKS = Meters Kilograms Seconds

1) *MKS are the base units we will use for length , mass and time*
2) *All derived units will use these base units [such as 1 Newton = 1 kg m/sec^2]*
3) *Must convert all units to MKS: don't use cm, mg, mm, mL , etc.*

Data Anaylsis , Representing and Interpreting Data

1) The goal of an experiment is to determine relationship between sets of data
2) Independent variable : horizontal axis dependent variable : vertical axis
3) Position vs time: time is independent variable
4) Use graphing paper, straight edge.
5) Use MKS units : meters, kilograms, seconds
6) The trendline predicts equation type
7) Types of equations: **Types of graphs to know**:

8) linear: **$y = kx$**
   parabolic: **$y = kx^2$**
   inverse: **$y = k/x$**
   inverse square: **$y = k/x^2$**
   square root: **$y = k\sqrt{x}$**
   { as in " lens equation"} **$1/y = k/x$**
   (as in "Snells law") **$k_1 \sin y = k_2 \sin x$**

9) Linearizing nonlinear data

1) **Graph original data**
2) **Look at the graph, and see if it is linear.**
3) **If not, determine which type of graph the data represents**
4) **Create new data set based on this graph**
5) **Graph new data [*is the new line straight??]***
6) **Use slope intercept to find relationship of variables**

Giancoli Chapter summaries

Chapter 1 is not covered in the AP exam.

Chapter 2:

1) **Major areas of 1-D motion stressed on AP exam**:
   a. Understanding average velocity vs instantaneous velocity
   b. Describing average velocity and instantaneous velocity graphically
   c. Understanding velocity , acceleration, and displacement as vectors
   d. Graphically relate the relationships between velocity, acceleration and displacement
   e. Qualitatively and graphically understand uniformly accelerated motion.
   f. Applying the relationships of uniform acceleration to physical situations
   g. Applying these characteristics to "free fall"
2) Δ means "the change in " = final – initial
3) Mechanics encompasses kinematics [describing motion of objects] and dynamics [force and energy related to motion]
4) Translational motion means no rotation.
5) Linear motion is 1 dimensional motion.
6) Frame of reference: describes orientation of object's motion with regard to position, distance, speed, and direction.
7) Reference frame anchors coordinate system; number of axes = number of dimensions to express position of object.
8) Scalar has only magnitude
9) Vector has magnitude and direction.
10) Displacement = vector change in object's position = $X_{final} - X_{initial}$
11) Distance = scalar path length
12) Average speed = a scalar : total distance/ time interval
13) Average velocity = vector: displacement / time interval $= \Delta x/\Delta t$
14) By definition, average velocity must be used whenever the acceleration is either zero or nonuniform.
15) Instantaneous velocity= velocity at precise instant; limit of velocity as time interval approaches zero.
    $V = \lim_{t \to 0} \frac{\Delta X}{\Delta t}$
16) Acceleration is the change in velocity = a vector
17) **Average acceleration = $\Delta v/\Delta t$**
18) Instantaneous acceleration is acceleration a precise instant $a = \lim_{t \to 0} \frac{\Delta V}{\Delta t}$
19) Deceleration **=** acceleration in direction opposite to Velocity vector.
20) Uniform acceleration: moving with constant acceleration
21) Kinematic variables: x_o, x_f, v_o, v_f, a,t where a = constant
22) 4 Kinematic equations : $v_f = v_o + a\,t$ $\quad v_{avg} = [\,v_f + V_o\,]/2$
    $X_f = X_o + v_o t + ½\, at^2$ $\quad v_f^2 = v_o^2 + 2a\,[X_f - X_o]$
23) Free fall: assume negligible air resistance: acceleration due to gravity **= "g" = -9.8 m/sec^2**
24) *Watch the +/- signs!*

25) **Remember:** g *always* points towards the center of the Earth.
26) Linear motion can be represented graphically as **x vs t** or **v vs t**
27) Time t is the independent variable [x axis], position or velocity is dependent variable [y axis].
28) Slope of position vs time graph = velocity
29) Slope of velocity vs time graph = acceleration
30) Area under curve in velocity vs time = total displacement
31) Review: Compare the way an acceleration vs time graph can provide information about the change in velocity and the way a velocity vs time graph can provide information about acceleration.

Chapter 3: 2-D kinematics

1) Major ideas in projectile motion:
   a. Vectors and vector addition
   b. Gravitational acceleration is only acting in the vertical direction
   c. The horizontal and vertical motions of a projectile are completely independent
   d. The velocity vector of a projectile is always tangent to the projectiles path [trajectory].
   e. Frame of reference is very important idea in solving advance projectile problems.
2) Length of vector proportional to magnitude
3) Vector variables represented by bold type or variable with arrow over italicized letter.
4) **Graphically adding vectors:** place vectors tip to tail and draw resultant vector from tip to tail.
5) Resultant vector is drawn from the tail of the first vector to the tip of the last vector .
6) Parallelogram method: place tails together and construct a parallelogram. Diagonal is the resultant vector.
7) Multiplication of a vector **V** by a scalar c : vector in same direction with magnitude c**V**.
8) Subtraction of vectors: reverse direction and add tip to tail [pink elephant]
9) **Adding by vector components:** using trig to resolve any vector into the sum of a vector in x-dir plus a vector in y-dir.
10) vectors can be added by summing the components.
11) Projectile motion: object falling with horizontal velocity traces parabolic path
12) Break velocity vectors into x and y components
13) Projectile motion: Constant **velocity** in **x** direction**,** constant **acceleration** , g, in **y** direction.
14) Components in projectile motion: $x_o, x_f, v_{ox}, v_{fx}, a_x, = 0, t$; $y_o, y_f, v_{oy}, v_{fy}, a_y, = -9.8 m/sec^2$, t
15) Time is the same in both dimensions.
16) Equations : $v_{fx} = v_{ox}$ $X_f = X_o + v_o t$ $v_{fy} = v_{oy} - gt$ $y_f = y_o + v_{oy} t - ½ gt^2$

$$v_{fy}^2 = v_{oy}^2 - 2g [y_f - y_o]$$

17) Parabolic motion: concave down [g is negative]
18) Relative motion: when motion of object observed from moving reference frame use vector addition to find relative velocity
19) Review: if 2-dimensional vectors can be expressed by their magnitude and a reference angle, think about an equivalent method of expressing 3-dimensional vectors and how that would affect vector summation.

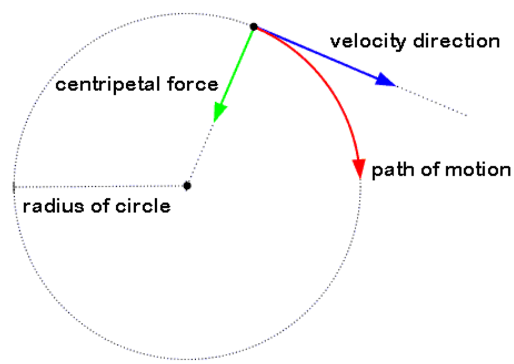
Chapter 4: Dynamics; motion and force

1) The major ideas that the AP physics exam will focus on are
    a. The nature of forces and the definition of a force
    b. The idea that mass as an inertial measurement
    c. The types of forces that exist in the physical world: gravitational, frictional, normal, tension, spring etc
    d. Free body diagrams
    e. The nature of friction and the coefficient of friction.
2) The AP exam problems will be
    a. Equilibrium and accelerated system problems [1^{st} and 2^{nd} laws]
    b. Multimass problems [3^{rd} law]
    c. Problems requiring rotation of the frame of reference [trigonometry and the inclined plane!!]
3) MKS = meter, kilogram second
4) Dynamics is the study of forces related to motion including changing rate of linear movement or maintaining uniform circular motion.
5) Newton's first law is the law of inertia
6) Force is a push or a pull; a vector
7) All forces are caused by 2 systems interacting with each other: a mass acting on a table and a table acting on a mass, etc.
8) You should be able to identify the object causing a force and the object receiving the force.
9) $\mathbf{F}_{12}$ or $\mathbf{F}_{1/2}$ means the force of object 1 acting on object 2.
10) Force can be measured by spring scale; a balance measures mass
11) Aristotle: "natural state" of body is to remain at rest.
12) Galileo: in absence of friction [external force] horizontal velocity is constant
13) Newton's first law: body at rest remains at rest, body traveling in straight line at constant velocity remains at same velocity unless acted upon by external unbalanced force [a net force].
14) Inertia = ability to resist changes in state of motion
15) Inertial reference frame: reference frame when 1^{st} law is valid.
16) Noninertial reference frame = when first law is not valid.
17) Body's inertia is quantity of mass, the ability to resist change in state of motion
18) Unit of mass = kilogram
19) Weight is the gravitational force of attraction between the Earth and a mass.
20) Weight does NOT equal mass. $W = mg$
21) Newton's 1^{st} law: $\Sigma F = 0$
22) Newton's 2^{nd} law: $\Sigma F = ma$
23) A nonzero force acting on an object will cause the object to accelerate in the direction of the applied force.
24) The unit of force is the newton. $1\ N = 1\ kg\ m/sec^2$
25) Newton's 3^{rd} law of motion: when one body exerts a force on another body, a force equal in magnitude but opposite in direction is applied on the first body by the second body.
26) Forces occur in pairs: action-reaction force pairs
27) Forces in Action-reaction force pairs act on different bodies.
28) The force by one body on anther is equal in magnitude but opposite in direction from the force of the first body by the second body.
29) Galileo stated all objects fall with the same acceleration.

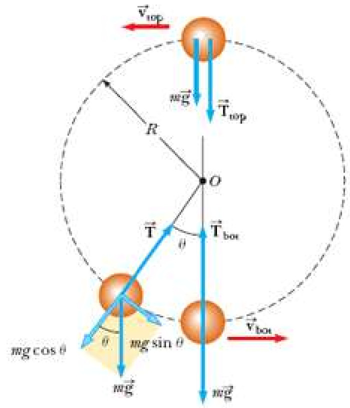
30) Solve Newton's law problems with a free-body diagram.
31) When **drawing free body** FBD
    a. Choose the "system" – the object or group of objects that are "internal"
    b. Indicate the coordinate system [direction of +/- x and y]
    c. The free body diagram represents an object's mass as a "point mass" that shows all EXTERNAL forces acting upon an object.
    d. Draw mass as a dot or a small box.
    e. Show all external forces acting on the system.
    f. Assume all mass concentrated at center of mass, and all forces pass through the center of mass
    g. If there are multiple masses interacting, draw a separate FBD for each mass.
32) Gravitational force: the force the Earth exerts on an object.
33) The magnitude of the gravitational force is the weight of the object.
34) Gravitational force is always directed down towards the center of the Earth.
35) An weight of object at rest on the surface of the Earth is opposed by the *perpendicular contact force* between the object and the Earth. This is the Normal force.
36) "Normal" means perpendicular.
37) Tension force is pulling force exerted by a string on an object. [strings cannot compress, only pull]
38) Tension force in a massless inextensible cord is uniform throughout.
39) Friction is *parallel contact force* that opposes sliding motion.
40) Friction force acts in opposite direction of motion.
41) Friction force is *proportional* to normal force.
42) $\mathbf{F_f = \mu F_n}$ where μ = coefficient of friction.
43) There are two types of friction: static and dynamic.
44) Static friction: when an object is about to start sliding. $\Sigma F = 0$
45) Kinetic friction: friction when an object is sliding. $\Sigma F = ma$.
46) Kinetic friction is < static friction. [easier to keep object moving than to start it moving]
47) So: $\mu_s > \mu_k$.
48) A spring force acts in opposition to the force acting on the spring.
49) $F_{spring} = -k\Delta x$
50) Applied forces: any external applied force, by a person or an object.
51) Review: Determine the forces involved for one block placed atop another block that is in turn placed on a surface, when any combination of these objects are in motion. Assume the two blocks and the surface are composed of the same material.

Chapter 5: Circular motion and Gravitation

1) UCM = UNIFORM circular motion
2) UCM means object moves in circular path at constant speed, v , but direction constantly changes.
3) An object moving in UCM is *accelerating.*
4) UCM = An object moving in a horizontal circle at constant speed [example merry go round].
5) UCM = an obect moving in a vertical circle at constant speed [example: ferris wheel] .
6) NONUNIFORM : moving in a horizontal OR vertical motion with a **varying** speed [example roller coaster].
7) Nonuniform circular motion: must use **energy** [chapter 6] to solve.
8) Centripetal acceleration = acceleration corresponding to changing velocity at a given point that is directed toward the center of a circle.
9) Velocity vector is always tangent to the circle; acceleration is directed toward center.
10) Radial acceleration = centripetal acceleration.
11) Centripetal means center seeking.
12) $a_{centrip} = a_c = a_{radial} = a_R = v^2/r$
13) $F_{centrip} = mv^2/r$

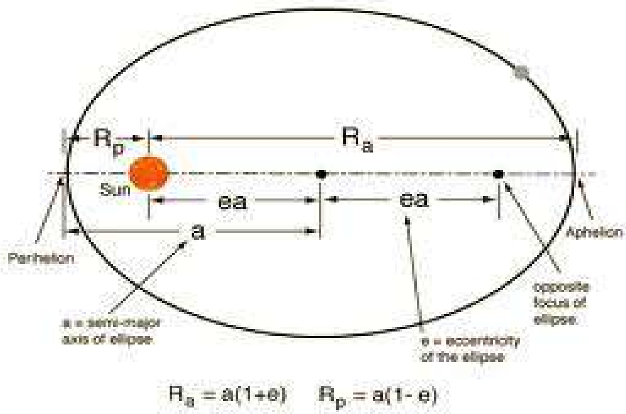


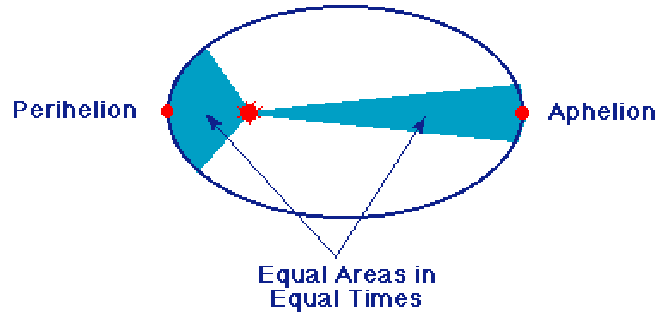
14) Velocity and acceleration of object in UCM are perpendicular .
15) Number of revolutions per second = frequency , f.
16) The time for 1 revolution = $T = 1/f$
17) Speed v =total distance traveled/time elapsed = $2\pi r/T$ where r = radius of rotation.
18) The force required to keep an object in uniform circular motion is directed inward towards the center.
19) If the force stops being applied, the object continues along a path in a straight line in the direction tangent to the circle.
20) Centripetal force:
    a. Object spinning on a horizontal circle on string: Tension is the centripetal force
    b. Car traveling along flat circular road: friction is the centripetal force.
    c. Satellites use gravity as centripetal force to remain in orbit.
21) Traveling in *horizontal* flat circle= UCM
22) Traveling in *vertical* circle: NON uniform circular motion.

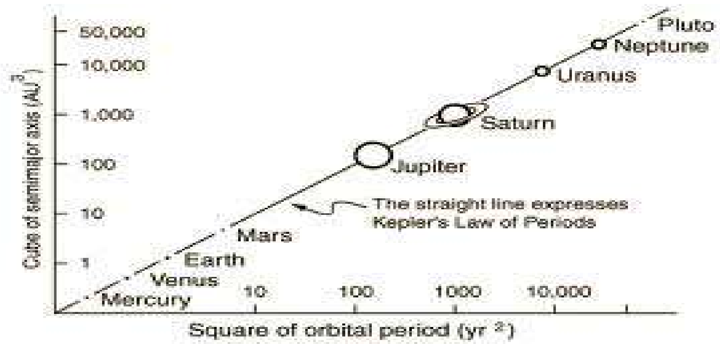


23) For nonuniform, net force is NOT directed towards center.
24) Velocity in nonuiniform can be broken into perpendicular components: radial force and tangential force. Acceleration can be broken into radial acceleration and tangential acceleration.
25) Change in speed in nonuniform circular motion due to tangential force and tangential acceleration.
26) When circular speed decreases, velocity is *antiparallel* [means parallel but in opposite direction] to the tangential acceleration.
27) Pythagorean theorem: acceleration a = $\sqrt{[a_R^2 + a_{tan}^2]}$
28) Universal gravitation: All objects that have mass exert gravitational attraction on each other at all distances.
29) Fgrav = Gm_1m_2/r^2 G = universal gravitational constant r = distance center to center.
30) G = $6.674X10^{-11}$ m^3 /kg-sec^2
31) Gravitational force of object on surface of Earth varies with distance from center of Earth.
32) Gravity is an *inverse square law*: it diminishes with $1/d^2$.
33) Satellites remain in orbit because of gravitational force. We approximate satellite orbit as a circular path
34) Apparent changes in the force of gravity are influenced by the frame of reference of the observer.
35) If the observer's reference frame is accelerating in the same direction as gravity, apparent weight will decrease [elevator accelerating down]
36) If the frame of reference is accelerating in the opposite direction as gravity force, apparent weight will increase [elevator accelerating up]
37) When a satellite orbits the Earth, apparent weight on the satellite is decreased due to the satellite's acceleration This is the phenomenon of weightlessness. Weightlessness is the feeling during free fall.
38) Kepler's laws were confirmed by Newton.

39) Kepler's 1st law: planetary paths are elliptical not circular . Sun is at one of focal points of an ellipse







40) Kepler's 2nd law: law of areas = an imaginary line from the Sun to a Planet sweeps out equal areas in equal periods of time.

41) Kepler's 3rd law: law of periods = ratio of cube of planet's mean distance from the Sun to the square of its orbital period is constant for all planets. $R_1^3/T_1^2 = R_2^3/T_2^2$

42) Kepler's 3rd law applies to any 2 objects circling a 3rd object [such the Moon and a GPS satellite circling the Earth]

43) Satellite orbits are not exactly elliptical, due to forces of the other planets or satellites. Deviation from the elliptical are called *perturbations*. [that is how existence of Neptune was predicted and detected]

44) Review: analyze the forces operating on a mass uniformly revolving in a circle whose plane is parallel to the force for gravity

Chapter 6 Work and Energy

1) Motion of an object can be evaluated in terms of its energy. This can prove advantageous because energies are scalar quanties rather than vector quantities and because energy is conserved in certain conditions.
2) Energy is independent of the path.
3) When work done by a constant force is applied to an object, the work done on it is equal to the product of the component of the force that is *parallel to the direction of displacement* times the magnitude of displacement.
4) $W = F \cdot d \cdot \cos\theta = F \Delta x \cos\theta$, where θ represents the angle of the force wrt the displacement vector.
5) Joule = unit of work. $1 J = 1 N \cdot m = 1 kg \cdot m^2/sec^2$
6) The perpendicular component of the force does no work.
7) Only the component of the force that is parallel to the direction of motion does work.
8) No work is done unless there is a component of the force // to the direction of displacement.
9) Examples of work done: dragging an object across a non-smooth horizontal floor; lifting an object .
10) Examples of **no** work: carrying a heavy object across a room; sliding an object without friction.
11) Friction opposes all motion, therefore friction does negative work on an object.
12) Friction can be thought of as work done BY the object rather than work done ON the object.
13) Work done by a varying force can be determined from a distance vs force graph.
14) Work done by a varying force is the area under the curve between the 2 points of displacement.
15) Kinetic energy is energy associated with motion.
16) KE results from an object(or system) having mass being in motion
17) KE refers to the energy associated with motion, an action which has a capacity to do work.
18) And object's translational KE $= ½ mv^2$
19) Work energy principle: work done by all forces on an object equivalent to change in object's KE.
20) Work energy principle: $W_{net} = \Delta KE = ½ (mv_f^2) - ½(mv_i^2)$
21) The increase or decrease in a body's KE depends on the sign of work done on that body.
22) Potential Energy , U, describes forces on a body that are a function of position.
23) Gravitational potential energy $GPE = U_g = mgy$. GPE is proportional to height.
24) An objects change in GPE can be calculated as function of its vertical distance between 2 points in space.
25) A stretched or compressed spring has elastic potential energy , $EPE = U_{spring}$.
26) $EPE = ½ kx^2$ where k is the spring constant and x is the displacement.
27) A stretched or compressed spring can do work when the dislocating force is removed.
28) Hooke's law: $F_{spring} = kx$
29) The total mechanical energy of a system = $TE = KE + U_g + U_{spring}$.
30) Some problems consider all three forms: example an oscillating spring on an incline.
31) Conservative forces are forces for which the work done is independent of the path taken.
32) Conservative forces return to the system all the energy gained from an otside source.
33) Three conservative forces are gravitational, spring, and electrostatic.
34) $Work_{conservativeforce} = - \Delta U_{conservativeforce}$
35) The **negative sign** means when the conservative force is doing negative work on the system, the system is gaining potential energy.
36) Conversely, when conservative forces do positive work on the systems , the system LOSES potential energy.
37) An example : during free fall of an object, the work done by the gravitational force is positive and the potential energy of the object decreases.
38) Nonconservative forces are dissipative forces.

39) Examples of dissipative forces are friction and air resistance.
40) Nonconservative forces [such as friction] depend on the path.
41) Work energy theorem for nonconservative forces: the work done by the system equals the change in energy of the system.
42) Work energy theorem : $Work_{system} = \Delta Energy_{system} = W_{NC} = \Delta KE + \Delta PE$
43) Work can be positive or negative
44) When using work-energy theorem, need only information about initial and final states.
45) Mechanical energy = ME = KE + PE
46) Total mechanical energy of a system is conserved when only conservative forces are acting on it.
47) Conservation of Mechanical energy: $KE_1 + PE_1 = KE_2 + PE_2$
48) Total mechanical energy of a system is constant in the absence of nonconservative forces.
49) The types of conservation of energy on the AP exam usually are
    a. The pendulum
    b. The projectile or object sliding without friction on a pathway due to gravity
    c. A perfectly linear elastic spring and mass
50) Apply conservation of energy when only a conservative force is doing work on a system.
51) There may be other forces acting in the system that are NOT doing work.
52) Example: two forces act on a pendulum: tension and weight. Tension does zero work because it is perpendicular to the displacement of the pendulum.
53) In general, centripetal forces do not do work on a system. They NEVER change the energy of the system, they only change tie direction of the velocity.
54) When gravity is only force acting: $KE_1 + PE_1 = KE_2 + PE_2$ becomes $½ mv_1^2 + mgh_1 = ½ mv_2^2 + mgh_2$
55) When the only force comes from a massless spring: $KE_1 + PE_1 = KE_2 + PE_2$ becomes $½ mv_1^2 + ½kx_1^2 = ½ mv_2^2 + ½ kx_2^2$
56) All forcms of energy , including chemical , nuclear, electrical, and thermal are essentially KE or PE at a microscopic or atomic level.
57) All forms of energy can be converted to others. This conversion may involve the energy transfer between bodies.
58) The total energy remains constant during the transfer or transformation of energy involving both conservative and nonconservative forces. This is a statement of conservation of energy
59) Some mechanical energy can be transformed into thermal energy during force-related processes
60) Nonconservative forces such as friction that cause this are called dissipative forces.
61) Whn gravity and friction are present in a process, the mechanical energy equation must be amended to account for this: : $KE_1 + PE_1 = KE_2 + PE_2 = ½ mv_1^2 + mgh_1 = ½ mv_2^2 + mgh_2 + F_{friction} \cdot d$
62) Power is the rate at which work is done or energy is transformed. Power = work done/time interval
63) Power is ther rate of energy change or energy consumption.

64) $P_{avg} = \Delta Energy/\Delta Time = Work/\Delta Time = Force \cdot velocity_{avg}$

65) Use power = force ●velocity when an objecte is being lifted in equilibrium.
66) Watt is the unit of energy. 1Watt = 1 W = 1 Joule /sec
67) Review: analyze how the conservation of mechanical energy would be applied to situations in which gravitational force and the elastic force of a spring are present.

Chapter 7: Linear Momentum and Impulse

1) The law of conservation of momentum is a restatement of Newton's 1st and 2nd laws.
2) Collisions between objects can be evaluated using laws of conservation of energy and conservation of linear momentum.
3) We often regard the colliding objects as particles.
4) An object's linear momentum for a particular instant is given by the product of its mass and its velocity vector at that instant.
5) Momentum is a vector. Symbol of momentum **= p = mV**
6) For an object's momentum to change, force is required such that the net formce on an object is equal to the ratio of its change in momentum in that time interval. $\Sigma F = \Delta p/\Delta t$
7) Conservation of momentum: $F\Delta t = 0 = \Delta p$
8) A collision involves internal forces in the system, and internal forces do do not count as outside forces.
9) Conservation of momentum in collisions: total momentum before a collision equals the total momentum after the collision.
10) $m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$ where v1 is the initial velocity of m_1 and v_3 = final velocity of m_1 and v_2 and v_4 are the initial and final velocities of m_2.
11) Watch the signs for the directions of the velocities!
12) Isolated system = If there are no external forces acting on a system
13) In collisions the force changes considerably over the course of the interaction.
14) Another way to think of momentum is the amount of inertial needed to stop a moving object.
15) To stop an object that has momentum, an impulse will have to act on the object to change its state of motion.
16) Impulse = product of the force and a time interval, which is equal to the change in momentum
17) Impulse $I = F\Delta t = \Delta p$
18) $F \Delta t = \Delta p$ s o $F = \Delta p/\Delta t = \Delta\{mv\}/\Delta t = m[\Delta v /\Delta t] = ma$
19) In elastic collisions, net kinetic energy is conserved. Elastic collisions occur on an atomic scale.
20) We idealize elastic collisions for ordinary objects
21) In elastic collisions, objects are hard enough so that no thermal energy is produced from permanent structural deformation.
22) At the instant of collsion, all energy is elastic potential energy .
23) For an elastic collision: $\frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2 = \frac{1}{2} m_1v_3^2 + \frac{1}{2} m_2v_4^2$
24) Using conservation of energy and conservation of momentum , calculate the magnitude of the relative speed two objects is the same before a head on collisions as it is after the collision:
25) **Magnitude of relative speed:** $\mathbf{v}_1 - v_2 = -(v_3 - v_4)$
26) COR = coefficient of restitution: a measure of bounciness of a collision.
27) COR ranges from 0 [perfectly inelastic] to 1 [completely elastic]
28) COR =(v4 – v3) /(V1 – V2)
29) If COR = 1, we get equation for magnitude of relative speed.
30) In an inelastic collision, some KE is lost during the interaction.
31) For inelastic collisions, $KE_{1i} + KE_{2i} = KE_{1f} + KE_{2f}$ + thermal energy and other non KE.
32) Perfectly inelastic = When objects stick together after a collision
33) Perfectly inelastic: $m_1v_1 + m_2v_2 = [m_1+m_2]\ v_3$
34) Conservation of momentum should not be confused with conservation of energy.'

a. Conservation of momentum is only applicable in the absence of outside forces. This is a rate occurrence in the real world.
b. Usually momentum problems involve frictionless objects.
c. Energy conservation, on the other hand, can occur with outside forces [such as springs or gravit.]
d. Be sure to apply the conservation laws correctly.

35) Conservation of momentum can be applied to 2 dimensions: $p_{1xi} + p_{2xi} = p_{1xf} + p_{2xf}$ and $p_{1yi} + p_{2yi} = p_{1yf} + p_{2yf}$

36) Review: without using the relative speed relation for elastic collisions, solve and elastic collision question involving conservation of linear momentum and kinetic energy using the quadratic formula

Chapter 8 rotational motion

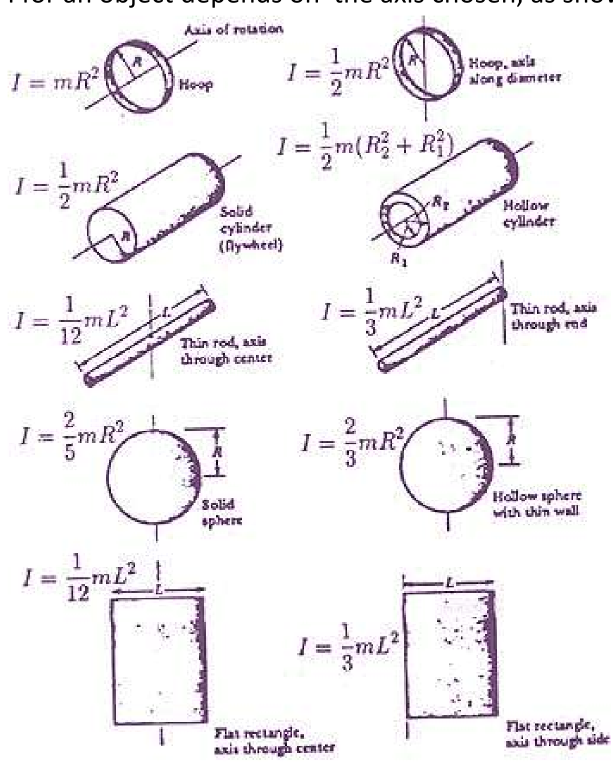
Chapter 9 bodies in equilibrium: elasticity and fracture

1) The rotational motion of an ideal rigid body , an object of fixed shape, describes the movement of each of its particles in a circle around a line called the axis of rotation.
2) For any point on an object experiencing rotational motion, its distance fom the axis of rotation is the radius r, of the circle traveled by that point.
3) The distance of rotation is given by the angle θ created by the movement wrt a reference line.
4) The arc traversed by the particle when it moves that angle is a measure of distance L.
5) The angle θ is measured in radians, relating the arc length and radius: $\theta = L/r$.
6) There are 2π radians in a circle, so 1 radian = $360^o/2p = 57.3^o$
7) Angular displacement refers to the angular change due to rotation, so average angular displacement is defined as $\omega = \Delta\theta/\Delta t$.
8) Average angular acceleration is defined as $\alpha = \Delta\omega/\Delta t$
9) Instantaneous angular acceleration is defined $\alpha = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t}$
10) The units for anglular acceleration are radians/sec^2
11) Angular acceleration is uniform for each point on the object.
12) Linear velocity at a point r away from the center is related to angular velocity such that $v = \omega r$
13) Linear velocity is NOT constant for each point on an object.
14) The linear velocity is in the direction of motion, tangent to the radius at that point.
15) Tangential acceleration is given by $a_{tan} = r\alpha$
16) Radial acceleration = $a_R = \omega^2 r$
17) Radial acceleration is proportional to the distance from the center.
18) Since $V = \omega r$, $\omega = V/r$ and $\omega^2 = V^2/r^2$
19) Substituting: $\omega^2 r = r\ V^2/r^2 = V^2/r$
20) The number of revolutions per second =frequency f
21) Frequency $f = \omega/2\pi$
22) Unit of frequency = hertz = cycles/sec or sec^{-1}
23) Time for 1 revolution $T = 1/f$
24) Unit of time T = seconds
25) Comparing kinematic equations for uniformly accelerated rotational motion and linear motion:

$\omega_f = \omega_o + \alpha t$	$v_f = v_o + at$
$\theta = w_o t + ½ \alpha t^2$	$x = x_o t + ½ a t^2$
$\omega_f^2 = \omega_o^2 + 2\alpha\theta$	$v_f^2 = v_o^2 + 2a[x_f - x_o]$
$\omega_{avg} = [\omega_f + w_o]/2$	$vavg = [v_o + v_f]/2$

26) Rolling motion of an object depends on friction between the object and a surface, so that the object does not slip.
27) The rolling object has an interrelated motions of translation corresponding to linear speed v of the center of rotation, and the rotation corresponding to the angular velocity at the radius of a rotating circular or spherical object such that $v = \omega r$
28) As shown, the forces involved in rotational motion are also analogous to those in linear kinematics.

29) The perpendicular component of a force $F_{\perp r}$ applied to an object at a distance from the axis of rotation causes the rotational motion to change.
30) Lever arm =r = distance from the axis of rotation
31) Perpendicular component of the force applied to the lever arm is proportional to the angular acceleration it produces.
32) Torque τ is the product of the lever arm times the perpendicular component of the force.
33) $\tau = F_{\perp} \cdot r = F \cdot r_{\perp}$
34) The most efficient direction of force is perpendicular to a radius from the axis of rotation
35) The least efficient direction of force is parallel to a radius from the radius of rotation.
36) Torque is additive when force is applied in the same angular direction and is subtracted when force is applied in the opposite angular direction.
37) Counterclockwise torques , ccw torques , are positive, by convention.
38) Clockwise torques are negative quantities
39) Use the right hand rule to determine if a torque is positive or negative.
40) The sum of torques , where each sign corresponds to a reference direction, is proportional to thet angular acceleration
41) For a mass m, rotating a distance r, $\Sigma\tau = mr^2\alpha$
42) Moment of inertia = mr^2
43) Moment of inertia is the sum of the products of the mass of all particles in an object and the square of the distances r at which they are rotating.
44) Generally, $\Sigma\tau = I\alpha$
45) With I representing the moment of inertia of a fixed rotating object which depends on the size, shape and density of an object wrt the axis of rotation.
46) I for an object depends on the axis chosen, as shown below



47) Moment of inertia is proportional to the square of the distance of the concentrated mass from the axis of rotation.
48) We will use formulas for moment of inertia, NOT calculate it.
49) Kinetic energy of a rotating body is proportional to the moment of inertia ,I, and the square of the angular velocity ω,
50) Rotational kinetic energy = KE = $\frac{1}{2} I\omega^2$
51) The symbol cm means "center of mass" In linear motion we assume forces act through the center of mass
52) Total KE of an object that is translating and rotating is Total KE = $\frac{1}{2} mv_{cm}^2 + \frac{1}{2} I_{cm}\omega^2$
Where m is the mass of the object,V_{cm} is the linear velocity of the objects center of mass,
53) Rotational KE is measured in joules.
54) NOTE: friction for rolling is static (no slipping,) and parallel to the surface. So friction does not figure into the energy equation.
55) Work performed by torque through an angle θ is given by Work W = $\tau\Delta\theta$
56) angular momentum for a fixed body rotating around an axis is product of moment of inertia X angular velocity
57) Angular momentum = $I\omega$
58) Units of angular momentum = kg m^2/sec
59) The rotational analog for Newton's 2^{nd} law $\Sigma F = ma$ is $\Sigma\tau = I\alpha = \Delta L/\Delta\tau$
60) This relates torque to the rate of change of angular momentum
61) iff means "if and only if"
62) Angular momentum is conserved **iff** there is no net torque acting on a body.
63) Therefore, on a frictionless surface, angular velocity of a rotating object is inversely proportional to the moment of inertia.
64) Use right hand rule to determine positive direction of the vector quantities: angular velocity, angular acceleration and angular momentum.

65) The direction will be perpendicular to the plane of motion.
66) Equilibrium: $\Sigma F = 0$ AND $\Sigma\tau = 0$
67) A body at rest has net zero force acting on it. If net force = 0, torque = 0.
68) Review: derive the kinematic equations for constant angular acceleration from their corresponding linear analogs for a specific rotating body.

Chapter 10 Fluids

1) Most ordinary matter is arranged as solids , liquids or gases
2) Solids have constant shape and volume
3) Liquids have constant volume and take shape of container.
4) Gases assume shape and volume of container.
5) Liquids and gases are fluids = matter that flows.
6) Density = mass/volume = ρ "rho"
7) Units of density = kg/m^3
8) Specific gravity = density ofliquid/density of water.
9) Specific gravity is a dimensionless number
10) Pressure = P = force/area $P = F/A$
11) Units of force = N/m^2 = pascals 1 Pa= 1 N/m^2
12) For a liquid with uniform density, pressure is proportional to depth where measured
13) Pascal's principle: $P = \rho gh$
14) Pressure is uniform everywhere along a plane at a depth h
15) Pressure is independent of the cross-section of a container.
16) Units of pressure: atmospheres, bars and pascals.
17) 1 atm = $1.013X10^5$ N/m^2 = pressure at sea level.
18) 1 bar = $1.00X10^5$ N/m^2
19) Gauge pressure represents pressure above atmospheric. Absolute pressure = gauge pressure + atmospheric pressure or $P = P_{atm} + P_{gauge}$
20) Pascals principle: internal pressure of a confined fluid increases uniformly by the amount of pressure applied to it.
21) Hydraulic lifts use Pascal's principle: initially the pressure applied to an output piston = pressure applied to an input piston that are initially at the same height. The ratio of force on the output piston to the force on the input piston is equal to the ratio of the area of the output piston to the area of the input piston or $F_{out}/F_{in} = A_{out}/A_{in}$ = mechanical advantage of a hydraulic lift.
22) Manometer = horseshoe shaped tube with fluid of uniform density
23) Change in height of a column open to a known atmospheric pressure can be used to measure pressure of a system at the other end. $P = Po + \rho gh$
24) If the fluid is mercury, pressure is referred to as height of a mercury in the column or mm of Hg

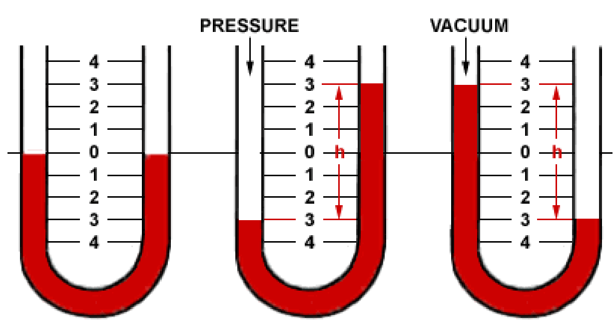


Fig. 2-1 Fig. 2-2 Fig. 2-3

25) Torr is another name for mm of Hg.
26) Barometer is a modified manometer with one closed end. Pressure at the closed end is zero. Atmospheric pressure is measured at the open end.
27) 76 cm Hg or 760 torr is standard atmospheric pressure

28) the pressure on the underside of a object immersed in a fluid increases with depth.
29) Archimedes principle: an upward buoyant force , F_B, on a submerged object is equal to the weight of the fluid it displaces.
30) $F_B = \rho_F gV$ where V is the volume of the fluid, g = 9.8 m/sec2 , ρ = density of fluid
31) An object will float in a fluid of lower density
32) The ratio of the volume of the object that is submerged to the volume of the entire object is equal to the ratio of the objects density to the density of the fluid $V_{sub}/V_{obj} = \rho_{obj} / \rho_F$
33) Density of ice = 910 kg/m3 density of water = 1000 kg/m3 the submerged volume = 0.91 ice floats
34) There are 2 types of fluid flow: streamline and turbulent
35) Streamline flow: laminar flow = adjacent layers of fluid slide over each other
36) Laminar flow of an incompressible fluid In a tube depends on cross sectional area $A_1V_1 = A_2V_2$ as area is reduced, velocity increases so that flow is continuous.
37) Equation of continuity: $A_1V_1 = A_2V_2$ is a statement of conservation of mass.
38) In turbulent flow, interaction of the layers creates small eddie currents [circular currents] . eddies absorb energy.
39) Viscosity is the internal friction of a fluid that is present in both types of flow.
40) Viscosity is the resistance to flow.
41) Bernoulli's principle states velocity and pressure arfe inversely proportional for fluids: the higher the fluid's velocity the lower its pressure.
42) Bernoulli equation is applied to incompressible fluids. It is a statement of conservation of energy
43) Bernoiuli $P + 1/2\ rv_1^2 = rgy_1 = P_2 + ½(\rho v_2^2) + \rho gy_2$ where y1 an dy2 are heights of centerline [cl] of pipe.
44) Review: follow the derivation of Bernoulli's equation from the work-energy principle, and consider how it serves to model the conservation of energy.

Chapter 11 Vibrations and waves

Chapter 12 Sound

1) http://www.youtube.com/watch?v=3mclp9QmCGs
2) Vibrations produce waves that travel through a medium, functioning as both a source and detector of waves.
3) Waves occur on both microscopic and macroscopic scales
4) Cicyld vibrations or oscillations are periodic.
5) An object connected to a spring, displaced and released produces cyclic motion.
6) Horizontal spring mass on a surface: assume no friction and a massless spring.
7) The natural length of the spring is the length when the force on the object = o.
8) Equilibrium position: when object is attached to a spring that is at natural length.
9) When object is moved, the lengthof the spring is changed.
10) Force of spring on object = F = -kx. Where: k = spring constant for that spring and x is distance from the equilibrium position. The negative sign shows it is a "restoring force".
11) Hooke's law F = -kx is valid for all displacements unless the spring is permanently deformed [example: overstretched.]
12) F = -kx means force is proportional to displacement. The spring force acts in opposite direction of displacement.
13) When the mass is displaced, the force pushes the object back towards equilibrium position, but the spring overshoots and the mass is displaced on the other side of equilibrium the same distance.
14) Amplitude = A = The initial displacement.
15) When the spring is released, the object oscillates back and forth between –A and A.
16) Each complete oscillation[from -A to A and back to –A] is called a cycle.
17) The time for one cycle is the time period T
18) The frequency , f, is the number of cycles per second.
19) T = 1/f and f = 1/T
20) Units of frequency : hertz or cycles/sec or sec^{-1}
21) Units of period = seconds
22) The equilibrium position is different for the same spring-mass if it is hung vertically because the equilibrium position would be due to stretching by gravity.
23) Subsequent displacements from equilibrium causes a vertical mass-spring to oscillate also.
24) Simple harmonic motion = SHM = motion of simple harmonic oscillators obeying F = -kx.
25) A spring that is not in equilibrium position stores energy : PE = ½ kx^2
26) Total energy of a spring not in equilibrium position = KE + PE = ½ mv^2 + ½ kx^2
27) Ideally, the total mechanical energy of the spring is conserved.
28) SHM: The spring is displaced distance A, and the velocity = 0
    a. At time = 0, velocity = 0, and x = A
    b. KE + PE = ½ mv^2 + ½ kx^2 = ½ mv^2 + ½ kA^2 = ½ kA^2
    c. The spring is released, and the velocity increases and x decreases.
    d. KE + PE = ½ mv^2 + ½ kx^2 = ½ mv^2 + ½ kA^2 = ½ mv_{max}^2
    e. Remember Energy is conserved so total energy at x= A = total energy at x = 0: so ½ mv_{max}^2 = ½ kA^2
    f. Solve for v_{max}: mv_{max}^2 = kA^2 Vmax = √(kA^2/m)
    g. At the equilibrium position, velocity is maximum, x = 0. [All KE]
    h. Past equilibrium position, spring begins to slow down.
    i. Spring continues motion to x = -A and velocity = 0 [all PE]

j. The spring velocity reverses direction and the spring accelerates towards the equilibrium position etc.

k. Equation of motion at any point : $½ mv^2 + ½ kx^2 = ½ kA^2 = ½ mv_{max}^2$

l. Solve for any v : $mv^2 + kx^2 = kA^2 = mv_{max}^2$ becomes: $V = V_{max}\sqrt{(1- X^2/A^2)}$

29) The period of a spring mass during SHM is INDEPENDENT of the initial displacement:

30) Projecting circular motionto one dimension along the plane of the circular pathway provides a precise alanog to evaluate SHM. This enables velocity in terms of amplitude A and frequency f : $v = 2 \pi A f$

31) So Frequency of spring mass $f = v/2\pi A$

32) $T = 1/f = 2\pi A/v = 2\pi\sqrt{(m/k)}$

33) Similar analysis provides SHM position as a function of amplitude and frequency $x = A\cos 2\pi t/T$

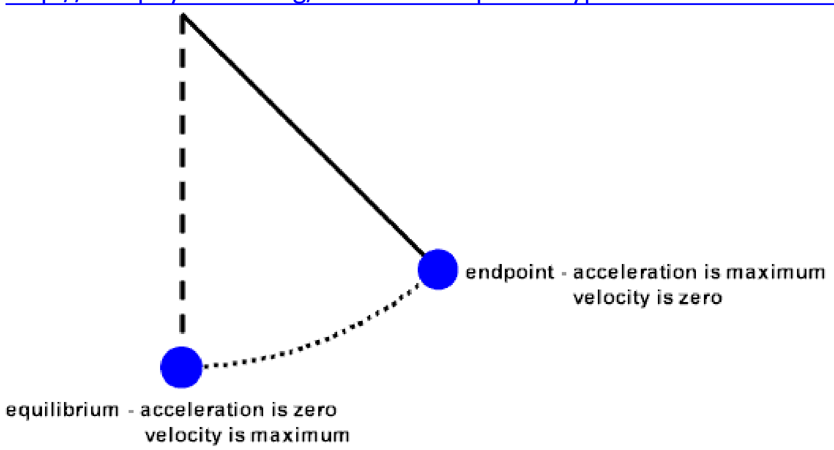
34) SHM is sinusoidal function. [sine or cosine curve]

35) Displacement: $x = A\cos 2\pi t/T = A\cos 2\pi ft$

36) Velocity = $\Delta X/\Delta t = -V_{max} \sin \sin 2\pi t/T$ $v_{max} = kA^2/m$

37) Acceleration = $\Delta v/\Delta t = - a_{max} \cos(2\pi t/T)$ where $a_{max} = kA/m$

38) SHM is also modeled by a simple pendulum, a mass swinging on a taut string.
http://dev.physicslab.org/Document.aspx?doctype=3&filename=OscillatoryMotion_PendulumSHM.xml



39) http://www.sakshieducation.com/EAMCET/QR/Physics/Jr%20Phy/10Simple%20Harmonic%20Motion_163-182_.pdf

40) Ideal simple pendulum: Must ignore friction and air resistance for simple pendulum

41) the pendulum is displaced through a small angle θ , a small height above equilibrium

a. Maximum displacement , v = o

b. Restoring force approximately proportional to angular displacement, and in opposite direction.

c. $F = - mg\sin\theta$

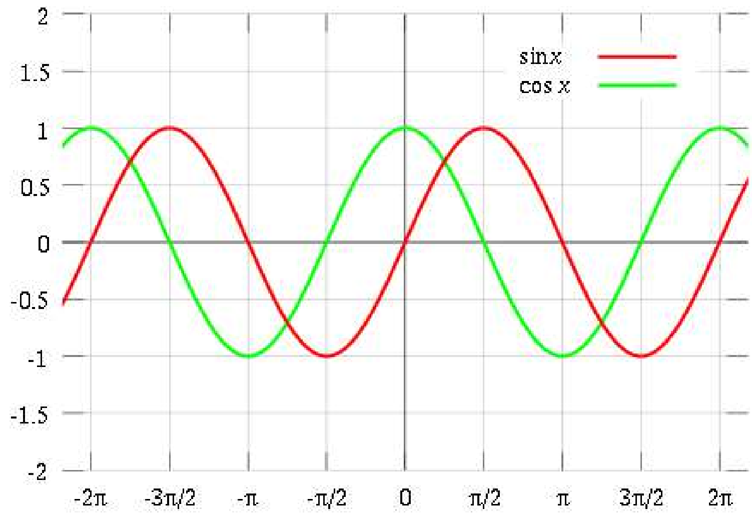
d. Pendulum released, velocity increases to equilibrium point

e. Pendulum begins to slow and stops momentarily at same height

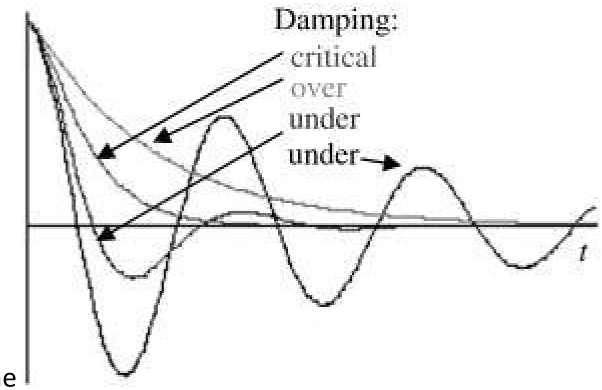
f. Increases speed, passes through lowest point,

g. Slows and stops momentarily at starting point. 1 complete cycle

h. Period of pendulum $T = 2\pi\sqrt{(L/g)}$

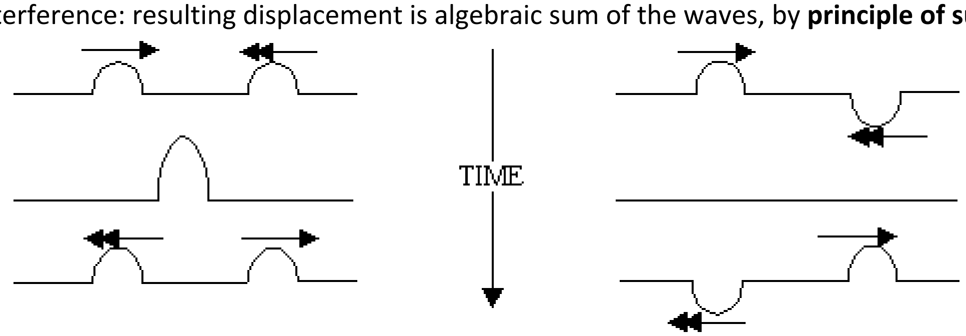


42) Real systems exhibit damped harmonic motion due to air resistance and friction
43) http://www.oberlin.edu/physics/catalog/demonstrations/waves/damping.html



44) With damping, Amplitude decreases over time
45) Overdamped: system returns to equilibrium without oscillating
46) Underdamped: system oscillates, gradually stops
47) Critical damping: system comes to rest in shortest time without oscillating
48) Forced vibration: produced by a vibrating system that interacts with external force.
49) System adopts frequency of external force rather than natural frequency of system.
50) Resulting amplitude si function of natural frequency and frequency of forced vibrations.
51) Resuling amplitude is maximized when these frequencies are equal.
52) Resonance: natural frequency same as forced vibration
53) And the bridge falls down.
54) Mechanical waves require a medium.
55) Transverse Mechanical waves : particles of medium travel perpendicular to wave, and oscillate above and below equilibrium points
56) A wave is an oscillating motion traveling through a medium and transporting energy across a distance
57) A pulse = any disturbance imparted to as string that can create a vibration that produces a mechanical wave
58) Each adjacent particle moves up and down carrying the wave alongs the string's length
59) A continuous oscillating disturbance creates a continuous or periodic wave
60) In a perfectly elastic medium, a simple harmonic vibration creates a sinusoidal path along the string's length, and every particle has sinusoidal motion as a function of time.

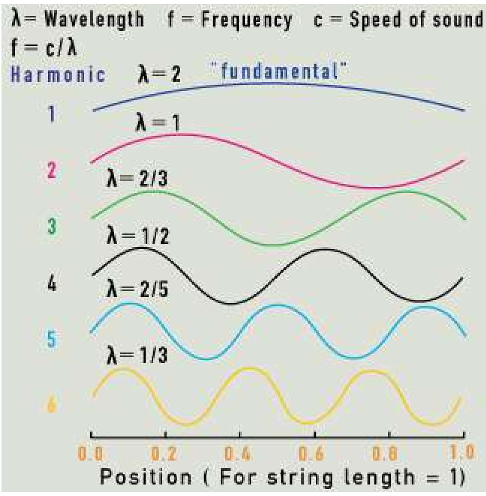
61) A particle's maximum displacement from equilibrium is the wave's amplitude, and the distance between 2 consecutive matching points on the wave is referred to as the wavelength , λ,
62) The frequency, f is the number of cycles per second
63) Frequency = 1/period or $f = 1/T$
64) The wavel velocity , v, is the velocity at which any part of the wavelength travels perpendicular to the motion of the individual particles. Velocity $v = \lambda f$
65) The wave velocity for a string is a function of the string tension F_T , string mass m and string length L
66) $v = \sqrt{[F_T/(m/L)]}$
67) In a transverse wave the particles of the medium move perpendicular to the wave velocity
68) In a longitudinal wave, the particles of the medium move parallel to the wave velocity
69) Imparting a pulse in a spring in the direction parallel to its length can create longitudinal waves as compressions and expansions (rarefactions) travel its length.
70) Sound is a longitudinal wave that travels through air or some other medium.
71) For a uniform medium, the energy in waves travels as a serie3s of increasigly larger concentric spheres
72) The energy carried by waves is quantized by intensity.
73) Intensity = energy pre second per unit area perpendicular to direction of energy flow.
74) I = power/surface area = $P/(4\pi R^2)$
75) Both energy and intensity are proportional to the square of the waves's amplitude.
76) The ratio of the intensities at two distances from the source of a spherical wave is given by : $I_2/I_1 = r_1^2/r_2^2$
77) The corresponding relation in terms of amplitude is given by $A_2/A_1 = R_1/R_2$
78) For an idealized one-dimensional wae, intensity and amplitude do not decrease with distance
79) Some or all of a wave is reflected when it strikes a barrier
80) http://www.acs.psu.edu/drussell/Demos/reflect/reflect.html
81) A transverse pulse on a string that reaches a fixed end wil reflect and reverse.
82) A transverse pulse in a string that reaches a free end will reflect.
83) When a string's pulse reaches a heavier section of string , some of the pulse will be reflected as if hitting a fixed end, and some of the pulse will transmit, with smaller amplitude.
84) For a multidimensional wve, the is a linear creast called a wave front
85) Wave fronts are perpendicular to rays, lines denoting a plane wave's direction of motion from a given point.
86) When a wave front strikes a barrier at any angle, the angle of incidence is described as the angle between the incident rat and a line perpendicular to the barrier.
87) Angle of incidence = angle of reflection.
88) Interference describes the interaction of waves.
89) Interference: resulting displacement is algebraic sum of the waves, by **principle of superposition**.



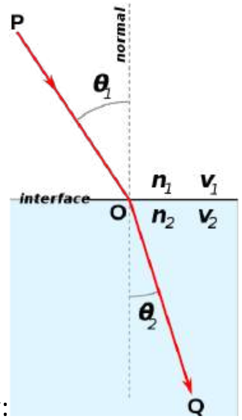
Constructive interference destructive interference

a. **Constructive** :Two interacting pulses of equal amplitude on the same side of a string experience constructive interference, and their joint amplitude at the moment of interaction is doubled.
b. **Destructive:** Two interacting pulses of equal amplitude on opposite sides of a string experience destructive interference , and their joint amplitude at the moment of interaction is zero.
c. For the interaction of continuously oscillating waves, interference may occur at several locations.
d. When all interference is constructive, the waves are said to be in phase.
e. When waves are out of phase, interference is partially or completely destructive.

90) Standing wave: when two ends of a cord are fixed, certain vibrations can produce a wave that appears not to move.



91) The nodes of a standing wave in a cord are locations wehre it appears motionless as the consequence of destructive interference [zero amplitude]
92) Antinodes of a standing wave in a cord are locations of maximum amplitude due to constructive interference
93) Fundamental frequency: a standing wave with a single antinode and nodes at each end
94) The fundamental of a string L is 1/2 of a wave with wavelength λ = 2L.
95) Integer multiples of the fundamental frequency , called natural or resonant frequencies, also produce standing waves.
96) The wavelengths for resonant frequencies are a function of the string length, L. $L = n\lambda_n/2$ for n = 1,2,3….x
97) The fundamental frequency, f_1, is called the first harmonic.
98) All subsequent harmonics are given a prefix indicated by the applicable value of n where $f_n = nf_1$.
99) Overtones is another name for the higher harmonics.
100) Use n-1 to name the overtones: 5^{th} harmonic = 4^{th} overtone, etc.
101) The energy of a standing wave is zero at the nodes, therefore energy is not transmitted down a string's length.
102) Refraction: the changing of a wave's direction as it enters a different medium.
103) Diffraction: the bending of a wave front after it meets an obstruction.
104) Refraction is a function of incident angle and the wave velocity in each medium.



105) Law of refraction = Snell's Law: $$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

106) The index of refraction for each medium is n1, n2 describes how light or other radiation propagates through a medium.

107) The approximate angle of diffraction is a function of the wavelength of the wave front, λ , and the width of the obstruction, L, such that θ [measured in radians] is $\theta \approx \lambda/L$.

108) Longitudinal waves created by a vibration are received by the human ear and perceived by the human brain as sound.

109) Longitudinal waves require a medium to propagate. [transverse waves do not]

110) Speed of sound waves depends upon the medium, and the temperature and pressure of the medium

111) Speed of sound in air is 331 m/sec at 0oC and 1 atm.

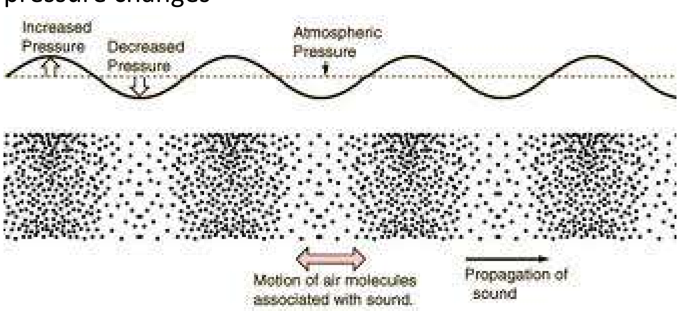
112) Speed of sound is faster in liquids than gases , and fastest in solids.

113) Pitch refers to the frequency of sound.

114) Audible range is 20 Hz to 20,000 Hz.

115) Frequencies below audible range are infrasonic; frequencies above audible range are ultrasonic.

116) Longitudinal waves can be viewed as pressure waves since expansions and contractions produce pressure changes



117) Intensity is the perceived loudness of a sound. Intensity , B , is a logarithmic function.

118) $\beta = 10 \log(I/Io)$ where Io is a reference level: Io = 1X10-12 W/m2

119) The unit of sound intensity β is the decibel

120) The quality of a sound is known as the timbre or tone color in music. Quality refers to audible distinctiveness, and depends on the overtones that accompany a fundamental frequency.

121) A large number of frequencies and overtones can render individual pitches indistinguishable, and would be perceived as noise.

122) The human ear uses vibrations to transform sound waves to electrical impuses through a multistep process.

a. sound waves travel througut the ear canal and vibrate the eardrum and the adjacent bones of the middle ear.

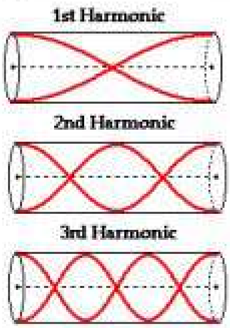
b. These structures vibrate the oval window of the inner ear and carry the vibrations to the liquid filled cochlea.

c. In the cochlea, vibrations are converted into electrical impulses to be interprede by the human nervous system.

123) Vibrating strings function as standing waves whose pitch corresponds to the fundamental frequency given by $f = v/2L$.

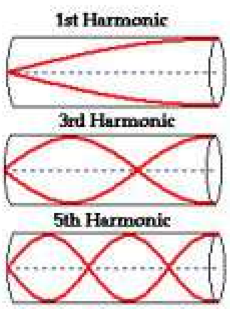
124) This equation is the same for standing waves in open pipes. Strings or Open pipes $f1 = v/2L$.

125) For closed pipes, the closed end is an antinode, so the fundamental is $f_1 = v/4L$.



Open at Both Ends	Harmonic	Wavelength λ	Frequency f
	1^{st}	$2L$	f_1
	2^{nd}	L	$2f_1$
	3^{rd}	$2L/3$	$3f_1$

Odd and Even Harmonics



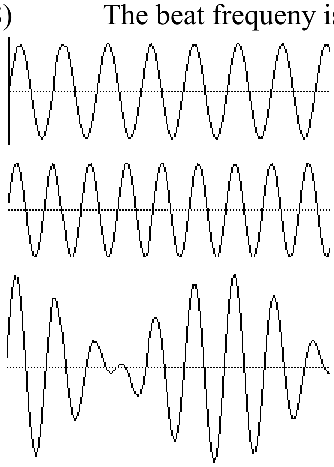
Closed at One End	Harmonic	Wavelength λ	Frequency f
	1^{st}	$4L$	f_1
	3^{rd}	$4L/3$	$3f_1$
	5^{th}	$4L/5$	$5f_1$

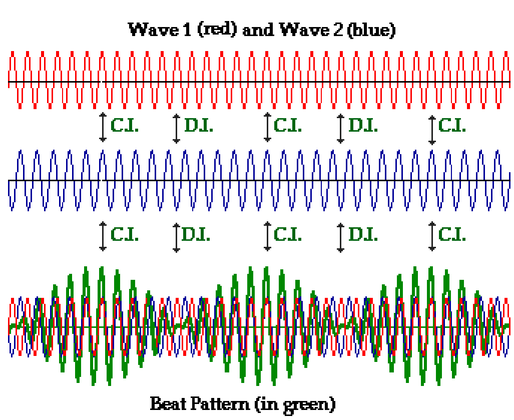
Odd Harmonics

126) The expansions and contractions of sound waves from different sources interfere with each other in a manner such that if two sources emit the same frequency in phase, constructive interference will occur when their compressions and expansions align. Otherwise, destructive interference will occur in varying degrees dependent upon the misalignment of wavelength.

127) Interference of two sources of similar frequency produce audible recurring intensity changes called beats.

128) The beat frequeny is given by the frequency difference of the two waves.





129) http://www.fearofphysics.com/Sound/dopwhy1.html

130) Doppler effect: describe frequency perceived by an observer as a function of the velocities of the source that is emitting the sound waves and the observer

Velocity of source = vs velocity of observer = vo

fs = frequency of source. fo = apparent frequency observed

$$f_o = f_s\left[\frac{(v \pm v_o)}{(v \mp v_s)}\right]$$

Be careful with the +/- signs for the velocities.

- If the source and observer are moving towards each other, use both top of the +/- signs in the equation.
- If source and observer are moving away from each other, use both bottom signs
- if observer approaching use (top sign) +vo if source moving away use (botton sign) +vs
- if observer is moving away use bottom sign –vo , if source is approaching, use top sign –Vs

http://www.premedhq.com/2011/06/mcat-sound-doppler-effect-moving-sound.html

this equation assumes that v_s, v_o are < < c, the speed of sound

131) Doppler effect applies to all waves including light waves.

132) Red shift is when a source is moving away, and light appears to be lower frequency.

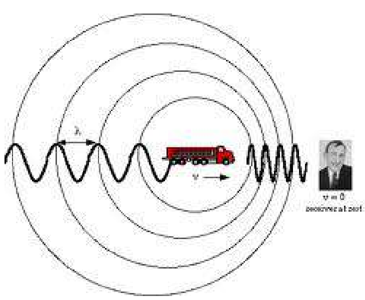
133) Blue shift is when a source is approaching,and light appears to be at a higher frequency.

134) Supersonic speed is speed less than the speed of sound.

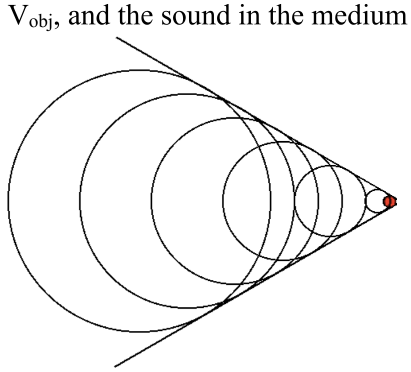
135) Mach number is ther ratio of an object's velocity to the speed of sound in the same medium.

136) Shock waves occur when a sound wave source travels faster than the speed of sound and creates a powerful constructive interference by its coinciding wave fronts.

137) The angle of the cone, θ , that is created at the front of an object traveling at supersonic speeds is related to the velocity of the object, V_{obj}, and the sound in the medium V_{snd}, by $\sin\theta = v_{snd}/v_{obj}$.



A. Doppler



B. Mach cone

138) Review with regard to its energy, consider which properties of waves and which properties of particles apply to light.

Chapter 13 Temperature and Kinetic theory

1) Heat, temperature and thermodynamics topics covered in the AP exam:
   a. Mechanical equivalent of heat
   b. Heat transfer and expansion
   c. Kinetic theory and the model of the internal energy of a gas
   d. Gas laws
   e. Thermodynamic processes: PV diagrams, Newton's first and second laws in cycles.
2) The atomic theory of matter states that matter has a limited number of subdivisions.
3) The smallest individual piece is the atom.
4) Modern evidence for atomic theory comes from the law of definite proportions and Brownian movement.
5) Law of definite proportions: describes the atomic makeup of compounds. Any amount of a given compound has the same proportion of constituent elements by mass as any other amount of the same compound.
6) Brownian movement describes the continuous random motions of the atoms in all matter
7) Electrical attractive and repulsive forces keep molecules within discrete range of distances
8) These electrical forces affect the molecules' state of matter.
   a. For solids, attractive forces keep molecules in relatively fixed positions, vibrating in place.
   b. For liquids, molecules have more rapid movement an roll over each other.
   c. For gases, molecules have high speeds that move in every direction, filling containers and occaisionally colliding.
9) Temperature relates to how relatively hot or cold objects are
10) Changes in temperature can change the properties of matter [volume occupied, physical state].
11) Thermometers use thermal expansion to quantify temperature changes
12) The adjustable constant-volume gas thermometer compensates for pressure differences and is used to provide the standard temperature scale.
13) Scales for measuring temperature include Celsium [also known as centigrade] , Fahrenheit, and Kelvin.
   a. Kelvin is the absolute temperature scale.
   b. OK = zero kelvins = absolute zero.
   c. The standard conversion from F to C is C = 5/9 [F-32]
   d. The conversion from C to F is F = 9/5 [C] + 32
   e. The conversions between C and K is K = C + 273.15 and C = K – 273.15
14) Thermal equilibrium: Two objects that are initially at different temperatures will converge on a single temperature.
15) Heat flows from object at higher temperature to object at lower temperature. Only.
16) When 2 objects are at thermal equilibrium no heat energy flows between them.
17) Zeroth law of thermodynamics: if two objects independently have the same temperature as a third object, the two objects have the same temperature. If A=C **and** B=C then A=B
18) Temperature changes can yield difference in length and volume of an object.
19) Change in length as a function of temperature: $\Delta L = \alpha L_o \Delta T$ where:

Lo is the initial length, α is the coefficient of linear expansion, and ΔT is the change in temperature

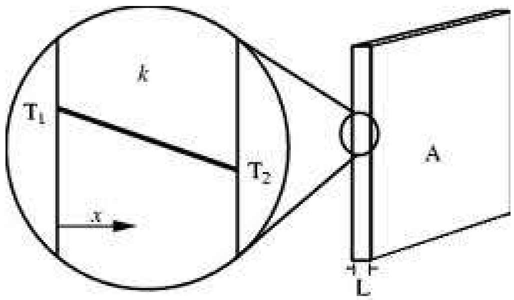
20) The change in volume is a 3-dimensional function of temperature $\Delta V = \beta V_o \Delta T$ where
    Vo is the initial volume β is the coefficient of volume expansion
21) Barring a change in phase, the linear and volumetric expansion of all materials follows these equations.

22) Water is the exception: water has maximum density at 4oC . the volume of water decreases from oC to 4C
23) Pressure, temperature and volume are interrelated for gases
24) Boyles law: volume is inversely proportional to pressure at a constant temperature
25) Bolyes law: $P_1V_1 = P_2V_2$
26) Charles law: volume is directly proportional to absolute temperature at constant pressure.
27) Charles law: $V_1/T_1= V_2/T_2$
28) Gay-Lussac law: pressure is directly proportional to absolute temperature at a constant volume
29) Gay lussac: $P_1/T_1 = P_2/T_2$
30) Ideal gas law : combining the three laws, where n = # moles of a substance and R = universal gas constant
31) Ideal gas law: PV = nRT R = 8.315 Joules/[mol-K]
32) The number of moles of a substance is equal to the ratio of a sample's mass in grams to its molelcular mass in grams. Where the molecular mass is the sum of the atomic masses for each component of a molecule.
33) For the ideal gas law, the temperature scale is Kelvin, where K = 273.15 + C
34) STP = standard temperature and pressure: T = 273 K, P = $1.013X10^5 N/m^2$ [= 101.3 kPa]
35) The volume occupied by 1 mole of any gas at STP = 22.4 L = .0.224 m^3
36) R is derived from conditions of 1 mole of any gas at STP: R = PV/nt $= \frac{[1.013X10^5 N/m2] \quad [\ .0224m^3]}{1\ mole \quad 273\ K}$
37) R = **8.31 J/mol-K**
38) R, the proportionate constant of the ideal gas law depends on Avogadro's hypothesis
39) Kinetic theory of gases is the foundation of the ideal gas law , the model of the internal energy of a gas, and the definition of kinetic energy of molecues.
40) Kinetic theory is the idea that molecules of a gas act like point particles as they bounce into each other and the walls of a container.
41) Derived from kinetic theory is the classic relationship of the ideal gas law. This is a state function that relates a gas's pressure and volume to the absolute temperature.
42) Avogadro's hypothesis: equal volumes of different gases whose temperature and pressure are equal contain equivalent number of molecules .
43) Avogadro's number = $6.02X10^{23}$ = number of particles in a mole
44) Restating ideal gas law as PV = Nkt where k is the Boltzmann constant = $1.38X10^{-25}$J/K and N equals the number of molecules (NOT moles!) in the sample.
45) Kinetic theory of gases states all matter is composed of atoms in random motion.
46) Pressure is defined as a measure of the collisions of molecules against the walls of their container.
47) Calculating the average force using the average momentum of molecules in a gas, we can apply the ideal gas law and determine the average kinetic energy.
48) The average translational kinetic energy of all molecules in a gas = KE = ½ (mv^2) where v is the average velocity of all molecules in the gas.
49) Using PV = nKT: we get KE = 3/2 kT
50) Rearrange and we find average velocity [root-mean-square velocity] in terms of temperature and mass: $v_{rms} = \sqrt{3kt/m}$
51) Review: consider how the postulates of kinetic theory justify the component laws of the ideal gas law.

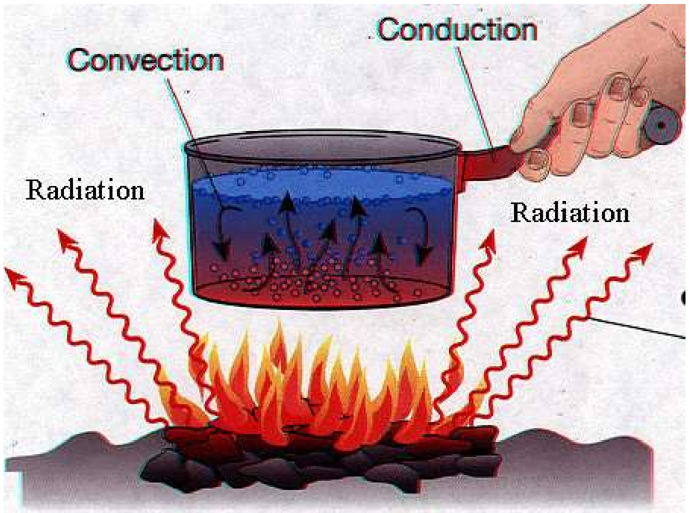
Chapter 14 Heat

1) . Heat flows naturally from a warm body to a cool body in contact untily they reach the same temperature, a state known as thermal equilibrium
2) One calorie , a unit of heat, represents the amount of heat that must be added to increase the temperature of 1 gram of water by 1 degree Celsius
3) In practice, the kilocalorie, or Calorie is used. A kcal is 1000 calories. It is the amount of heat to raise the temperature of 1 kilogram of water 1 degree Celsius
4) The mechanical equivalent of heat , 4.186 joules, is the amount of work equal to the transfer of 1 calorie of heat.
5) 1 cal = 4.186 J and 1 J =.0239 cal
6) Both internal energy and thermal energy refer to the aggregate energy of an object's constituent molecules.
7) Temperature depends on the average kinetic energy of a single molecule
8) Heat is the energy transferred as objects seek thermal equilibrium
9) Heat is measured in joules, the unit of work
10) The internal energy of a monatomic ideal gas , U, is a function of the mass of molecules and their temperature.
11) For monatomic ideal gas: $U = 3/2\ nRT = 3/2\ NkT$
12) For nonmonatomic ideal gas molecules, the rotational and vibrational motion of the individual molecules will cause an increase in internal energy.
13) Note that the internal energy of ideal gases [unlike real gases] is independent of pressure and volume.
14) Every material has a proportionality constant called the specific heat, c, which relates the transfer of heat to its change in temperature.
15) The mechanical equivalent of heat is a very simple topic. The underlying concept implies that when mechanical work is done by friction, work appears in the system as increased heat.
16) When a block slides to rest on a tabletop,both the tabletop and the block heat up, and the temperature change in the object can be computed or measured.
17) The law for this heat exchange is summarized as $\Delta Q = mc\Delta T$.
    a. ΔQ = heat gained or lost in joules
    b. c is the specific heat of the substance measured in J/kg-C or J/kg K
    c. ΔT is temperature change measured in degrees C or in kelvins.
    d. For all quantities that invole a CHANGE in temperature , degrees C can be used [easier numbers].
    e. For the gas laws you MUST use kelvins.
18) The heat transferred, ΔQ, is a function of its mass, the change in temperature, and the specific heat.
19) Conservation of energy applies to the heat transfer within an isolated system as thermal equilibrium is sought, such that the amount of heat removed from part of a system is equal to the amount of heat acquired in another part of a system.
20) All heat must be accounted for during heat transfer.
21) Conduction occurs when one object comes in contact with another, causing one of the objects to lose heat and the other to gain heat.
22) The equation for conduction: $Q = ,c\Delta T$
23) The equation for the rate of heat transfer or power conducted through a medium: $\frac{\Delta Q}{Dt} = \frac{kA\Delta T}{d}$
    a. Where k is the coefficient of conductivity
    b. A is the surface area of contact between the two temperature differences
    c. d is the thickness of the material

24) Conduction: heat transfer results from molecular collisions.
    a. Conduction occurs when part of an object is heated, the molecules in that location increase their motion and their collisions with molecules in adjacent parts of the object.
    b. The energy from the collisions is transferred, causing the adjacent molecules to increase their motions and collisions
    c. The process repeats throughout the object , transferring heat.
    d. The rate of heat flow is given by $\Delta Q/\Delta t = kA\Delta T/l$
        i. where k = thermal conductivity
        ii. A is cross sectional area
        iii. l is the distance between 2 points that are at temperatures T1 and T2



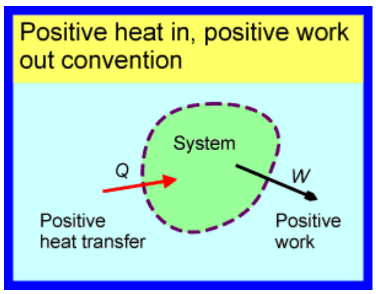
25) A high value for k implies the substance is a good conductor of heat
26) A low k value means the substance is a good insulator
27) Solids transfer heat through conduction.
28) Convection results from the movement of molecules over relatively long distances , as opposed to movement due to collisions.
29) Fluids such as water and air can transfer heat through convection.
30) Heated molecules move in swirls, bringing cooler molecules toward the heating element: those cooler molecules in turn begin to move in swirls when heated.
31) As a continuous process, heat is transferred from warmer regions to cooler regions.
32) Radiation heat transfer requires no matter as a medium.
33) Radiation relies on electromagnetic waves to transfer energy.
34) The rate of radiation heat transfer is given by $\Delta Q/\Delta t = \varepsilon\sigma A\, T^4$ where
    a. ε = emmisivity and σ is the Stefan-Boltzmann constant
    b. ε varies from ~ o τo 1 and $\sigma = 5.67X10^{-8}\ W/m^2K^4$
35) Emissivity is a constant of proportionality that depends on the material receiving the radiation.
36) Note that Temperature is measured in kelvins raised to 4^{th} power.
37) In practice, the emitting object at temperature T1 in in an environment of T2, and the radiation equation becomes $\Delta Q/\Delta t = \varepsilon\sigma A(T_1^4 - T_2^4)$



38) Review: consider specific examples in which a substance's specific and latent heats are considered in determing its functional uses

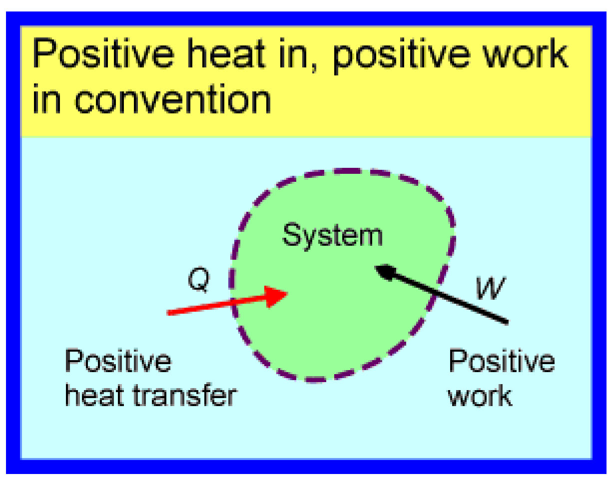
Chapter 15 the laws of thermodynamics

1) Thermodynamics is the investigation of the energy transferred either as heat (which occurs when thermal equilibrium is sought) or as work (which describes any other transfer of energy)
2) Any object or environment can be considered a system.
3) Closed system: no mass is transferred to or from outside the system
4) Open system: mass can transfer into or out of system
5) Isolated system: a closed system with no energy transferred into or out of the system
6) First law of thermodynamics: the change in internal energy of a closed system is equal to the difference between heat added and work done.
7) TEXT BOOK: First law of thermodynamics: $\Delta U = Q - W$
    a. Heat ADDED TO a system is positive +
    b. Work done BY a system is positive +
    c. This is the traditional convention.
    d. This is an expression of conservation of energy.



lets not use this!

8) **The AP exam defines +W as work done ON a system .**
9) So the equation becomes : $\Delta U = Q + W$
    a. Work done on ON the system is positive +
    b. Work done BY the system is negative -



39) AP exam uses the "positive in" convention.
40) By definition, in an isolated system, $W = Q = \Delta U = 0$
41) Work transfer and heat transfer are processes done on the system or by the system
42) Internal energy is a property of the system
43) Isothermal process: temperature is constant.

   a. From ideal gas law: PV = constant value in a closed system that undergoes an isothermal process.
   b. This is idealized in a container with a moveable piston and heat reservoir
   c. The reservoir keeps the temperature constant as heat is added
   d. Because the internal energy of an ideal monatomic gas is a function of the absolute temperature, if $\Delta T = 0$, then $\Delta U = 0$.
   e. So the work done BY the system must equal the heat added TO the system [W = Q]

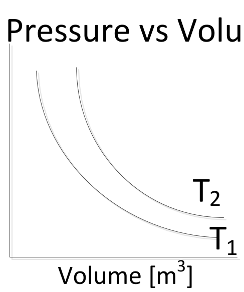
44) Curves known as isotherms can be sketched for changes in pressure and volume on a P vs V graph
   a. From ideal gas law, if T is constant, the pressure and volume of the gas at two different states are related as $P_1V_1 = P_2V_2$
   b. From kinetic theory, U = 3/2 nRT = 3/2 NkT where N_A is Avogadro's number and $k = R/N_A$
   c. The average Kinetic energy of a gas molecule is derived from this relationship: $\frac{1}{2} mV_{rms}^2 = 3/2\ kT$.
   d. The root mean square velocity is therefore: $V_{rms} = \sqrt{[3kT/m]}$
   e. The velocity of molecules is a distribution and individual velocity of molecules differ because of collisions
   f. We will only use Vrms.

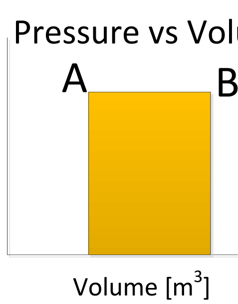
45) The states of a gas undergoing different processes [heating, cooling, expanding, etc] can be expressed using a PV diagram.

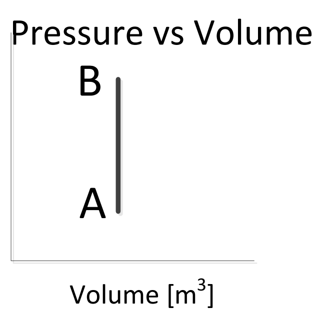
46) Consider gas under pressure inside of a piston.
   a. The particles are in constant motion, with KE = $\frac{1}{2} mV_{rms}^2 = 3/2\ kT$.
   b. If the volume is changed, the pressure will also change.

47) There are several processes that can change the volume:
   a. Move the piston head
   b. Heat or cool the gas

48) This is a typical PV curve for constant temperature:
   a. an inverse relationship between P and V for a sample of gas at two different temperatures.
   b. These curves are called "isotherms" or isothermal lines.
   c. As the temperature is increased from T_1 to a new constant temperature T_2, the curve shifts upward.







Isothermal **isobaric** **Isochoric** **Adiabatic**

49) Isobaric is another type of PV relationship.
   a. Isobaric means constant temperature.
   b. If the volume of a gas changes at constant pressure, we get a graph like the one above.
   c. The line AB is called an isobaric process and represents aa change in volume at constant pressure.
   d. the area under the line AB in the PV diagram represents the work done BY the gas
   e. Work = $PV_{final} - PV_{initial} = P\Delta V$
   f. If the gas expands to a new volume it does work to push the piston against pressure

g. If the process had gone instead from B to A, work would have been done ON the gas by an outside force [pressure]

h. Units of pressure = N/m2 units of volume = m^3 units of work $P\Delta V$ = N m = joule

50) In an isochoric process, the gas increases and decreases in pressure at constant volume.

a. This is usually achieved by putting a latch on the piston and either heating or cooling the gas in the chamber.

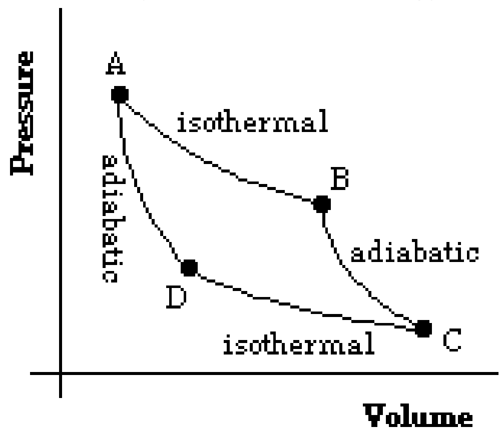
b. NO work can be done or or by the gas since $W = P\Delta V$ and $\Delta V = 0$.

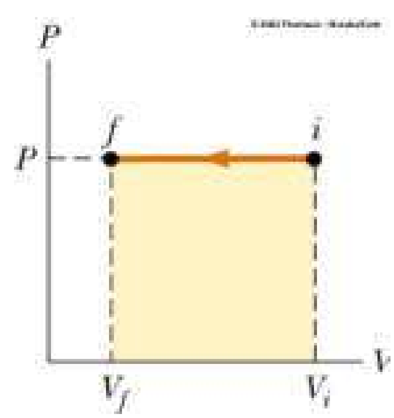
51)

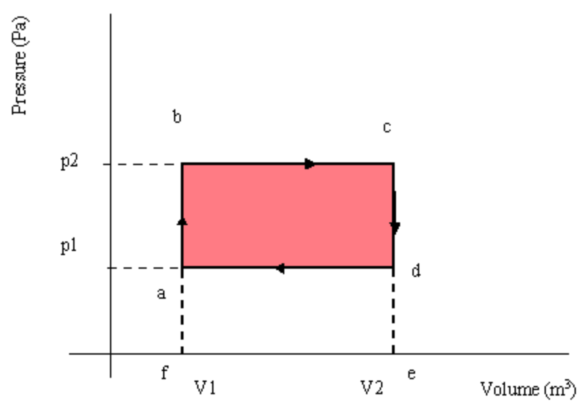
52) adiabatic process means heat does not move into or out of the system.

53)

54) In adiabatic process internal energy and temperature increase





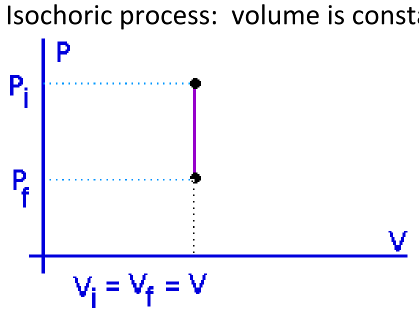


55) Isobaric process = constant pressure

56) In isobaric process, work done BY the system is equal to the product of pressure and the change in volume.

57) When pressure is constant $W = P\Delta V$

58) Isochoric process: volume is constant, so work done on and by the system is zero [$\Delta V = 0$]

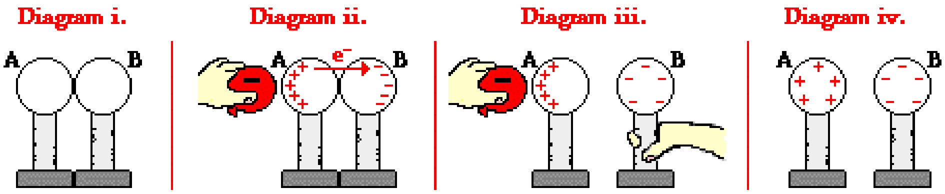


59) Heat engines turn thermal energy into mechanical work.
60) Heat engines use a portion of the heat that flows from a high temperature to a low temperature.
61) For the law of conservation of energy, the sum of the work produced (W) and the heat flowing out of an engine (Q_L)must be equal to the heat flowing into the engine(Q_H).
62) Efficiency of an engine is defined as the ratio of the work produced to the heat flowing in.
63) Efficiency $e = W/Q_H = 1 – Q_L/Q_H$ since $Q_H = W + Q_L$
64) Real engine processes are irreversible due to the heat unavoidably lost from internal friction.
65) The maximum efficiency for a hat engine is called the Carnot limit.
66) Carnot limit = ratio of temperature change in operation in kelvins to the high temperature of operation
67) Carnot limit = ideal efficiency = $e_{ideal} = \Delta T/T_H$
68) For refrigerating units, work must be added to cause heat to flow from a lower temperature to a higher temperature.
69) A refrigerators coefficient of performance, COP, is given as the ratio of heat removed to work inputted.
70) $COP = Q_L/W$
71) For a carnot ideal refrigerator COP ideal = $T_L/\Delta T$.
72) For heat pumps the same process applies, but efficiency is measured as the rato of $CP = Q_H/W$
73) There are several ways of stating the second law of thermodynamics
74) Clausius statement of 2nd law: heat flows from a warm body to a cool body without outside interference- but not the converse.
75) Kelvin-Planck statement of 2nd law:no engine can turn all heat into work . Absolute Carnot efficiency would require an exhause tempterature of absolute zero, which is impossible.
76) Entropy is disorder.
77) The change in entropy of a system is the ratio of heat added to a system to the constant temperature in kelvins at which it is added
78) 2nd law of thermodynamics: $\Delta S = Q/T$ or $Q = T\Delta S$
79) Within a closed system, the overall entropy always increases, even though there may be isolated localized decreases in entropy
80) As a result of natural processes, entropy will always increase, causing a system to move from a state of order to a state of disorder.
81) The categories that keep a system ordered are called information.
82) Entropy causes a decrease in a system's information over time
83) Energy loses its capacity to do work over time.
84) Review: consider the operational differences (and there resulting implications) for both an ideal engine and a real engine.

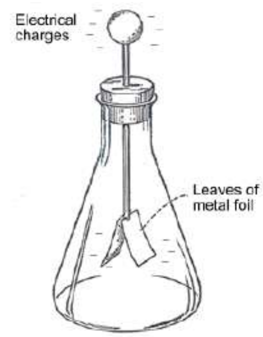
Chapter 16: electric charge and electric field.

1) Early experiments with the effects of static electricity on different substances placed in contact or proximity provided many of the conventions for electricity used today.
2) Electric charge: of an object, is a discrete quantity that can be acquired or transferred.
3) The charges of objects affect their interaction
4) There are 2 types of charge: positive and negative [Benjamin Franklin].
5) Like charges repel each other , opposite charges attract.
6) Objects with no charge are neutral
7) Charge can be transferred or induced onto objects, but the net quantity of charge always remains constant.
8) Law of conservation of electric charge: charge neither created nor destroyed.
9) Electric charges are responsible for most forces at the microscopic level.
10) The atom is composed of individual negatively charged particles, called electrons that orbit around a positively charged nucleus.
11) The net charge of a neutral atom is zero: # positive charges = # negative charges.
12) Atoms that gain or lose electrons are called ions.
13) Ions are charge atoms.
14) Cations : + charge [metals lose electrons]
15) Anions : - charge [nonmetals gain electrons]
16) Polar molecule: Some molecules distribute their electrons such that there is a charge difference between parts of the molecule, even though the overall charge is zero.
17) Water is a polar molecule because of nonuniform distribution of + and – charges within each molecule.
18) The ability of a material to be influenced by external charge depends on the mobility of its electrons.
19) Materials that allow charge to cross them are called conductors. [example : metals]
20) Electrons in conductors are relatively fluid in ther movement within the materials ["sea of electrons"]
21) Materials whose electrons are less fluid and consequently do not allow charge to cross them are called insulators.
22) Charge can be imparted to neutral objects by *contact* or by *induction.*
23) Coulomb = SI unit of charge.
24) When a charged object touches a neutral conductive object, electrons are transferred such that two objects have the same type of charge.
25) The direction of electron transfer depends on the initial type of charge.
26) In the example below, a charged object is brought near two uncharged conductors that are in contact.
27) When the charged object approaches the neutral conductive objects A and B without touching them, the electrons within the neutral object A shift such that the near end of A has the opposite charge of the charged object, and the far end of B has the same charge as charged object
28) In the example below, when spheres A and B are separated, the opposite charges distribute over the spheres..

Charging by Induction



Two metal spheres are mounted on insulating stands. **The presence of a – charge induces e⁻ to move from sphere A to B. The two-sphere system is polarized.** **Sphere B is separated from sphere A using the insulating stand. The two spheres have opposite charges.** **The excess charge distributes itself uniformly over the surface of the spheres.**



29) Electrical ground: a charge reservoir, an infinite "sink" X
30) Electroscope: device consisteing of two metal "leaves" attached to a central conducting node for measuring charge.
31) When charges is imparted to electroscope leaves, the behavior of the leaves indicates the relative charge of by the angle of separation of the leaves.
32) A charged electroscope indicates if the charge of another object brought into its vicinity is the same or opposite charge , but cannot indicate if it is positive or negative.
33) The force resulting from the interaction of charged objects is directly proportional to their charges, and inversely proportional to the square ofther separation distance.
34) Since Coulomb noted these relationships, the equation [developed later] is known as Coulomb's law.
35) Coulomb's law is an :inverse square law" similar to Universal Gravitational Law: $F = kQ_1Q_2 /d^2$

Where

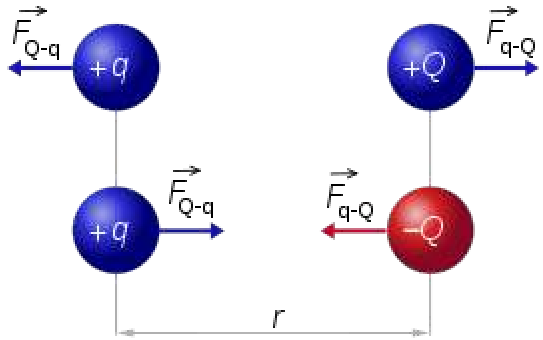
k = the proportionality constant = $9.0X10^9 Nm^2/C^2$

D = the separation distance [center to center] of the charges, measured in meters

And Q_1 and Q_2 = the charge of the particles, measured in coulombs. These can be + or -.

36) Coulomb's law is also expressed as $F = \frac{Q_1Q_2}{4\pi\varepsilon_o}$ where ε_0 is the permittivity of free space
37) $\varepsilon_0 = 8.85X10^{-12}\ C^2/N\cdot m^2$
38) The smallest unit of charge is called an elementary charge.
39) The electron and the proton are elementary charges of absolute value **$e = 1.602X10^{-19}$ C**
40) A single electron has the charge of **– e**. and a single proton has the charge **+e..**
41) Because electrons and protons are functionally indivisible, all charges must be integer multiples of this elementary charge, and charge is described as quantized.

42) While coulomb's law gives the magnitude of force, its direction is along the line joining the charges: like charges repel and opposite charges attract.



$$|\vec{F}_{Q\text{-}q}| = |\vec{F}_{q\text{-}Q}| = k\,\frac{|q \times Q|}{r^2}$$

43) A simplification of Coulomb's law is to assume the charges are immobile , one-dimensional **point charges** and that the size of charges is small relative to the separation distance between them.

44) Calculating the forces involving more than two particles at rest requires vectors.
   a. The force components are added in each of two perpendicular directions.
   b. If the point charges are not collinear, the magnitude of the resultant force can be determined by the Pythagorean formula.
   c. The direction of the resultant force can be found using trig.
   d. Note the signs on the components of this resultant force correspond to directions along each axis [not to the signs of the point charges]

45) http://dev.physicslab.org/Document.aspx?doctype=3&filename=Electrostatics_AdvancedCoulombsLawProblems.xml Xx

46) Electrical forces do not require contact for objects to influence each other's motion.

47) As with the gravitational force, this is a "force at a distance"

48) The force radiating from an electrical charge creates a field around the charge.

49) The interaction between point charges is explained by the behavior of each charge in the field of the other charge.

50) The strength of the field at a point in space can be measured by its force imposed on a **test charge**.

51) A test charge [or test particle] is an positive charge whose physical properties [mass, charge, or size] are considered "negligible" except for the property being studied, which is still insufficient to alter the behavior of the rest of the system.

52) The strength of the electric field at a point in space is the rato fot eh force on a test charge at that point to the magnitude of the test charge , so $E = F/q$.

53) Combining this with Coulomb's law, we find that the electric field at a distance r from a single point charge Q has magnitude $E = k\,Q/r^2$

54) **Superposition princible:** *for all linear systems, the net response at a given place and time caused by two or more stimuli is the sum of the responses which would have been caused by each stimulus individually*.

55) **Using Superposition principle**: For several point charges, the total strength of their electric fields at a point can be determined by summing their vector components : $\mathbf{E = E_1 + E_2 + E_3 + \ldots}$

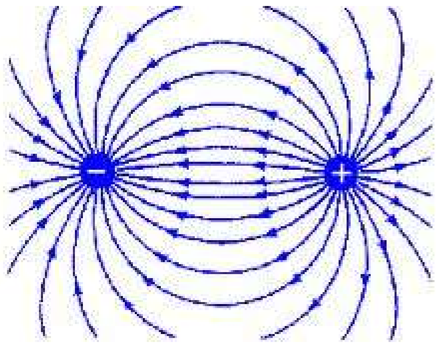
56) Electric fields are represented graphically with arrows extending away from positive charges or toward negative charges.

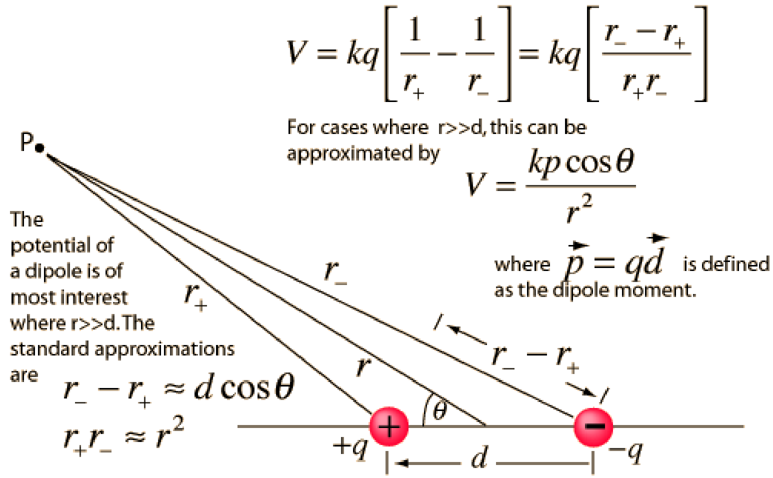
57) Electric field lines signify the direction of the force caused by the electric field.

58) The number of field lines in a given region is proportional to the magnitude of the force there.
59) The field's direction at any point is tangent to the field line at the point.
60) The strength of forces indicated by the proximity of field lines to each other, such that they are closer together near the charge source.
61) For oppositely charged parallel plates, the magnitude of the electric field is constant everywhere between the plates, so the field lines are evenly spaced.
62) When a conductor is placed inside the electric field produced by stationary charges,
    a. the strength of the electric field inside the conductor is zero.
    b. The electrons inside a conductor in an electric field arrange themselves by induction so that E=0 everywhere inside the conductor.
    c. However, the external field caused by the charge continues from the exterior surface of the conductor as thought the conductor was not present.
    d. The direction of the field is perpendicular to the external surface of the conductor.
63) Review: calculate the field strength due to several charges whre no more than two charges are collinear.

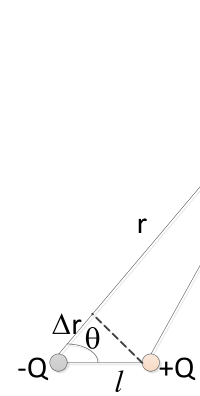
Chapter 17: Electric potential and electric energy: capacitance

1) Electric energy provides further quantitative descrioptions of electrical phenomena beyond force and fields.
2) Gravitational and elastic potential energy is measured as a difference of potential energies rather than an absolute value,
3) Similarly, electrical potential energy refers to the change in potential energy as a charge is moved between two points.
4) Electric potential energy is the **negative** of the work done BY the electric field to move a charge between two points
5) Because only a difference in potential energy is measured, a zero potential energy can be assigned to either point.
6) Electric potential , V, is defined as the quotient of potential energy to charge, such that $V_a = PE_a/q$
7) Electric potential $V_{ab} = V_a - V_b = -W_{ba}/q$
8) The units of electric potential are volts.
9) 1 volt = 1 joule/coulomb = 1 J/C
10) The terms **potential difference** and **voltage** are interchangeable.
11) The potential energy difference is defined as $\Delta PE = PE_b – PE_a = qV_{ba}$
12) For a uniform electric field, the relation to electric potential is given by $E = V_{ba}/d$ for a positive charge q moved from a point b to a pont a, separated by d meters.
13) The electric field is a vector that chan have equivalent units volts per meter [V/m] or newtons per coulomb [N/C]
14) Electrical potential is a scalar with equivalent units volts, V, or joules per coulomb, J/C
15) As field lines graphically represent electric fields, equipotential lines represent electrical potential.
16) The points that comprise an equipotential line hav the same electrical potential.
17) Equipotential lines run perpendicular to field lines at any point.
18) Equipotential lines are parallel to charged parallel plates and they are in concentric circles aoure single charges
19) The electric potential of these lines depends on their distance from the sources of potential.
20) On a microscopic scale, the electron volt is used for energy
21) One electron volt is **1 eV** = $1.6X10^{-19}$ J
22) 1eV is the energy gained by an electron other particle having charge $1.6X10^{-19}$ C, traveling across a one volt potential difference
23) **Point charge potential:** A point charge produces an electric field and an electric potential around it. The electric potential [voltage] of a point charge is the **electric potential energy per unit charge**
24) **Point charge potential:**. If we assume the electric potential is zero at a distance of infinity , the electric potential at a distance ***r*** from a point charge **Q** is given *by* $V = kQ/r$
25) **For multiple point charges:** the electric potential [voltage] at any point in space produced by any number of point charges can be calculated from the individual point charge expressions by simple addition **since voltage is a scalar**.
26) **For multiple charges** The combined electric potential of several point charges is given by the scalar sum of their individual potentials. NOTE the sign for each potential must match the sign of the charge.
27) **Voltage of Multiple point charges:** $V = kQ_1/r_1 + kQ_2/r_2 + kQ_3/r_3 + \ldots$
28) An **electric dipole** consists of two equal but oppositely charged point charges separated a distance in space.





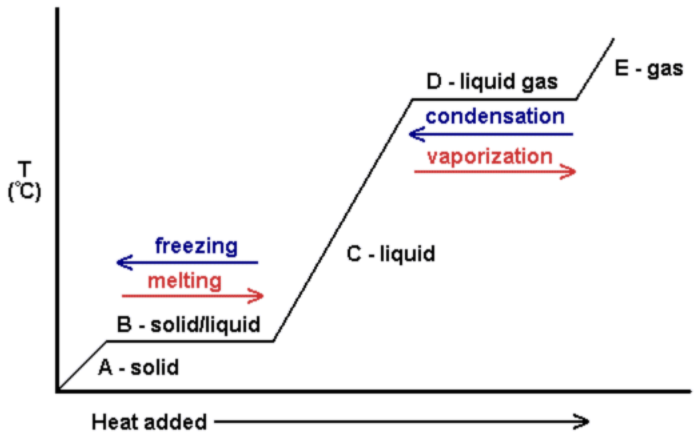
29) The Electric dipole potential is found by superposing the point charge potentials of the two charges.
30) For the case where the **r** >> ***l***, the distance between the charges in the dipole: The electric potential at a point that is **r** meters away from the *positive* charge of an electric dipole for which the charges are a distance *l* apart, is given by $\mathbf{V = kQ}\boldsymbol{l}\mathbf{\cos\theta/r^2}$
31) The product of charge and distance of separation is called a dipole moment, **p**, so that V = k**p**cosθ/r^2
32) Electric dipole potential: The distance from point A to the positive charge is r. the distacnce from point A to the negative charge is r+Δr.
33) θ is the interior angle between the line from the negative charge to the positive charge and a second line from the negative charge to the point of potential, point A



34) The length Δr is *l* cosθ. separating the charges , l, is approximately

64) Calorimetry is the quantitative measurement of heat transfer.
65) For a material to change its physical state, a gain or loss of energy is required, quantified in values called latent heats.
66) Every material has a heat of fusion, a constant representing the amount of energy needed to change 1 kg of that substance from solid to a liquid.
67) Similarly, every material has a heat of vaporization, another constant, representing the amount of energy to change 1 kg of that substance from a liquid to a gas.
68) When change of state occurs in the opposite direction, the values of latent heats refer to the quantity of energy released during the change of state.
69) Heat added to a solid substance raises the temperature of that substance until it reaches its melting point.

70) When heat is added to a solid at its melting point, the heat converts the solid to a liquid at constant temperature.
71) Once the substance is completely melted, as more heat is added the temperature rises again.
72) Heat added to a liquid substance raises the temperature until it reaches its boiling point. Then, heat added converts the liquid to a gas without raising the temperature.
73) When the entire amount of substance has been evaporated, adding additional heat will raise the temperature of the gas.
74) The heat required for a phase change is equal to the product of the mass and the latent heat of the substance
75) Heat for phase change: Q = mL



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