MCAT Physics Rapid Learning Series
Test-Prep Course Study Guide

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Core Unit #7 – Atomic and Nuclear Physics

In this core unit, you will learn about physics on the very small scale. The nature of the atom and even the tiny nucleus will be explored.

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- Applications of nuclear science

01: The Guide to Physics and the MCAT

Tutorial Summary:

The MCAT is a standardized test necessary for all students wishing to gain admission to a medical school. It is now administered as a computer based test instead of a typical pencil and paper test. There are two types of questions that may be found. Passage questions contain a short reading section with related questions. Stand alone questions are without any supporting text. You can improve your score on the MCAT by following the study suggestions outlined in this tutorial. The test taking and test preparation strategies can help greatly.

Tutorial Features:

- Detailed outline of test features, schedule, and contents.
- Concept map showing inter-connections of concepts introduced.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Introduction to the MCAT
  - The "new" MCAT
  - Test format
  - Test scoring
  - Schedule
- Rapid Learning for MCAT
- Physics and the MCAT
  - Passage based questions
  - Stand alone questions
- Test preparation strategies
  - Time management
  - Planning
  - Studying hints
- Test taking strategies
  - Answer selection hints

Content Review:

MCAT:
The Medical College Admissions Test is a standardized exam required to gain admission to medical school.

MCAT Courses
The new four-section MCAT requires seven college courses – general chemistry, organic chemistry, biochemistry, biology, physics, psychology and sociology. You can either take these colleges in college or self-study them.

Passage-Based Question
It is a type of questions relating to information in an accompanying passage. The answer may or may not be in the passage.

Discrete Question
A question that has a topic independent of a passage or other questions with four possible

answer options.

Test Sections
(1) Chemical and physical foundations (2) Critical Analysis and Reasoning Skills (3) Biological and Biochemical Foundations (4) Psychological, Social and Biological foundations.

General Chemistry
MCAT requires students to take two semesters of college-level chemistry for pre-med. A traditional college course with the mainstream curriculum will cover the scope of the test in general chemistry. The outline style of test prep books might not be sufficient for the mastery of general chemistry in MCAT.

Computer-based Test
MCAT is 100% to be taken on computer with on-screen timer but no calculator provided. All questions are multiple-choice now for easy computerized grading. There is no guessing penalty.

Scoring
Four sectional scores and one total score with midpoint

- Chem/Phys Section: 118-132 (midpoint = 125)
- Critical/Reasoning: 118-132 (midpoint = 125)
- Bio/Biochem – 118-132 (midpoint = 125)
- Psy/Social - 118-132 (midpoint = 125)

Composite Score: 472-528 (midpoint = 500)

Test Day Schedule
This is a lengthy exam of 7.5 hours.

- Chem/Phys: 95 minutes, 59 questions.
- Critical/Reasoning: 90 minutes, 53 questions.
- Bio/Biochem: 95 minutes, 59 questions.
- Psy/Social: 95 minutes, 59 questions.

There are 4 sections with 10 minutes break in between.

02: Introduction to Physics

Tutorial Summary:

The science of physics describes matter, energy and forces in many respects. To study physics many academic tools are needed. The metric system, significant figures and dimensional analysis make measurements and conversions of those measurements easier. These measurements are used with the scientific process to draw conclusions and expand our knowledge of the physical world.

Tutorial Features:

- Step by step easy explanation of example problems: dimensional analysis and significant figures.
- Concept map showing inter-connections of concepts introduced.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- The science of physics
- The metric and SI systems
    - Metric prefixes
    - SI units
    - Common non-SI units
- Dimensional analysis
    - Equalities
    - Steps to using dimensional analysis
- Measurement and Uncertainty
    - Tools common in physics labs
    - Taking measurements
    - Uncertainty
- Significant figures
    - How they're used
    - How to count them
- Scientific process
    - "The Scientific Method" versus Scientific Processes
    - Theory versus Law
    - Prediction versus Hypothesis
- How to study physics

Content Review:

Physics:
This is about the study of the physical world. It's the science of energy.

Metric System
The metric system is based on prefixes that indicate a power of 10 with base units.

Metric Prefixes commonly used in physics

Prefix	Symbol	Multiple
Kilo	k	1000
Deci	d	0.1

Centi	c	0.01
Milli	m	0.001
Micro	μ	0.000001
Nano	n	0.000000001

SI system
The International System of units gives a standard unit for each type of measurement.

SI Units commonly used in physics

Measurement	Unit	Symbol
Mass	Kilogram	kg
Volume	Liter	L
Temperature	Kelvin	K
Length	Meters	m
Time	Seconds	s
Amount of substance	Mole	Mol
Energy	Joule	J
Charge	Coulomb	C

Dimensional analysis:

To work dimensional analysis problems:
- Write your known down on the left side.
- Write down "=__________ [desired unit]" at the right side.
- Identify equalities that will get you from the known information to the desired unit. If there is no equality that involves both the known and unknown, you'll have to find more than one to more than one step.
- Arrange the equalities into a fractional form so that the known unit will cancel out and the desired unit will be left.
- Multiply across the top of the expression and divide numbers on the bottom.

Measurements and uncertainty:
Measurements must be taken accurately. Always write down one more decimal place than the instrument tells for certain—a "0" if it's "one the line" and a "5" if it's "between the lines."

Significant figures:
The significant figure rules are to allow people to read data or calculations and know with what precision the data was taken. The significant rules can be summarized in two rules: (1) If a decimal point is not present, count digits starting with the first the first non-zero number and ending with the last non-zero number; (2) If a decimal point is present anywhere in the number, start counting with the first non-zero number and continue until the end of the number.

Scientific process:
There are many paths to follow when undertaking "science"—there is no one scientific method. Science involves observing, posing questions, forming possible explanations (hypothesis), experimenting, processing/analyzing data, looking for trends, more formation of possible explanations or question posing. Scientific processes form theories (which

attempt to explain observed behavior) and laws (which describe or predict behavior, and are usually mathematical). A theory cannot become a law—one explains why and one describes what. A hypothesis is a proposed explanation for why something will occur (that may become a theory with enough evidence), while a prediction is simply a guess at what will happen—it does not attempt to say "why" it will happen.

03: Basic Math for Physics

Tutorial Summary:

Mathematics is vital to your study of physics. Algebra is needed to isolate and solve for whatever variable is desired. Physics often deals with very large, or very small values. Significant figures and scientific notation make these extreme numbers manageable. There are often many mathematical applications in physics. Your previous knowledge of geometry, trigonometry, and graphing will all come into play with physics. These tools will be used throughout many of the topics in this series.

Tutorial Features:

- Step by step mathematical examples showing all details: solving for variables, significant figures, scientific notation, etc.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Using algebra to solve for a variable
- Performing calculations with significant figures
- Using scientific notation
- Geometry and trigonometry
- The quadratic formula
- Graphing

Content Review:

Algebraic operations:

If a # is … to a variable,	then … the # to solve for the variable	Example
Added	Subtract	5 = x + 2 <u>-2 -2</u> 5-2 = x
Subtracted	Add	3 = x − 6 <u>+6 +6</u> 3+6 = x
Multiplied	Divide	<u>2</u> = <u>4x</u> 1. 4 2/4 = x
Divided	Multiply	2 · 6 = <u>x</u> · 2 2 2 · 6 = x

Adding & Subtracting with significant figures:

1. Perform the calculation.
2. Determine the least # of decimal places in problem.
3. Round answer to that # of decimal places.

Multiplying & Dividing with significant figures:

1. Perform the calculation.
2. Determine the least # of sig figures in problem.
3. Round answer to that # of sig figures.

Scientific Notation—a short hand method of writing numbers using powers of 10.

Writing scientific notation:

1. The decimal point is always moved to after the 1st non-zero number.
2. Count the number of times the decimal point is moved and use this as the power of 10.
3. "Big" numbers (>1) have positive exponents. "Small" numbers (<1) have negative exponents.

Trigonometry review:

Trig functions are often used to find resultants and components. The most useful relationships are:

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} \qquad \tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

Quadratic formula:

The quadratic formula is sometimes useful for squared functions:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Graphing:

Data is often graphed in physics. These relationships are often analyzed to fit mathematical model.

04: Graphing and Error Analysis

Tutorial Summary:

This tutorial describes the basics of graphing and error analysis. Several types of graphs are presented and interpreted. Various equations and their corresponding graphs and characteristics are explained. The definitions and formulas for basic statistical descriptors like mean and standard deviation are explained. Finally, the normal distribution is explained with accompanying examples.

Tutorial Features:

- Many graphs and charts to illustrate key points in graphing and statistics.
- Examples of error analysis are done step by step.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Cartesian coordinate system
- Semi log and log-log graphs
- Random vs. systematic errors
- Error propagation
- Mean and standard deviation
- Gaussian/normal distribution
- Student t distribution
- Chi squared test

Content Review:

Cartesian coordinates:
According to this system, the position of any point in the plane is described by a pair of numbers (x, y). In this system of coordinates, the x- and y- axes are perpendicular to each other.

Quadrants:
The x and y axes divide the plane into 4 regions, or quadrants, according to the following table.

Slope-Intercept Form:
A standard way of describing a line in the Cartesian plane, by using the slope m, and the y-intercept b, of a line.

Semi-log Graphs:
A way of visualizing data with an exponential relationship (of the form $y = e^x$ or $y = b^x$), in which one of the axes is plotted on a logarithmic scale.

Log-log graph:
A way of visualizing data that is changing with a power law relationship, in which both horizontal and vertical axes are plotted on a logarithmic scale.

Mean:
The best value of an experimentally measured quantity is given by the sum of the measurements divided by the number of measurements. Also known as average.

Standard Deviation:
A measure of the spread of the distribution of N measurements of an experimentally measured quantity x is given by: (1) taking the sum of squared deviations from the mean; (2) dividing by the degrees of freedom; (3) taking the square root of the quantity.

Error Propagation:
A way of computing errors from a computed, not directly measured, quantity. If the physical quantity of interest is computed from adding or subtracting measured quantities, the errors simply add. If a physical quanity of interest is computed from multiplying or dividing measured quantities, the relative errors add.

Random error:
The difference between a computed or measured value and the true or theoretically correct value. This is typically caused by random deviation in the act of measurement.

Systematic error:
A difference between a measured or computed value and the true or theoretically correct value which is caused by non-random deviation.

Gaussian/normal distribution:
A common probability distribution which is peaked about the mean and has an exponentially decreasing probability the further away from the mean. This is the most common probability distribution for randomly distributed variables with greater than 30 measurements. If the number of measurements is high enough, any distribution will look Gaussian.

Student's *t* distribution:
A probability distribution peaked about the mean, like the Gaussian distribution, but when the number of measurements is fewer than 30. This distribution has a greater probability than the Gaussian near the tails. This distribution is also used to compare whether the means of two different distributions are equal.

Chi-squared:
A measure of deviation between observed distribution of data and the theoretically expected distribution. The larger the value of chi-squared, c^2, the greater the discrepancy. Used in conjuction with chi-squared test to conclude whether data matches a given distribution.

05: Problem Solving in Physics

Tutorial Summary:

Problem solving doesn't just apply to working out physics problems. It applies to many academic and real life topics. This tutorial gives a very general outline to help attack any type of problem. A common difficulty with science classes is the dreaded word problem. The KUDOS method gives the student a place to start and a step by step method to begin the solution. KUDOS stands for known, unknown, definition, output, and substantiation. In addition to problem solving, this tutorial give hints to succeed on tests. Multiple choice, free response, and essay tips are all covered.

Tutorial Features:

- Step by step examples to help apply problem solving techniques.
- Graphic organizers to help convey the problem solving tips discussed.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- When to follow problem-solving techniques
- A general problem-solving technique
- How to solve word problems
- How to prepare for an exam
- Tips for taking exams

Content Review:

5 step problem solving strategy:
Step 1: Identify what's being given
Step 2: Clarify what's being asked.
  If necessary, rephrase the question
Step 3: Select a strategy
  Trial & error, search, deductive reasoning, knowledge-based, working backwards
Step 4: Solve using the strategy
Step 5: Review the answer

KUDOS method for solving work problems:
K = Known
U = Unknown
D = Definition
O = Output
S = Substantiation

SURE method for answering passage questions:

S = Skim	Skim through the passage quickly.
U = Understand	Understand the key facts and main ideas.
R = Read	Read the problem statement or question carefully.
E = Examine	Examine the answer choice and pick the best one.

Physics exam prep tips:
Stay ahead of the game
Make a cheat-sheet
Know the format of the test and information that's fair game
Make a mock exam
Attend the review session
Get help early

Exam taking tips:
Arrive early and prepared
Listen & Read instructions carefully
Memory dump first
Skim the test and form a plan
Answer questions sequentially
Apply the guessing rule

Multiple-choice tips:
Scan all the choices
Avoid word confusion
Beware of absolutes

06: Translational Motion

Tutorial Summary:

This tutorial describes motion in one direction. This motion will be described with vectors that convey magnitude and direction information. Other vector operations including addition, and separation into components will be covered. Motion at a constant rate will be discussed. In this type of motion the velocity remains the same. Accelerated or changing motion will also be analyzed. An example of this is a falling object that continually picks up speed as it descends. The concept of vectors and scalars will be applied. Various kinematic equations will be used to calculate various quantities in physics problems. General problem solving hints will be applied to these formulas.

Tutorial Features:

- Easy explanation of sometimes confusing complex physics formulas.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Constant Velocity
    - Distance
    - Displacement
    - Speed
    - Velocity
    - Average Velocity
    - Constant Velocity
- Constant Acceleration
    - Definition
    - Formula
    - Units
    - Free Fall
- Vectors
    - Definition and notation
    - Addition of vectors
    - Components

Content Review:

Kinematics:
The mathematical description of motion without any reference to the cause. The cause of this motion will be described in a later tutorial.

Vector:
A quantity that has magnitude, size, and direction. Velocity and displacement are examples.

Scalar:
A quantity that has only magnitude, or size. Speed, distance, and time are examples.

Instantaneous velocity:
The speed of an object at any particular instant.

Average velocity: The total distance traveled divided by the total time of travel.

Acceleration: The rate of change of velocity. Acceleration describes how fast an objects speed is changing per amount of time.

Kinematic Equations:
Formulas that relate the variables of motion:

- $v=d/t$
- $a = \Delta v/\Delta t=(v_f-v_i)/t$
- $d=v_it+at^2/2$
- $v_f^2=v_i^2+2ad$
- acceleration due to gravity = -9.8 m/s^2

Free Fall: Motion where gravity is the only force acting on an object. Gravity will accelerate an object at -9.8 meters per second per second.

Vector Addition:
When vectors are graphically added, they are drawn head to tail. This may also be described as placing the arrowhead of one vector next to the tail end of another vector.

Resultant:
The result of adding two or more vectors; vector sum. It is drawn from the tail of the first vector to the tip of the last vector.

Phythagorean Theorem:
$c^2=a^2+b^2$

Vector Component:
The parts into which a vector can be separated and that act in different directions from the vector.

07: Force and Motion

Tutorial Summary:

This tutorial will describe Newton's three laws of motion. These simple, but very powerful statements can describe a great deal of the behavior of motion. Additionally, the concept of equilibrium will be introduced. This is a situation where the net force on an object is zero. In situations like this, forces such as friction and air resistance may come into play. Both of these forces tend to slow, or resist any movement. Finally, dynamics problems will be addressed. Here, there is no equilibrium. There is a net force exerted on something that causes an acceleration.

Tutorial Features:

- Graphically see force diagrams with animated components, especially the inclined plane problems.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Newton's Laws
  - Inertia
  - Net Force
  - Action and reaction forces
- Resisting Forces
  - Friction
  - Air resistance
- Dynamics Problems

Content Review:

Newton's 1st law:
Inertia, the tendency to continue in a given state.

Newton's 2nd law:
The acceleration of an object is directly proportional to the net force, and inversely proportional to the mass. F=ma.

Newton's 3rd law:
For every force, there is an equal and opposite force.

One Newton:
The force need to accelerate 1kg at 1 m/s/s.

Normal Force:
A reaction force pointing perpendicular to the surface.

Equilibrium:
When all the forces on an object balance out, or cancel out, the object has a net force of 0.

Friction:
A force that always opposes motion.

Coefficient of friction:
The ratio between the frictional force and the normal force.

08: Circular Motion and Gravitation

Tutorial Summary:

Gravity is a force that you notice almost everyday. This tutorial explains how to calculate or quantify that force. The gravitational inverse square law depends upon the masses involved, and the distant between them. A universal gravitational constant is also needed.

In previous tutorials, motion in a line was extensively described. However, motion in a circle is also very common. The rate at which an object moves in a circular path is described by rotational speed. The rate at which its direction changes in that circular path is called centripetal acceleration. The force that provides this acceleration is called centripetal force. For motion in a circle, the direction of motion is main quantity that will be described.

Tutorial Features:

- Problem-solving techniques are used to work out and illustrate the example problems, step by step.
- Vector diagrams showing force components for a car traveling around a banked curve.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered

- Gravity
  - Formula
  - Gravitational constant
  - Gravitational fields
  - Gravitational pull at various points on Earth
- Circular Motion
  - Linear speed versus rotational speed
  - Centripetal acceleration
  - Centripetal force
  - Centrifugal force
  - Banked roads
  - Simulated gravity

Content Review:

Universal law of gravitation:
The mathematical formula that relates the pull of gravity between two massive objects that are some distance apart. $F_g=Gm_1m_2/d^2$

Gravitation constant:
A proportionality constant that relates the strength of gravitational attraction in Newton's law of universal gravitation. $G=6.67x10^{-11}Nm^2/kg^2$ This value always remains constant.

Gravitational field:

The map of influence that a massive body extends into space around itself.

Rotational speed:
Number of rotations or revolutions per unit of time, often measured in rpm, revolutions per minute. Linear speed is the straight path distance moved per unit of time, also referred to as tangential speed.

Centripetal acceleration:
The acceleration that describes the change in direction for an object in a circular path.

Centripetal force:
A center seeking force for an object moving in a circular path.

Centrifugal force:
An apparent, but nonexistent, outward pointing force for an object moving in a circular path. A rotating object may seem to be pushed outward, but actually must be pulled inward in order to maintain any circular path.

09: Equilibrium

Tutorial Summary:

Equilibrium is a condition where all the forces on an object balance out to give a net force of zero. An object could be in motion or stationary. In either case, there would be no acceleration since there is no net force. This can also occur for force like quantities such as torque. Torque is the measurement that causes rotation. It is a force like quantity. This equilibrium situation would be called rotational equilibrium. In these rotational situations, the quantity of mass is replaced by rotational inertia. Rotational inertia accounts for where the mass is located relative to the axis of rotation. This is important since it is more difficult to rotate a mass that is far away from the axis. For either linear, or rotational motion, equilibrium is an important condition that is often studied.

Tutorial Features:

- Problem-solving techniques are used to work out and illustrate the example problems, step by step. In equilibrium situations, the problems are diagramed to show the relevant forces, torques, or distances.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Equilibrium
  - Static
  - Dynamic
  - Newton's second law application
- Torque
  - Units
  - Direction
  - Applications
- Moment of Inertia
  - Description
  - Example
  - Formulas
- Rotational Equilibrium

Content Review:

Newton's 2nd law:
The acceleration of an object is directly proportional to the net force, and inversely proportional to the mass. F=ma.

Equilibrium:
When all the forces on an object balance out, or cancel out, the object has a net force of 0.

Static Equilibrium:
When an object is in equilibrium, and not moving, this is called static equilibrium.

Dynamic Equilibrium:

An object moving at a constant velocity; no net force acting on it.

Torque:
The rotational quantity that causes rotation; the product of force times lever arm.

Moment of inertia:
Also called rotational inertia, The rotational equivalent of linear inertia; a measure of the ease of rotating some object.

Newton's second law for rotational motion:

$\Sigma \tau = I \alpha$ The sum of the torques is equal to the rotational inertia times the angular acceleration.

Rotational Equilibrium:
The situation when the net torque on an object equals zero.

10: Work, Power and Energy

Tutorial Summary:

This tutorial will show you how to calculate work. Additionally, if the time taken to complete this work is known, the power generated can be found too. Work is related to energy. In fact, work is defined as the change in energy. This is the work energy theorem. This energy can come in many forms. Two of the main types of mechanical energy are kinetic and potential. Kinetic energy is energy of motion, while potential energy is stored energy. In many situations, conservation of energy can be applied to help solve problems. This says that energy isn't created or destroyed, just transferred from one type to another.

Tutorial Features:

- Easy explanation for sometimes confusing physics formulas.
- Animation showing conservation of energy by a skydiver.
- Example problems with step by step solutions and accompanying diagrams to help illustrate the usage of complex formulas.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Work
    - Direction of force
    - Sign conventions
- Power
    - Calculation of power
- Energy
    - Kinetic energy
    - Potential energy
    - Work energy theorem
    - Conservation of energy
- Conservative and non conservative forces

Content Review:

Work:
The work, W, done by a constant force on an object is defined as the product of the component of the force along the direction of displacement and the magnitude of the displacement.

Calculation of Work:
When calculating work, only the force that is applied in the direction of motion is considered. $W=Fd\cos\theta$

Postive Work:
If the force and displacement are in the same direction, that would be considered positive work.

Power:

Power is a measure of how quickly work is done.

Kinetic Energy:
Kinetic energy is energy of motion. All moving object possess kinetic energy.

Gravitational Potential Energy:
Gravitational Potential energy is the energy an object possessed due to its position.

Base Level:
The point that height is measured from. Any point can be used as a base level because the energy amount you calculate will be relative.

Conservation of Energy:
Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.

Conservative Force:
A force is classified as conservative if the work it does on a moving object is independent of the path between the initial and final position, OR it does no net work on an object moving around a closed path, starting and finishing at the same point. Friction or air resistance is an example of a non conservative force.

11: Momentum and Collisions

Tutorial Summary:

This tutorial describes the concept of momentum. This is very similar to inertia in motion. Once a moving object has momentum, it may be changed and brought to a halt. This change in momentum is called impulse. Anytime there is some type of collision or interaction, momentum is transferred. This tutorial describes three main types of momentum collisions: hit and stick, hit and rebound, and explosion. In all of these, the conservation of momentum is observed. Momentum isn't created or destroyed, it's just transferred from one item to the next.

Tutorial Features:

- Problem-solving techniques are used to work out and illustrate the example problems, step by step.
- Animated diagrams to accompany example problems, specifically vector diagrams to show conservation of momentum in 2 dimensions.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Momentum
  - Definition
  - Formula
- Impulse
  - Formula
  - Examples
  - Bouncing versus sticking
- Conservation of momentum
  - Collisions
  - Inelastic versus elastic collisions
  - 2 dimensional collisions

Content Review:

Momentum: Momemtum may be described as inertia in motion. It is the product of mass times velocity. $P = mv$

Impulse: A change in the momentum of an object. It is the product of force times time. $J=Ft$ The impulse may occur over a long or short time period, and with a large or small force applied to make the change in momentum.

Conservation of momentum: Momentum isn't created or destroyed in a given system. It may be transferred from one object to another. Only an outside or external force will change the total momentum.

- When comparing a bouncing collision to a collision where an object is brought to a halt, the bouncing object experiences a much larger impulse.
- A hit and stick collision is when one object impacts another, then they stay as one.

- A hit and rebound collision is when one object hits another and they both remain separate.
- An explosion collision is when an object breaks apart. It may not necessarily be an explosion.

Elastic collision: An elastic collision is one where:

- Momentum is conserved.
- The objects colliding aren't deformed or smashed.
- Thus no kinetic energy is lost; kinetic energy is conserved also.
- *Ex:* billiard ball collisions.

Inelastic collisions: An inelastic collision is one where:

- Momentum is still conserved, but kinetic energy is lost.
- The lost kinetic energy will be transformed into other types.
- The objects often interlock and stick together, they may also be deformed and mangled.
- Ex: car crash.

12: Waves and Periodic Motion

Tutorial Summary:

Periodic motion likes waves come in many types. Mechanical waves need a medium to travel, electromagnetic waves don't. Transverse waves vibrate perpendicular to the wave motion, longitudinal waves parallel. Even a simple swinging pendulum exhibits wave behavior. All of these waves can be described in certain ways. They all have speed, frequency, period, amplitude and wavelength. Wave can also combine, or superimpose with each other. This phenomena leads to interference. This can be constructive or destructive interference. In some situations where there is a boundary to reflect from, this leads to a standing wave that seems to sit in one location. This creates points of no movement, nodes, and points of maximum movement, antinodes.

Tutorial Features:

- Animations to illustrate the dynamic properties of waves.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Simple harmonic motion
    - Vibration
    - Displacement
    - Amplitude
    - Period
    - Frequency
    - Angular frequency
    - Phase
    - Uniform circular motion
    - Pendulums
    - Oscillating springs
    - Resonance
- Wave motion
    - Mechanical vs. electromagnetic waves
    - Transverse vs. longitudinal waves
    - Wave speed
- Wave superposition
    - Interference
    - Wave reflection
    - Standing waves
    - Nodes and antinodes

Content Review:

Amplitude:
The maximum displacement of the body in vibration.

Period:
The time taken by a body to complete one vibration.

Frequency:
Frequency is the number of oscillations completed in a unit time ($f = 1/T$).

Resonance:
The natural frequency of a body executing forced vibrations is equal to the input frequency. The body vibrates with maximum amplitude. The frequency is called resonant frequency.

Mechanical Wave:
A mechanical wave is just a disturbance that propagates through a medium.

Electromagnetic Wave:
An electromagnetic wave is simply light of a visible or invisible wavelength. Oscillating intertwined electric and magnetic fields comprise light. Light can travel without medium.

Transverse Wave:
In a transverse wave the particles in the medium move perpendicular to the direction of the wave. Eg. Light waves, waves on strings.

Longitudinal Wave:
The particles in the medium move parallel to the direction of the wave. Eg. Sound waves.

Interference:
The superposition of two waves of the same frequency and wavelength traveling with a phase difference which remains constant with time. This phenomenon is called interference. The pattern so formed is called interference pattern.

Standing Wave:
Superposition of two waves of same amplitude and wavelength moving in opposite direction with no energy propagation.

Nodes:
The points of no displacement when standing waves are formed.

Antinodes:
The points along the medium which vibrate back and forth with maximum displacement.

13: Sound

Tutorial Summary:

Sound is one of the most important waves to us. It is both a transverse and longitudinal wave. It exhibits all the regular features of other types of waves. We can describe its frequency and period as it relates to the pitch of a sound heard. We can describe its amplitude as it relates to the intensity or loudness of a sound heard. Sound can travel through a variety of substances, but it must be traveling through something as it is a mechanical wave. There are a variety of mathematical formulas to find the speed of sound through a particular substance. Many times sound waves reflect off hard surfaces. This is called an echo. We can use the Doppler effect for various applications. This relates the change in frequency of a wave to the speed of a moving wave source or wave observer.

Tutorial Features:

- Several example problems with step by step illustrations of solutions.
- Animations showing wave motion as it relates to sound.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- The nature of sound
    - Our ears
    - Audible and inaudible sounds
    - Speed of sound
    - Types of waves
    - Speed of various sounds
- Properties of sound
    - Intensity
    - Pitch
    - Octaves
- Beats
- The Doppler effect
    - Definition
    - Formula
    - Applications
- Echoes
- Diffraction

Content Review:

Audible sounds:
The audio spectrum extends from approximately 20Hz to 20,000 Hz.Sounds of frequency between 20Hz and 20,000Hz can be heard by human ear.

Infrasonic sounds:
Sounds of frequency less than 20Hz are called “infrasonics”.

Ultrasonic sounds:
Sounds of frequency greater than 20,000Hz are called‟ultrasonics”.

Ex: Sound produced by bats.

Nodes:
The points of no displacement when standing waves are formed.

Antinodes:
The points along the medium which vibrate back and forth with maximum displacement.

Sound Intensity:
The loudness of sound is directly proportional to the square of the amplitude or intensity (I). It is convenient to use a logarithmic scale to determine the intensity level $\beta = 10$ log (I/I_0).

Pitch:
Pitch is the highest or lowest sound an object makes.

Beats:
Beats are the periodic and repeating fluctuations heard in the intensity of a sound. Two sound waves of nearly same frequencies interfere with one another to produce beats
The intensity of the resultant wave at a given point in the medium becomes maximum (waxes) and minimum (wanes) periodically.

Doppler Effect:
The apparent change in the frequency of sound due to relative motion between the sound source and observer is called Doppler Effect.

Echoes:
The sound obtained by reflection at a wall, cliff or a mountain is called an echo.

Diffraction:
When waves encounter an obstacle with an edge, some of the wave energy bends around the edge behind the obstacle. This bending is called diffraction.

14: Fluids

Tutorial Summary:

The nature of fluids is described through key concepts like Pascal's, Archimede's, and Bernoulli's principle. Various types of fluid flow are described. Smooth laminar flow and chaotic turbulent flow are contrasted. This idea is extended with Bernoulli's equation which describes the relationship between the pressure, kinetic and potential energy in a system as a constant. Throughout, real world examples are describes in the context of fluid flow.

Tutorial Features:

- Example problems with step by step solutions and accompanying diagrams to help illustrate the usage of complex formulas.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Fluids
    - Pascal's principle
    - Buoyancy and Archimedes principle
    - Surface tension
    - Capillary action
- Fluids in motion
    - Viscosity
    - Continuity
    - Laminar and turbulent flow
    - Bernoulli's equation

Content Review:

Buoyancy:
The force caused by pressure variation with depth to lift immersed objects.

Surface tension:
The force to attract surfaced molecular to make the surface area of fluid as small as possible.

Capillary action:
The phenomena of fluids automatically raising in open-ended tubes.

Continuity:
The net rate of flow of mass inward across any closed surface is equal to the rate of increase of the mass within the surface.

Viscosity:
The inter-friction mechanism in fluid to dissipate energy.

Laminar flow:
Every particle passing a particular point moves exactly along the smooth path followed by particles passing that point early.

Turbulent flow:
The irregular flow when the velocity of the flow is high.

15: Solids

Tutorial Summary:

This tutorial covers two topics, solids and fluids. The difference between the ordered atomic structure of crystalline solids, and the random nature of amorphous solids is discussed. Other properties of solids like thermal expansion and various deformations of solids are covered too.

Tutorial Features:

- Animations illustrating Young's and bulk modulus.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- States of matter
- Solids and elasticity
  - Crystalline materials and their properties
  - Amorphous materials and their properties
- Thermal expansion
- Deformation of solids
  - Young's modulus
  - Shear modulus
  - Bulk modulus
- Applications

Content Review:

Matter:
Anything that has mass and takes up space.

Crystalline:
Solids with ordered atom-structure and fixed melting point.

Amorphous:
Solids with in ordered atom-structure and without melting point.

Young's modulus:
Ratio of stress to strain when solids is under tension.

Shear modulus:
Ratio of stress to strain when solids is under shear.

Bulk modulus:
Ratio of stress to strain when solids is under hydraulic pressure.

16: Electrostatics

Tutorial Summary:

Electrostatics describes the state of non moving charges. These charges originate from electron movement. Electrons may be added or removed from some object, but overall charge amount must be conserved. Like charges will repel, and opposite charges attract. This force can be calculated using Coulomb's law. The scope of this electric force can be shown or visualized with an electric field. Electric potential is a quantity that describes the amount of electric potential energy per amount of charge.

Tutorial Features:

- Animation of the concept of charging by induction; shows the movement of charges.
- Animation of the polarization of a neutral object; shows the movement of charges.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- The nature of electric charge
    - Charged particles
    - Charge movement
        - Charging by contact
        - Charging by induction
- Electric Forces
    - Coulomb's law
        - Formula
        - Examples
    - Electric Fields
    - Polarization
- Electric Potential
    - Definition
    - Units
    - Diagram
    - Formula

Content Review:

Electric Charge:
A fundamental intrinsic property of matter that gives rise to the attractions and repulsions between electrons and protons.

Coulomb:
The typical unit for measuring charge; a set number of electrons. 1 Coulomb = 6.25×10^{18} electrons

Charging by Contact:
The transfer of electric charge from one object to another by simple contact or conduction.

Charging by Induction:
Redistribution or charging of an object by bringing a charged item in close proximity to, but not touching, an uncharged object.

Coulomb's Law:
Mathematical relationship between electric force, charge, and distance. The electric force varies directly with the product of the charges, and inversedly to the square of the distance between the charges.

Polarization:
Separation or alignment of the charges in a neutral body so that like charges are grouped together, resulting in a positive and a negative region.

Electric Field:
A force field that fills the space near any charge.

Electric Potential:
The ratio of electric potential energy to electric charge at a particular spot in an electric field. It is often referred to as voltage since it is measured in volts.

Equipotential Line:
A line where all points have an equal electric potential, or voltage.

17: Electromagnetic Radiation

Tutorial Summary:

The electromagnetic spectrum is a map of all the various types of electromagnetic radiation. All of these are combinations of oscillating electric and magnetic fields oriented perpendicular to each other. The various types of waves have a variety of uses. One important phenomena is the greenhouse effect. It illustrates how materials may be transparent to some wave, but not others. This is also a prime example of how physics concepts impact real world issues.

Tutorial Features:

- Animation of oscillating electromagnetic wave.
- Animation of greenhouse effect
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Electromagnetic spectrum
  - Types of electromagnetic waves
  - The nature of EM radiation
- Speed of light calculations
  - Roemer's method
  - Michelson's experiment
- Transparent vs. opaque materials
- The greenhouse effect

Content Review:

Electromagnetic Spectrum:
A diagram that illustrates all the varieties of electromagnetic waves based on their relative frequency/wavelengths. Our eyes observe only a small amount of this spectrum.

Electromagnetic Wave:
A transverse wave composed of a combination of varying electric and magnetic fields that are combined.

Transverse Wave:
A wave where the particles vibrate perpendicular to the direction of the wave motion.

Longitudinal Wave:
A wave where the particles vibrate in a parallel direction to the wave motion.

Transparent:
A material that allows a wave to pass through with relatively little loss of energy.

Opaque:
A material that doesn't allow a wave to pass through. The energy is absorbed or lost in the vibrations of the material's atoms.

Roemer's method:
First mathematical determination of the speed of light. The known diameter of Earth's orbit was used as the distance. Together with a time difference in observing Jupiter's moons, a fairly accurate speed of light was determined.

Michelson's method:
A later and more accurate measurement of the speed of light. A light beam was sent on a round trip to a distance mountaintop. A rotating multisided mirror was used to time the trip. The time and distances were used to refine the speed of light measurement.

18: Magnetism

Tutorial Summary:

Magnetism is a naturally occurring phenomena. In most materials, the magnetic domains are randomly aligned. However, in some cases, they are all aligned to produce a magnet. This creates a magnetic field that extends around the object, moving from North to South. A magnetic field can also be created from a moving charge, or current. The right hand rule is used to visualize this field. When a charge moves through an existing magnetic field, a magnetic force is exerted on it. Magnetic flux describes the number of magnetic field lines passing through a particular area. This idea is similar to rain falling through a hula hoop. Faraday's law describes the induced electromotive force as the change in flux per amount of time. Lenz's law describes the direction of that induced current. Again, the right hand rule can be utilized. A conductor moving through a magnetic field can also create an induced electromotive force. These concepts are the basis for an electric generator. Mechanical motion is converted into electric energy.

Tutorial Features:

- Diagrams showing various magnetic fields.
- Illustrations showing all aspects of the right hand rule.
- Animation showing the relationship between magnetic flux and the induced current.
- Diagrams and animations showing induced emfs in moving conductors.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Magnetism in nature
    - Magnetic domains
    - Ferromagnetism
    - Magnetic field diagrams
- Magnetism, force and moving charge
    - Right hand rule
    - Magnetic field notation
    - Magnetic force on a current carrying wire
    - Magnetic force on a moving charged particle
- Magnetic flux
    - Formula
    - Angle
    - Units
    - Hoop analogy
    - Example
- Faraday's law
    - Formula
    - Induced electromotive force
    - Example
- Lenz's law
    - Right hand rule application
    - Examples
- Electromotive force in a moving conductor

- Applications

Content Review:

Magnetic Domain:
Microscopic areas of atoms where the magnetic fields are aligned.

Ferromagnetic:
A naturally magnetic class of materials where the magnetic domains are ordered and do not cancel out.

Magnetic Field:
Lines showing the shape and extent of a magnetic field around a permanent magnet or a moving charged object. To signify a field coming directly out of the plane of a page, dots are used. To signify a field going directly into the page, an X is used.

Right Hand Rule. RHR:
1. The fingers extend or curl in the direction of the magnetic field.
2. The outstretched thumb points in the direction of conventional current, or the direction of a positively charged moving particle.
3. A line perpendicular to the palm indicates the direction of the magnetic force.

Mass Spectrometer:
A device that magnetically separates charged ions according to their mass. A magnetic field is used to accomplish this separation.

Magnetic flux:
A measurement of the number of magnetic field lines passing through a particular area or surface.

Faraday's law:
The voltage induced is directly proportionoal to the number of loops and the change in the magnetic flux. It is inversely proportional to the time that this change occurs throughout.

Lenz's law:
The induced emf always gives rise to a current whose magnetic flux opposed the original change in magnetic flux. Thus, the induced current tries to maintain the level of magnetic flux.

Electromotive force:
A voltage that gives rise to a current flow. This voltage can be induced or created by a changing magnetic field.

Right hand rule, RHR:
The fingers extend or curl in the direction of the magnetic field. The outstretched thumb points in the direction of conventional current.

Generator:
A machine that produces electricity by a rotating coil of wire immersed in a stationary magnetic field. This rotating motion could be obtained from a variety of sources.

19: Circuit Elements

Tutorial Summary:

Materials may conductor charge flow, resist charge flow, or some variation between those two. The resistance of a piece of wire depends upon several factors: the type of material, the length of wire, the cross section of wire, and the temperature of the wire. Capacitors are oppositely charged sections of conductors held near each other. Although they have a net charge, they store energy due to the proximity of the oppositely charged plates. The strength or capacitance of a capacitor depends on the area of the plates, the distance between them, and a constant. This capacitance could also be increased by adding an insulating material between the plates. This is called a dielectric.

Tutorial Features:

- Animated diagram of a capacitor charging and discharging.
- Problem-solving techniques are used to work out and illustrate the example problems, step by step.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Conductors
  - Conductors
  - Insulator
  - Semiconductors
  - Superconductors
  - Resistance of a piece of wire
- Capacitors
  - Definition
  - Units
  - Diagram
  - Charge stored in a capacitor
- Dielectrics
  - Polarization
  - Dielectric constant

Content Review:

Conductor:
Material where electrons are loosely bound and are able to flow throughout due to the free electrons.

Insulator:
Materials where electrons are bound and don’t flow easily.

Semiconductor:
Materials in between insulator and conductor.

Superconductor:

A material where electrons flow without any resistance. Generally, superconductivity only occurs at very low temperatures.

Resistivity:
An intrinsic property of a material that partially determines the resistance of a wire.

Capacitor:
A device used to store or accumulate electric energy. This is done by oppositely charging two nearby conductive surfaces that are not in contact with each other.

Dielectric:
An insulating material is inserted between the plates of a capacitor.

Dielectric Constant:
The factor that describes the additional capacitance gained by adding a dielectric material between the plates of a capacitor.

20: Electric Circuits

Tutorial Summary:

Electric circuits come in a variety of styles. Voltage may be direct or alternating. Regardless of the type, Ohm's law can be used to find a few basic quantities. Voltage is equal to current times resistance. Also, power can be calculated by current times voltage. When circuit components are arranged one after another in a loop, this is a series circuit. When the components are arranged in separate, independent connections to the voltage source, that is a parallel connection. Capacitors too may be combined in series or parallel. In either of these cases, the particular connection has particular properties.

Tutorial Features:

- Circuits diagrams simplified into less complex circuits.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Ohm's law
    - Circuit diagrams
    - Alternating current
    - Direct current
    - Internal resistance
- Electric power
    - Formula
    - Example calculations
    - Alternating power formulas, rms.
- Series circuits
    - Resistors combined in series
    - Current and voltage characteristics
    - Example calculations
- Parallel circuits
    - Resistors combined in parallel
    - Current and voltage characteristics
    - Example calculations
- Capacitor combinations

Content Review:

Current:
Electrical charge flow past a given point per unit of time.

Direct current:
Electrical current that flows in only one direction.

Alternating current:
Electrical current that oscillates forward and backwards.

Voltage:

The ratio of electric potential energy to electric charge at a particular spot in an electric field. It is often referred to as voltage since it is measured in volts.

Ohm's law:
Basic law that describe current electricity; Voltage equals current times resistance.

Internal resistance:
Resistance from the processes inside a voltage source; resistance due to the battery itself.

Series circuit:
A circuit where the components form one continuous loop. The current is constant throughout.

Parallel circuit:
A circuit where each component is connected to form its own separate independent branch. The voltage is constant throughout.

Fuse/Circuit breaker:
A safety device designed to melt or disconnect a circuit after a predetermined amount of current is exceeded.

21: Light

Tutorial Summary:

Light can behave as a particle, or a wave. In this tutorial topic, the wave nature of light is emphasized. Young's double slit experiment shows how light can constructively and destructively interfere. The alternating bright and dark fringes are explained mathematically. Diffraction grating of multiple slits also exhibit similar behavior. Another wave feature of light is polarization. Because light is a transverse wave, it can be polarized to vibrate in only one direction. This can be accomplished with polarizing filters. Malus' law describes the reduced light intensity caused by a pair of polarizing filters.

Tutorial Features:

- Diagram showing interference during Young's double slit experiment.
- Examples with step by step assistance to solve problems.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Principle of superposition
    - Constructive interference
    - Destructive interference
- Coherent and monochromatic light
- Young's double slit experiment
    - Maxima positions
    - Minima positions
    - Formulas
    - Examples
- Diffraction gratings
    - Formula
    - Examples
- Polarization
    - Unpolarized light
    - Filters
    - Malus' law

Content Review:

Electromagnetic spectrum:
A diagram that illustrates all the varieties of electromagnetic waves based on their relative frequency/wavelengths. Our eyes observe only a small amount of this spectrum.

Principle of superposition:
When two or more waves occupy the same region of space simultaneously, the resulting wave disturbance is the sum of separate waves.

Constructive interference:
Two or more waves superimposing to create a resulting wave that has a larger amplitude.

Destructive interference:
Two or more waves superimposing to create a resulting wave that has a smaller amplitude.

Thin film interference:
The principle that creates colors on thin layers of transparent substances. The light reflecting off the interior of the substance interferes with light reflecting off the exterior.

Coherent light:
Light wave that are all in phase or in step.

Monochromatic light:
Light waves that possess the same frequency, color, or wavelength.

Diffraction:
The bending of waves around obstacles, corners, or openings.

Polarized light:
Light where the electric field fluctuates in only one direction.

22: Geometric Optics

Tutorial Summary:

Light can reflect as it bounces off a sufficiently smooth barrier. In doing this, it will obey the law of reflection that says the incident angle is equal to the reflected angle. Reflection can also occur for curved mirrors, both convex and concave. In these instances, real or virtual images can be formed. Ray diagrams can be used to trace the behavior of light and determine the image. The mirror formula can also be used to calculate variables. When light passes into transparent materials, it may refract or bend. Snell's law describes this quantitatively. Sometimes the light is bend so much that it doesn't emerge from the transparent material. This is called total internal reflection. This bending of light is the basic behind the operation of a lens. Convex and concave lenses can form real and virtual images too. Again, both ray diagrams and the lens equation can be used to describe the resulting image.

Tutorial Features:

- Many animated ray diagrams for mirrors and lenses showing image formation.
- Examples with step by step assistance to solve problems.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Plane mirrors
  - Law of reflection
  - Virtual images
  - Diffuse reflection
  - Importance or wavelength
- Curved mirrors
  - Concave mirror ray diagram
  - Convex mirror ray diagram
  - Mirror equation and example
  - Magnification equation and example
- Refraction
  - Index of refraction
  - Refraction example and analogy
  - Snell's law
  - Dispersion
  - Total internal reflection
  - Fiber optics
- Lenses
  - Convex lens ray diagram
  - Concave lens ray diagram
  - Lens equation and example
  - Lens combinations
  - Lens defects

Content Review:

Law of reflection:
The angle of incidence equals the angle of reflection.

Diffuse reflection:
Reflection from a rough surface where variations in the direction of the surface cause light to reflect in different directions.

Convex mirror:
Also called a diverging mirror, a surface that diverges light as if it originates from a point behind the mirror, a focal point.

Concave mirror:
Also, called a converging mirror, a surface that converges light to a single point, focal point.

Real image:
An image where the rays of light actually meet at a location. It can be projected onto a screen.

Virtual image:
An image that cannot be projected onto a screen. The rays of light don't actually converge there, they just seem to originate from that location.

Refraction:
The bending of light due to its change in velocity in various media.

Index of refraction:
The ratio between the speed of light in a vacuum and a particular medium.

Snell's law:
The formula that describes the amount of refraction of light based on the two different media and the angle of the light ray: $n_1\sin\theta_1=n_2\sin\theta_2$

Total internal reflection:
The complete reflection of light when it strikes the boundary between two media at greater than a critical angle.

Convex lens:
A converging lens that gathers incoming light to a single focal point.

Concave lens:
A diverging lens that diverges light as if it originates from a point behing the lens, the focal point.

Spherical aberration:
A lens defect where light is imperfectly focused near the focal point.

Chromatic aberration:
A lens defect where various color focus at different locations.

23: Atomic Physics

Tutorial Summary:

Atomic physics deals with the structure and behavior of the atom. One of the most elementary and important parts of the atom is the electron. It was discovered in 1897 by J. J. Thomson. The behavior of these electrons, and thus the whole atom itself, was described by the Bohr theory of the atom. This said the electrons occupy certain discrete, quantized orbits. They cannot occupy the areas in between the set orbits. This unusual explanation explains atomic spectra observations very well. Another important aspect of atomic structure is the wave particle duality. Sometimes light can behave as a wave, other times as a particle. The same can be said of matter. Louis deBroglie explained how particles can have wave attributes like a wavelength. These ideas, along with other contributions, helped explain the structure of the atom.

Tutorial Features:

- Animations of the discovery of electrons, the Bohr model of the atom, and electron transitions.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- The discovery of electrons
- The Bohr model of the atom
    - Postulates
    - Radii and energy level values
    - Quantization
    - Spectrum explanation
- X rays
    - Characteristics
    - Production
- The wave nature of matter
    - Particle and wave duality
    - Formulas
- deBroglie hypothesis
- Heisenberg's uncertainty principle

Content Review:

Electron:
Electron was discovered during experiments on the discharge of electricity through rarified gases. The magnitude of electric charge (e) was determined by Millikan. Charge of the electron = 1.602×10^{-19} coulomb

Bohr Model of the Atom:
Proposed by Neil Bohr in 1913. Bohr applied the Planck's quantum theory to the Rutherford nuclear atom with remarkable success.

First postulate:

An atom consists of a positively charged nucleus at the centre. The electrons move round the nucleus in certain stationary orbits of definite radii and not all possible radii.

Second postulate:
The radius of the orbit is such that the angular momentum of the electron is an integral multiple of h/2p.

Third postulate:
Electron may jump from one orbit to the other, in which case the difference in energy between the two states of motion is radiated in the form of a light quantum.

X-Rays :
Invisible electromagnetic radiations, Wavelengths range form 0.010A – 100A. These are discovered by Roentgen. When a fast moving electron is suddenly stopped a part of its kinetic energy is converted into X-ray photon the rest of the energy is converted into heat.

Wave Particle Duality:
To understand any given experiment, we must use either the wave or the photon theory, but not both. Light sometimes behaves like a wave and some times like a particle.

de Broglie Hypothesis:
Photons are treated as "packets of light" behaving like a particle. Momentum of a photon: $p = E / c = h/\lambda$ Energy of a photon: $E = hc/\lambda$

Heisenberg Uncertainty Principle:
If position is identified the momentum cannot be measured. If momentum is measured the position is lost. $\Delta x \times \Delta p \geq h / 4\pi$

24: Nuclear Physics

Tutorial Summary:

This tutorial specifically describe the structure and behavior of the atomic nucleus. The nucleus is composed of neutrons and protons. Obviously the similarly charged protons repel each other, but nuclear forces usually overcome that tendency and the nucleus is kept intact. However, sometimes that repulsion is too great and the nucleus crumbles apart. This is the process of radioactivity. Alpha, beta, and gamma are the three types of nuclear radioactivity. Each has different properties. A nucleus may also break apart into roughly two equal pieces, this is the process of nuclear fission.

Tutorial Features:

- Animations depicting nuclear processes like fission and radioactivity.
- Step by step analysis of an example of the concepts of binding energy and mass defect.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Animated examples—worked out step by step.
- A concise summary is given at the conclusion of the tutorial.

Concepts Covered:

- Nuclear composition
    - Notation
    - Forces
    - Binding energy
    - Mass defect
    - Isotopes
- Radioactive decay
    - Alpha decay
    - Beta decay
    - Gamma decay
    - Nuclear equations
- Half life
- Applications of nuclear science

Content Review:

Atomic Number:
The number equal to the number of protons in an atom that determines its chemical properties. Symbol: Z

Atomic Mass:
The mass of an atom expressed in atomic mass units.

Strong (nuclear) Force:
A fundamental force that is associated with the strong bonds between quarks and other subatomic particles.

Weak (nuclear) Force:
One of the four fundamental forces that is associated with nuclear decay.

Binding Energy:
The energy needed to separate the constituent parts of an atom or nucleus.

Mass Defect:
The difference between the mass of an atom and the sum of the masses of its individual components.

Mass-Energy Equivalence:
All mass represents an equivalent amount of energy. 1 amu = 931 MeV.

Radioactivity:
Emission of radiation as a consequence of a nuclear reaction, or directly from the breakdown of an unstable nucleus.

Half Life:
The time required for half of the nuclei in a sample of a specific isotope to undergo radioactive decay.

Alpha Particle:
A positively charged helium nucleus (consisting of two protons and two neutrons).

Beta Particle:
An energetic electron produced as the result of a nuclear reaction or nuclear decay.

Gamma Particle/Ray:
Very high frequency electromagnetic radiation emitted as a consequence of radioactivity.

Fission:
The process whereby one item splits to become two.