## MECHANICS - KINEMATICS

M-K5 Stroboscopic observation of motion.

M-K6 Vectors: Shadow projection of a vector to obtain a component.

M-K1 Addition of Vectors: A moving toy car on a moving road.

M-K7 Uniformly accelerated linear motion: A roller on an inclined plane.

M-K8 Uniformly accelerated linear motion: A falling projectile leaves a position versus time record on a spark tape which can be shown on an overhead projector.

M-K2 Independence of free fall and initial velocity: A ball shot vertically from a moving car lands back on the cart.

M-K3 Independence of free fall and initial velocity: The motions of two falling balls, one dropped and one projected horizontally, are compared.

M-K4 Independence of free fall and initial velocity: Shooting a falling target with a dart gun. We have a new and easier setup on this old favorite.

## MECHANICS - DYNAMICS

M-D5 The large air track

M-D11 The air table

M-D1 Acceleration is an inverse function of mass: A spring-driven auto with weights

M-D4 Acceleration is an inverse function of mass: Two unequally loaded carts shoot apart by a spring.

M-D2 Force action and reaction: A spring-driven auto on a glass road on an air table.(The original spring driven auto is broken but a battery powered truck can be use with a similar results.)

M-D9 Rocket propulsion: A CO2 propelled rocket plane on overhead wire.(This is only available in Room 5 Physics)

M-D3 Acceleration of a body does not depend upon the source of the force: Two large equipment carts and a rope. Or two roller skates and a rope.

M-D13 Newton's Laws: A working version of Atwood's machine.

M-D12 Inertial mass: An inertial balance whose oscillation frequency is a measure of the mass of an object placed on a platform.

M-D6 Inertia experiment: A steel ball resting on a removable card.

M-D7 Inertia experiment: A heavy ball suspended by a string.

M-D8 Inertia experiment: A wooden pencil standing on end on a piece of paper.

M-D10 Gravitation: A coin and a wad of cotton fall in an evacuated glass cylinder.

M-D14 Gravitation(Out of Order): A Laser beam aimed at the mirror of a Cavendish balance is reflected onto a wall or a screen.(Note: the Cavendish balance is broken)

M-D15 Chaos pendulum

## MECHANICS - ENERGY AND MOMENTUM

M-Eng Mom 12 The air track and air table

M-Eng Mom 1 Conservation of energy: A large pendulum suspended from the ceiling.

M-Eng Mom 4 Conservation of energy: A toy yo-yo.

M-Eng Mom 5 Conservation of energy: A pendulum with a changeable length.

M-Eng Mom 6 Conservation of energy: Rollers on inclined planes.

M-Eng Mom 7 Conservation of energy: Roller on a wavy track.

M-Eng Mom 8 Conservation of energy: Ball in a glass funnel.

M-Eng Mom 14 Conservation of energy: A flexible track for constructing a loop-the-loop.

M-Eng Mom 15 Conservation of energy: A can containing a hidden weight on a horizontally stretched rubber band returns after being rolled away.

M-Eng Mom 10 Conservation of energy: The pile driver.

M-Eng Mom 18 Conservation of energy: The Hopper Popper. A hollow rubber hemisphere turned inside out gains kinetic energy when dropped.

M-Eng Mom 13 Conservation of energy: A bowling ball suspended from the ceiling is used to demonstrate potential energy transformed into kinetic energy.

M-Eng Mom 9 Potential energy and neutral equilibrium: Parallelogram configuration of the platform balance.

M-Eng Mom 11 Mechanical system seeks minimum potential energy: Double cone on sloped diverging rails.

M-Eng Mom 17 Center of mass: A set of heavy cardboards which are tossed in the air to illustrate the parabolic motion of the center of mass point.

M-Eng Mom 2 Conservation of momentum: A ballistic pendulum.

M-Eng Mom 3 Nearly elastic collisions: Steel impact balls.

M-Eng Mom 16 Impulse: The average force between a hammer and a nail are estimated by measuring the contact time. A vise can also be used to estimate the force necessary to advance the nail into a board.

M-Eng Mom 19 Conservation of angular momentum: rattleback.

M-Eng Mom 20 The vortex: (similar to M-Eng Mom 8) A cent or ball enters the funnel with some kinetic energy and spins round and round.

## MECHANICS - SURFACE TENSION

M-ST1 Pressure in a small soap bubble is greater than in a large bubble: A small bubble blows up a large bubble.

M-ST2 Strength of surface tension of water: The containing of water in a sieve or strainer.

M-ST3 Strength of surface tension of water: Cheesecloth and a glass tumbler.

M-ST4 Soap films on wire frames.

M-ST5 The lowering of the surface tension of water by camphor: A camphor-driven paper boat.

## MECHANICS - CIRCULAR MOTION

M-CM1 Angular Measurement: Device showing a variable angle.

M-CM6 Forces in circular motion: Steam engine fly-ball governor.

M-CM7 Forces in circular motion: Puzzle consisting of two balls mounted on a wooden arc.

M-CM2 Forces in circular motion: A large conical pendulum hung from ceiling.

M-CM3 Forces in vertical circular motion: Pail or glass with water spun by hand in a vertical circle.

M-CM9 Forces in vertical circular motion: A penny balanced on a coat hanger is spun in a vertical circle.

M-CM4 Forces in circular motion: A rolling chain loop.

M-CM5 Forces in circular motion: Mechanical model of a cream separator.

M-CM8 The centrifuge: Separation of mercury from colored water in a model centrifuge.

## MECHANICS - ROTATION

M-Rot 7 Moment of inertia: A set of two long similar tubes of equal mass, one weighted in the center and one weighted at the ends.

M-Rot 1 Moment of inertia and conservation of energy: Various cylinders and spheres on an inclined plane.

M-Rot 5 A falling stick which pivots about one end has points that accelerate faster than g: A hinged stick with several cups attached to catch a ball.

M-Rot 2 Conservation of angular momentum: Two masses spinning in a circle of variable radius.

M-Rot 3 Conservation of angular momentum: A bicycle wheel and a large rotating platform.

M-Rot 8 Conservation of angular momentum: Hoberman Sphere, a colorful plastic globe that can contract and expand.

M-Rot 4 Principles of the gyroscope: A motor driven gyroscope and a bicycle wheel suspended at one point on its axis.

M-Rot 6 Rigid body rotation: A bowling ball mounted on an air bearing demonstrates precession and nutations.

## MECHANICS - STATICS

M-S2 Equilibrium of forces: A weight supported in the middle of a long, nearly horizontal rope.

M-S5 Equilibrium of forces on an extended body: Long plank supported by two scales.

M-S7 Equilibrium of forces on an extended body: Toy monkey on a string who goes up when pulled down!

M-S10 Equilibrium of forces on an extended body: A large slipping ladder for the lecturer to climb.

M-S12 Equilibrium of forces on an extended body: A string which supports a floating object at one end always remains vertical.

M-S18 Equilibrium of forces on an extended body: Model sailboat in a tank of water.

M-S20 Equilibrium of forces on extended bodies: One side of an arch is constructed of similar blocks past the point most students expect collapse.

M-S14 Quasi-equilibrium of forces on an extended body: Large yellow yo-yo that can be made to roll forward, backward or to skid.

M-S8 Equilibrium near a potential energy minimum: A loaded disc on an inclined plane.

M-S19 Equilibrium near a potential energy minimum: Hammer tied to meter stick dangling below support point.

M-S21 Equilibrium near a potential energy minimum: A toy clown with long weighted outriggers rides a unicycle on a sloped high wire.

M-S11 Potential energy and neutral equilibrium: Parallelogram configuration of the platform balance - same as Eng-Mom 9.

M-S9 Stable equilibrium when center of gravity is over the base of an object: Model of the leaning power of Pisa.

M-S16 Stable, unstable, and neutral equilibrium: A solid cone.

M-S13 Simple machines: A differential hoist supporting a heavy weight.

M-S4 Simple machines: Various pulley systems.

M-S17 Simple machines: A screwjack.

M-S15 Orientation of frictional force: A wooden block held between the hands.

M-S1 Normal and frictional components of a contact force: Object in equilibrium on a large inclined plane.

M-S6 Influence of normal force on friction: Meter stick on two movable supports.

M-S3 Fooling the senses: Two identical packages, one light and one heavy.

## Mechanics - Hydrostatics

M-HS1 Pascal's Principle: The hydraulic press.

M-HS2 Pressure in a liquid yields a force outwardly normal to the container surface: Tube with a bottom made of sheet of plastic in a vessel of water.

M-HS4 Pressure in a liquid yields a force outwardly normal to the container surface: A flat object pressed flat against the bottom in a container of mercury will remain in place.

M-HS14 Pressure in a liquid depends on its density and the depth: A U-tube with water in one side and kerosene in the other.

M-HS5 Pressure in a liquid in an open vessel depends only on the depth below the free surface: Pascal's vases.

M-HS18 Pressure in a liquid: The pressure in a liquid increases as the depth below the surface of the liquid increases.

M-HS11 The response of a mercury barometer to changing pressure: A mercury barometer and a vacuum pump.

M-HS6 Air has weight: Balance with a hollow sphere that can be evacuated.

M-HS7 Atmospheric pressure: A large weight is lifted by a piston subjected to atmospheric pressure on one side.

M-HS10 Atmospheric pressure: Magdeburg hemispheres.

M-HS15 Atmospheric pressure: A board extending over the edge of a table and covered by a newspaper at the other end is broken when the free end is struck sharply.

M-HS19 Atmospheric pressure: To show how substantial atmospheric pressure is by vacuuming a can (if you can find one) to crush it.

M-HS20 Atmospheric pressure: Air in a metal can is replaced with water vapor (steam) which is condense back to water thereby creating a partial vacuum, and the can is crushed by external atmospheric pressure.

M-HS9 The siphon: A water siphon and a gaseous CO2 siphon.

M-HS3 Buoyancy of a compressible object whose average density is nearly that of water: The Cartesian diver.

M-HS12 Buoyant objects in accelerating fluids: A balloon in a car or a cork in a bottle. Accelometer: Ping-Pong ball in water.

M-HS13 Pressure gauges: A Bourdon gauge and an aneroid gauge.

M-HS8 Hydraulic puzzle.

M-HS16 Buoyancy: Sinking battleship.

M-HS17 Buoyancy: A vat full of water (brimful) and the same vat full of water with wood floating in it.

## Mechanics - Hydrodynamics

M-HD-1 The water bell.

M-HD-3 Bernoulli's principle: A ball drawn into a funnel and a card drawn to a flat disc with air emerging through a hole in its center.

M-HD-2 Bernoulli's principle applied to jets: Balls in water and air jets, drawing together of two balls by an air jet, the atomizer.

M-HD-4 Bernoulli's principle applied to jets: A balloon supported by a vertical column of air from an electric fan.

M-HD-6 Bernoulli's principle: Ping pong balls supported above metal tube with holes.

M-HD-7 Bernoulli's principle: Ping pong ball supported by air flow from funnel above it.

M-HD-5 The Magnus phenomenon: Throw curve balls with a launching trough .

## MECHANICS - SIMPLE HARMONIC MOTION

M-SHM1 Comparison of projected circular motion and simple harmonic motion: A rotating wheel and a mass on a spring.

M-SHM2 Simple harmonic motion: A vibrating hacksaw blade.

M-SHM3 Simple harmonic motion: A large pendulum suspended from the ceiling.

M-SHM4 Simple harmonic motion: A small torsional pendulum with an adjustable moment of inertia.

M-SHM8 Simple harmonic motion: A large torsional pendulum.

M-SHM5 Simple harmonic motion: A heavy physical pendulum with adjustable period.

M-SHM6 Coupled oscillators and resonance: Two coupled pendula of similar length; a Wilburforce pendulum constructed of a mass on a helical spring tuned to have a vertical translational frequency nearly equal to the rotational frequency.

M-SHM7 Lissajous patterns: Pasco synthesizer allows perfectly stable patterns to be displayed on an oscilloscope.

## WAVE MOTION AND SOUND

WMS-1 Types of traveling waves: The large, mechanical wave machine.

WMS-2 Transverse waves: Waves on a hand-driven rope, standing wave on a machine driven string.

WMS-3 Longitudinal waves: A giant slinky suspended horizontally.

WMS-14 Sound does not travel through a vacuum: An evacuated jar containing a bell.

WMS-10 A sounding body is in mechanical motion: A tuning fork and ping pong ball.

WMS-11 The motion of a tuning fork: A large tuning fork and a stroboscope.

WMS-13 Relation of pitch to frequency: The siren and a card held against a toothed wheel.

WMS-12 The frequency limit of human hearing: Galton whistle, oscillator, speaker, microphone and oscilloscope.

WMS-30 Combinational tones: The audience hopefully hears the sum and difference frequencies of two loud tones.

WMS-7 Synthesis of standing waves: A small mechanical wave machine whose shadow is projected.

WMS-8 Standing sound waves: Speakers, microphone, and oscilloscope.

WMS-17 Three dimensional standing sound waves: Two speakers, oscillator, and amplifier generate standing waves throughout lecture room.

WMS-33 Standing sound waves: A flexible corrugated plastic tube emits a loud pure tone when swung in a circle while holding one end. [AJP 42, 278 (1974)].

WMS-34 Standing sound waves: Long aluminum rod rings loud and clear when held at a nodal point and stroked longitudinally with rosin on chamois.

WMS-38 Standing waves: A long thin plastic rod shaken by hand.

WMS-9 Standing waves on a vibrating plate: Nodes of two-dimensional standing waves are made apparent by sand on vibrating Chladni plates.

WMS-29 The harmonic nature of the overtones of a vibrating string: The sonometer.

WMS-31 The harmonic nature of the overtones of a vibrating air column: The harmonic pipe.

WMS-22 The pitch of an instrument depends on the speed of sound: An organ pipe that is sounded with either air or natural gas.

WMS-24 The pitch of an instrument depends on the speed of sound: Speaking with your vocal cavities filled with helium.

WMS-26 The vibrational frequency of a struck bar depends on its rigidity: Wooden bars with rectangular cross sections.

WMS-27 Resonant frequencies of objects depend on their dimensions: Musical slats.

WMS-28 Vibrating bars: The metallophone, a xylophone-like instrument.

WMS-16 High quality sound rods and forks.

WMS-25 An artificial larynx.

WMS-4 Propagation of waves: A commercial ripple tank.

WMS-5 Propagation of sound: A set of large, glass slides.

WMS-6 Refraction of waves: A mechanical analog.

WMS-15 Reflection of sound waves: A watch at the focus of a large parabolic mirror can be heard tens of feet away.

WMS-36 Interference of waves: Transparencies to show Moire interference patterns.

WMS-37 Wave propagation, interference and diffraction: A set of three ultrasonic transducers can be used to show traveling sinusoidal waves, double source interference, and diffraction.

WMS-19 Interference of sound waves of the same frequency: A special tuning fork designed to radiate from the prongs.

WMS-18 Interference of sound waves of differing frequency (beats): Two audio oscillators with speakers or two similar organ pipes.

WMS-43 Beats using 2 function generators.

WMS-35 Fourier synthesis: Several periodic waveforms can be approximated with up to 9 harmonics using the Fourier synthesizer and oscilloscope.

WMS-21 Resonance: A set of two sounding bars, one of which can excite the other from a large distance.

WMS-23 Resonance: Amplifying the sound from a tuning fork with your large open mouth.

WMS-39 Resonance: Three pairs of rods weighted at the free ends. When a rod is made to vibrate, the corresponding pair also vibrates.

WMS-41 Resonance demo with a drinking straw.

WMS-20 The Doppler effect: A mechanical analog of a traveling string with paper riders.

WMS-45 Doppler whistle. Sonalert connected to a power supply.

WMS-46 Doppler whistle on a motor.

WMS-32 Pre-recorded effects: A set of two records demonstrating various musical and physical effects, including musical scales, overtones and the Doppler effect.

WMS-40 Organ pipe.

WMS-42 The wave demonstrator.

WMS-44 Standing wave patterns in a closed box. Volume is adjustable.

WMS-47 Interference of two sources: The locus of points in 3-dimensional space.

WMS-48 Musical Instruments: Collection of miscellaneous musical instruments.

WMS-49 Savart's Wheels: Teeth with a ratio of 4, 5, 6, and 8 produce a major chord.

WMS-50 Speaker and Candle: a flickering candle demonstrates the longitudinal nature of sound waves.

WMS-51 Kundt's Tube: a glass tube show standing wave generated from a speaker.

## HEAT

H-1 An exhibit of thermometers.

H-46 Constant volume air thermometer.

H-2 Thermal expansion of materials: The expansion of a long current-carrying wire.

H-6 Thermal expansion of materials: The demonstration of the expansion of a hole using a ball and ring.

H-7 Thermal expansion of materials: The expansion of a cavity in a solid is demonstrated by noting the initial reverse response of a model thermometer.

H-8 Thermal expansion of materials: A working model of a compensated pendulum.

H-41 Thermal expansion of materials: A large meter is mechanically driven by an expanding rod heated with steam.

H-3 Differential thermal expansion: Various bimetallic strips with one arranged to open and close a switch to turn lights on.

H-4 Thermal expansion of a gas: The Galilean gas thermometer, an early type of gas thermometer.

H-5 Differential gas thermometer: Franklin's pulse or palm glass.

H-10 The dependence of the electrical resistance of metals on temperature: An electric light is greatly dimmed by the heating of wire in series with it.

H-12 Low temperature behavior of materials: Various liquid nitrogen demonstrations.

H-13 An alloy with a melting point near room temperature: A teaspoon made of Wood's metal melts in a cup of hot water.

H-14 Thermal conductivity: The thermal diffusivity (conductivity) of various rods with uniformly spaced balls supported by wax are compared.

H-15 Thermal conductivity: The boiling of water in a paper box over an open flame.

H-16 Thermal conductivity: A flame chars thin paper in contact with wood but not paper in contact with metal.

H-17 Thermal conductivity and the flash point of a gas: The containment of a flame by a wire screen - the Davy safety lamp.

H-18 Convection of gases: A vertical windmill driven by an electric lamp, a candle in a divided vertical glass tube.

H-19 Thermal radiation: A cone heater, two concave metal reflectors and an ordinary rotating-vane radiometer.

H-22 Thermal radiation: Radiation from various surfaces of a cube is detected with a thermopile.

H-20 Absorption of radiation: The arc lamp ignites graphite-coated paper but not clean bond paper.

H-21 Transmission of visible and near infrared radiation by materials: Water is transparent in the visible and nearly opaque in the infrared, while iodine in CS2 solution is opaque in the visible yet more transparent in the infrared.

H-23 Thermal energy transfers: A thermos bottle exhibit.

H-9 The measurement of temperature differences and thermal radiation: The thermocouple and the thermopile.

H-24 Comparison of specific heats: Hot cylinders of different metals melt into a paraffin slab various distances proportional to their specific heats.

H-25 Critical temperature of a gas: CO2 in a pressurized tube is passed through the critical temperature while the liquid-gas interface is projected on the wall.

H-26 Regelation of ice: A weighted wire will pass through an ice cube yet leave it whole.

H-28 Cooling by evaporation: Water at one end of a closed glass container, a cryophorus, is frozen by evaporation when the other end is placed in liquid nitrogen.

H-29 Cooling by evaporation: CO2 escaping from a tank of liquid CO2 forms solid CO2.

H-42 Cooling by evaporation: Liquid nitrogen in a large transparent dewar freezes after rapidly boiling when a vacuum pump is turned on.

H-33 The dependence of the boiling point on pressure: A flask of hot water starts to boil when ice is placed against the top of the flask.

H-30 Liquification of air: Air in a balloon is liquified when placed into liquid nitrogen and gently squeezed.

H-31 Vapor pressure of liquids: The vapor pressure of liquids riding on top of mercury in barometer tubes are compared.

H-32 Nucleation aids condensation: A fog is alternately made and evaporated in a smoke-filled flask.

H-34 Adiabatic Compression of a gas: Cotton in a glass cylinder ignites when the air within is rapidly compressed.

H-35 Conversion of mechanical work to heat: A water-filled pipe pops its cork when it is tightly squeezed as it rapidly rotates.

H-36 Heat engines: A working model of Hero's engine.

H-38 Heat engines: A "dipping duck" engine driven by the cooling effect of evaporating water.

H-40 Heat engines: A large working engine consisting of a heavy wheel on a flexible axle which is driven by the asymmetric thermal expansion of the axle caused by a collection of heat lamps.

H-39 Heat engines: An exhibit of a model gasoline engine and a model steam engine.

H-45 Nitinol engine: Nitinol helical spring contracts when heated, expands when cooled. When it contracts, it provides torque to turn gear connected to pulley which then turn large rod disk.

H-49 Thermobile(Nitinol Engine):Nitinol wire is heated and then contracts causing a large wheel to turn.

H-47 Stirling cycle engine: The wheels connected to the engine rotate while the end of the piston is heated with an alcohol flame.

H-27 A geyser: A working model of a geyser.

H-43 Boyle's Law: Weights on a syringe piston.

H-44 Thermoelectric converter.

H-48 Water is a poor conductor of heat.

H-11 The principles and simulation of optical pyrometer.

## LIGHT

L-1 Rectilinear propagation of light: A pinhole projector.

L-2 Reflection of light by intersecting plane mirrors: Two mirrors hinged at their intersection, two large mirrors and a small retroreflecting cube.

L-4 Reflection of light: Moderately large concave, convex and plane mirrors.

L-5 The real image: The real image of a hidden light bulb is formed by a large concave mirror.

L-8 Reflection and refraction: The Hartl disc demonstrates ray paths through simple optical components.

L-45 Reflection and refraction: A blackboard optics kit consisting of two sources and various two-dimensional mirrors, lenses and a prism for large scale ray diagrams.

L-46 Reflection and refraction: Several parallel laser beams incident on a large mirror or lens are made visible with chalk dust.

L-11 Reflection and refraction: A change in the index of refraction at an interface is necessary for the reflection or refraction of light - a ground glass in a clear liquid with the same index of refraction is invisible.

L-3 Refraction of light: Water tank for demonstrating reflection, refraction and total internal reflection at the surface.

L-17 Refraction of light: The shadow of a card is shortened by passing through a glass cube.

L-15 Refraction of light: A mechanical analog - refer to WMS-6.

L-6 The continuous spectrum and the absorption spectra of solid materials: A spectrum is produced using a prism illuminated with an arc lamp or a slide projector.

L-7 Deviation, dispersion and achromatism: Prisms of various materials.

L-16 Prisms and glasses: An exhibit of various prisms and a sample of uranium glass.

L-44 Total internal reflection: A laser beam follows a parabolic stream of water emerging from a lucite box.

L-9 Total internal reflection: A soot-covered ball in water appears silvery.

L-10 Total internal reflection: A curled lucite rod illuminated at one end.

L-52 Total internal reflection of microwaves: Microwaves are reflected by a prism of salt and are transmitted along a flexible tube filled with plastic beads.

L-14 Spherical and chromatic aberrations: A large lens with various masks.

L-25 Polarization by reflection: Light from a white lamp is reflected from window glass and analyzed with a polaroid sheet.

L-26 Polarization of mechanical vibrations: Wooden bars with rectangular cross sections - see WMS-26.

L-27 Polarization of light: Two large polaroid sheets and a third small piece on the overhead projector.

L-28 Polarization of light: A mechanical analog of the demonstration L-27.

L-32 Polarization of scattered light: Light is scattered from an arc beam by a suspension of powdered milk.

L-31 Polarization of microwaves: A polarized source and detector of microwaves are used with a polarizing grid of parallel wires.

L-29 Double refraction of light: Various bi-refringent materials are displayed on the overhead projector.

L-30 Double refraction of light: Two Rochon prisms are mounted in a horizontal light beam.

L-48 Interference in thin films: An air wedge between two glass plates.

L-18 Interference in thin films: The projection of Newton's rings.

L-19 Interference in thin films: The reflected colors from a spherical soap bubble.

L-47 Interference in thin films: Light is reflected from a soap film on a wire frame. Either monochromatic or white light can be used.

L-20 Interference in thin film: Mercury light reflected from mica and a microwave analog.

L-21 Interference: The Michelson interferometer.

L-22 Fraunhofer diffraction: Various slit systems on a Cornell slitfilm diffract laser light onto wall; also available are pin holes made in Al foil with a needle, an adjustable slit and a strand of the lecturer's hair.

L-50 Fraunhofer diffraction: Each student makes pinholes in a piece of aluminum foil and views a tiny source of white light from the zirconium arc with the foil immediately in front of the eye.

L-23 Fresnel diffraction: The shadows of various objects in a diverging laser beam.

L-24 Diffraction gratings: A spectrum is produced using a grating illuminated by an arc lamp (much like in L-6).

L-49 Diffraction gratings and spectra: Each student uses a piece of plastic grating material to view a straight filament bulb, and mercury, hydrogen and sodium sources on the lecture tables.

L-51 Holograms: The three dimensional nature of the images produced by one of our collection of holograms is illustrated by viewing from different angles with the TV. camera.

L-34 Color by the subtractive method: A delicate set of Wratten filters.

L-37 Color by the additive method: An illuminated color triangle.

L-38 Color by the additive method: Colored discs mounted on a motor driven shaft.

L-39 Physics of color: Lecture notes.

L-35 The reflection of colored light: Various colored objects in colored illuminations.

L-40 Testing color vision: Ishihara color plates and slides.

L-13 Imaging on the human retina: Individual students form the apparently inverted shadow image of a pin on their retinas.

L-33 Line spectra: Mercury spectrum formed by a prism is projected.

L-36 Absorption bands: The narrow absorption bands of didymium glass blocks the sodium D lines.

L-41 Luminescent materials: Various phosphorescent and fluorescent materials illuminated by an ultraviolet lamp.

L-43 Photoelectric effect: The current through a vacuum phototube can be displayed or used to control a relay. (same as EM-C16).

L-12 Illumination measurement and comparison: The Lummer-Brodhun photometer head, paraffin block photometer, Weston sight meter, and the Weston illuminometer.

## ELECTRICITY AND MAGNETISM - STATICS

E&M-S6 The large electrostatic machine.

E&M-S13 A Van de Graaf electrostatic generator.

E&M-S1 Charging by friction: Assorted fur, silk, rods, balloons and rubber strands.

E&M-S2 Two kinds of electric charge plus conductors and insulators: Assorted materials and two electroscopes.

E&M-S3 Charging by induction and the behavior of charged conductors: Two spherical conductors,a pear-shaped conductor and various electrostatic equipment.

E&M-S4 Charging by induction: The electrophorus.

E&M-S5 Forces between electric charges: Ben Franklin's electric chimes and the small electrostatic machine.

E&M-S14 Electrostatic deflection of an electron beam: Cathode-ray tube on an open mounting with assorted electrostatic materials.

E&M-S7 Various electrostatic experiments: The Leyden jar, lightning rod, rotating pinwheel, electrical breakdown of glass.

E&M-S8 Various electrostatic experiments: Standing hair on a charge person, an electrically conducting lecturer, and a multi-student circuit.

E&M-S9 Electrostatic shielding: An electroscope inside a shield of screen wire.

E&M-S10 Capacitors with solid dielectric: A dissectible Leyden jar.

E&M-S11 Variation of potential of a capacitor with a change of geometry: A large, adjustable parallel plate capacitor.

E&M-S12 Construction of capacitors: An exhibit of capacitors.

E&M-S15 Storage of electric charge on a capacitor: A neon glow lamp relaxation oscillator.

E&M-S16 Capacitor: Using a 0.47 farad capacitor to light a light bulb

## ELECTRICITY AND MAGNETISM - CURRENT

E&M-C17 Resistance and resistivity: Two copper wires of identical length but different cross section in series.

E&M-C1 The series element with the greatest resistance develops the greatest heat: Copper and iron wires of the same cross section in series.

E&M-C2 In series connection, the lamp of smallest wattage burns brightest: Electric lamps in series and parallel.

E&M-C3 The potential drop of electric power lines: A working model transmission line.

E&M-C4 Circuit protection by a fuse: Lead fuse wire in a simple circuit.

E&M-C5 The dependence of the electrical resistance of metals on temperature: An electric light is greatly dimmed by the heating of wire in series with it. (Same as H-10).

E&M-C18 RC series circuit: Current and voltage waveforms in a series RC circuit driven by a square wave generator are displayed on an oscilloscope. Both C and R can be varied.

E&M-C6 Electrodeposition: The growth of a lead tree in an electrolytic cell is projected.

E&M-C7 Ions are necessary for electrolytic conduction: Electric conduction in a cell of variable ion concentration.

E&M-C9 Voltaic EMF: An EMF is generated by the electrodes and electrolyte of your choice.

E&M-C10 A secondary cell: A homemade lead storage cell rings a bell after being charged.

E&M-C11 An exhibit of batteries, both primary and secondary.

E&M-C12 Electrical conduction in gases: A long discharge tube driven by an induction coil is connected to a vacuum pump.

E&M-C14 Electrical conduction in gases and vacuum: A collection of working discharge tubes plus “plasma glober.”

E&M-C13 Control of current by the grid of a vacuum tube: A lamp is controlled by bringing charged objects near a large electrode connected to the grid of a tube.

E&M-C15 X-rays: A small operating unshielded X-ray tube.

E&M-C16 Photoelectric effect: The current through a vacuum phototube can be displayed or used to control a relay (same as L-43).

E&M-C19 RC circuit behavior by Dr. Stanford.

E&M-C20 Decrease of electrical resistance of a metal with decrease in temperature

E&M-C21 Piezoelectric Crystal: piezoelectric crystal connected to the neon lamp

## ELECTRICITY AND MAGNETISM - MAGNETISM

E&M-M1 Magnetic field due to an electric current: A current-carrying wire with a large compass needle on a supporting pin.

E&M-M5 Force on a current-carrying conductor in a magnetic field: A wire with a large current hops out of the gap of a strong magnet.

E&M-M21 The force between currents in parallel wires: Two spring-mounted vertical wires attract or repel each other depending on the relative direction of the current in each.

E&M-M26 Magnetic force on a moving electric charge: The electrons in a double beam, cold cathode tube are deflected with a magnet. (See E&M-C14.)

E&M-M27 Magnetic force on a moving electric charge: The electron beam of an oscilloscope tube is deflected with bar magnets or electro-magnets with large pancake pole faces. (See E&M-S14.)

E&M-M20 Magnetic force on a moving electric charge - the Hall effect: The Hall voltage of a semiconductor is displayed on a meter and can be used to measure the magnetic field near various wires and materials.

E&M-M23 The torque on a loop in a magnetic field: A freely-rotating single wire loop orients itself in the magnetic field between two electromagnets with large pole faces. A multiturn loop with pointer is also available.

E&M-M7 DC electric motor: A working model of an electric motor or generator.

E&M-M8 D'Arsonval meter movement: A large D'Arsonval galvanometer in a glass dome.

E&M-M2 Electromagnetism and magnetic forces on materials: A large solenoid with an iron core pulls nails from a box.

E&M-M4 Magnetic forces on materials: The magnetic and electrostatic forces on materials are distinct effects as demonstrated by various rods on a rotating mount that can be attracted or repelled either magnetically or electrostatically.

E&M-M12 Magnetic forces on materials: A ferrite ring is magnetically suspended in the field of another ring.

E&M-M3 Magnetic forces on materials: An electromagnet for lifting loads.

E&M-M17 Magnetic forces on materials: A vintage telephone receiver.

E&M-M16 Magnetic forces on materials: A vintage telegraph relay and sounder.

E&M-M6 Magnetic forces on materials and currents: A freely-rotating solenoid that can be attracted or repelled with a bar magnet or made to rotate as an electric motor demonstrates that the magnetic forces on a solenoid are similar to those on a bar magnet.

E&M-M14 The magnetic field of the earth: A dip needle.

E&M-M22 The magnetic field of the earth: A large demonstration dip needle.

E&M-M9 Common magnetic materials: A collection of samples of iron, chromium, manganese, nickel, cobalt, silicon and lodestone ore.

E&M-M13 Magnetization of materials: A bar magnet is broken to yield two half-sized bar magnets.

E&M-M15 Magnetization of materials: Several bars are magnetized using the field of the earth.

E&M-M11 Magnetization of materials: Two three-pole magnets on rubber wheels behave in a paradoxical fashion.

E&M-M10 Magnetic properties of materials: Steady magnetic fields penetrate most materials.

E&M-M28 Magnetic properties of materials: The hysteresis loop for iron is displayed on an oscilloscope. (See the write-up for E&M-AC4.)

E&M-M18 Magnetic properties of materials: The Curie point of iron is demonstrated by the decrease in magnetic force on an intensely heated piece of iron.

E&M-M19 Magnetic properties of materials: The Curie point of gadolinium and/or dysprosium.

E&M-M25 Magnetic properties of materials: Liquid oxygen, which is paramagnetic, clings to the pole faces of a small magnet and forms a liquid bridge.

E&M-M24 Magnetic properties of materials: A small rod of bismuth which is diamagnetic aligns perpendicular to the field of a small, powerful magnet.

E&M-M29 Make and give away an FM antenna.

E&M-M30 Lattice of compass needles to show ferromagnetic domains

## ELECTRICITY AND MAGNETISM - INDUCTION

E&M-Ind1 Electromagnetic induction: Various ways of inducing a current in a coil of wire.

E&M-Ind4 Electromagnetic induction: The back EMF of an electric motor is an example of induction of an EMF by motion of a circuit in a magnetic field.

E&M-Ind3 Electrical generators: A working model of an AC or DC generator.

E&M-Ind5 Electrical generators: A large hand-cranked generator lights several lamps.

E&M-Ind2 Principles of a transformer: An induction coil.

E&M-Ind8 Principles of a transformer: A lamp wired to a coil is lighted by a second coil hidden from view.

E&M-Ind9 Principles of a transformer: A very versatile demountable transformer.

E&M-Ind14 Step-up transformer: A Jacob's ladder connected to the secondary of a transformer has an arc which periodically strikes, rises, and extinguishes.

E&M-Ind6 Eddy currents: The motion of a swinging solid metallic vane in a magnetic field is rapidly damped while the motion of a slotted vane is not.

E&M-Ind7 Eddy currents: (Arago disc) A rotating copper disk has eddy currents induced by a compass needle which also begins to rotate as a result.

E&M-Ind10 Eddy currents: An aluminum ring hops off the core of an electromagnet which is suddenly energized.

E&M-Ind15 Eddy currents and the induction motor: Various metallic objects spin in a rotating magnetic field (see write-up for E&M-AC2).

E&M-Ind16 Self-inductance: Two low voltage bulbs, one in series with a large inductor and the other in series with a resistance equal to that of the inductor, are connected to a DC supply simultaneously.

E&M-Ind11 Self-inductance: An EMF is induced across an electromagnet by current changes in the coil.

E&M-Ind17 Self-inductance: Current and voltage waveforms in a series LR circuit driven by a square wave generator are displayed on an oscilloscope. Both L and R can be varied. Also LC or LRC.

E&M-Ind12 Self-inductance: A lamp and an electromagnet in series are excited by either AC or DC.

E&M-Ind13 There is an AC current in the line feeding a capacitor with AC, but no current (except transient) with DC.

E&M-Ind18 Same as E&M-Ind 1: with a scope replacing see through meter.

E&M-Ind19 Lenz's law demo. Aluminum tube and 2 special cylindrical magnets

E&M-Ind20 Kelvin water drop

## ELECTRICITY AND MAGNETISM - ALTERNATING CURRENT

E&M-AC7 Capacitors in AC circuits: An AC supply lights a bulb in series with a capacitor while a DC supply does not. (See description of E&M-Ind 13.)

E&M-AC8 LC circuits: The RF and demodulated signals from WOI received by a simple LC combination with a diode demodulator are displayed on a dual trace scope while the class listens to the station.

E&M-AC1 The series RLC circuit: the various phase relations in a tunable RLC series circuit are displayed.

E&M-AC5 High frequency electrical phenomena: A Tesla coil provides current at high frequencies to light bulbs to which it is not directly connected and to weld together two wires held in your bare hands.

E&M-AC6 Electromagnetic waves: A 3.24 meter transmitter with dipole antenna and several dipole receivers demonstrate EM waves, polarization and antenna current distributions. Standing EM waves are also produced on a helically wound wire. (also listed as E&M-Ind15).

E&M-AC2 Eddy currents and the induction motor: Various metallic objects spin in a rotating magnetic field (also listed as E&M-Ind15).

E&M-AC3 Phasors: Shadow project of a vector to obtain a component (see description of M-K 6).

E&M-AC4 Magnetic properties of materials: The hysteresis loop for iron is displayed on an oscilloscope. (Also listed as E&M-M28.)

## NUCLEAR

E&M-Nuc1 Geiger counter with sound.

E&M-Nuc2 Labnet Geiger counter computer controlled (Apple).

E&M-Nuc3 Cloud chamber: The path of Alpha particles or Beta particles can be seen in the chamber.

E&M-Nuc4 Gas model. Balls in wire cage agitated with blower. A collection of crystal models is available.