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ABSTRACT

The major program components of the Physics 30 curriculum are outlined in this document. These key elements include: (1) process skills; (2) psychomotor skills; (3) attitudes; and (4) concepts (subject matter). Each of the components has been assigned an emphasis rating (expressed in a percentage) and a priority rating (designated by a ranking of high, medium, or low). (ML)

DIPLOMA EXAMINATION

CURRICULUM SPECIFICATIONS
for
PHYSICS 30

Alberta
EDUCATION
April 1986

PHYSICS 30 CURRICULUM SPECIFICATIONS

A. Program Elements

The physics program is based on four elements: process skills, psychomotor skills, attitudes, and concepts (subject matter). The percentage emphasis of each component for instruction in Physics 30 is listed in the table below. Even though each component is listed separately, instruction should integrate process skills, psychomotor skills and attitudes with the development of concepts. Not all these elements have equal emphasis at each course level. Hence, development of these components should take place as the concepts are presented.

Content	Emphasis
Process Skills	30%
Psychomotor Skills	8%
Attitudes	12%
Concepts (Subject Matter)	50%

B. Priority Weightings

The following code is used in the specifications to indicate curriculum and instruction priority.

A = high priority
B = medium priority
C = low priority

PHYSICS 30 CURRICULUM SPECIFICATIONS

PROGRAM COMPONENTS

A. PROCESS SKILLS 30%

PRIORITY RATING		EMPHASIS IN PER CENT
A	1. Questioning 1.1 Formulating and expressing relevant questions 1.2 Defining problem statements 1.3 Recognizing limitations to scientific investigation of given questions and problems	30%
A	2. Proposing Ideas 2.1 Formulating hypotheses 2.2 Stating predictions	
A	3. Designing Experiments 3.1 Defining operationally 3.2 Identifying and controlling variables 3.3 Determining procedures 3.4 Evaluating experimental designs and suggesting modifications	
B	4. Gathering Data 4.1 Observing accurately 4.2 Measuring accurately 4.3 Recording data clearly and completely 4.4 Estimating quantities and measures	

PROGRAM COMPONENTS Cont.

PRIORITY RATING		EMPHASIS IN PER CENT
B	5. Processing Data 5.1 Organizing and presenting data 5.2 Determining patterns and trends in data 5.3 Determining experimental error both for original data and for values derived from these data	Cont.
A	6. Interpreting Data 6.1 Identifying limits to interpretations 6.2 Generating appropriate explanations, theories and/or models 6.3 Generating ideas for extending knowledge related to the area of investigation	

B. PSYCHOMOTOR SKILLS 8%

PRIORITY RATING		EMPHASIS IN PER CENT
Equal priority	Manipulating	8%
	Constructing	
	Assembling	
	Calibrating	
	Adjusting	

C. ATTITUDES 12%

Equal priority	Develop background knowledge related to social issues of current interest	12%
	Develop the ability to discuss the importance of objectivity in scientific research	
	Gain information and insights into vocational and career opportunities in the physical, engineering, and applied sciences	

PROGRAM COMPONENTS Cont.

D. CONCEPTS (SUBJECT MATTER) 50%

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
B	Nature and behavior of light	1. Propagation of light		11%
		a. Light is a form of energy		
		i. Light is essential to life	3	
		ii. Early ideas about light and vision	2	
		iii. The Greeks had some theories about light	2	
		b. Properties of light		
		i. Light travels in straight lines	3	
		ii. Point sources of light produce sharp shadows	2	
		iii. Galileo attempted to measure the speed of light	3	
		iv. Olaf Romer gathered data to measure the speed of light	1	
		v. Huygens calculated the speed of light	3	
A		2. Reflection and refraction		
		a. A light ray can be reflected.	2	
		b. An uneven surface produces diffused reflection.	2	
		c. When a light ray is reflected, the angle of reflection is equal to the angle of incidence.	1	
		d. When a light ray moves from one medium to another, it is refracted.	2	
		e. Refraction involves a change of wavelength and speed as a wave goes from one medium to another.	1	
		f. Huygens supported the wave model for light; Newton preferred the particle model.	1	

* 1 - high priority 2 - medium priority 3 - low priority

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
C	Nature and behavior of light	3. Interference and diffraction		Cont.
		a. Young showed that light rays produce interference patterns.	3	
		b. When a light ray is split into beams, interference results if two beams are allowed to overlap.	1	
		c. As the hole through which a light ray travels is decreased in size, the shadow does not become finer.	1	
		d. Poisson predicted, on the basis of Fresnel's wave theory, a bright point in the centre of the shadow when a small solid disc is placed in a beam of light.	2	
		e. Light is diffracted by any obstacle.	3	
		f. By 1850 the wave theory of light was generally accepted.	3	
B		4. Dispersion		
		a. Newton experienced a problem in constructing an astronomical telescope.	3	
		b. Newton passed sunlight through a prism and obtained a spectrum.	3	
		c. White light is a mixture of all colors.	1	
		d. The three primary colors of the Additive Theory of Light are red, blue, and green.	1	
		e. Newton explained the apparent color of natural objects.	2	
		f. The longer a wave is compared to the size of an obstacle, the less it is scattered by the obstacle.	1	
		g. Red light has a longer wave length than blue light.	2	
		h. The blue color of the sky can be explained by scattering.	1	

PROGRAM COMPONENTS Cont.

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
C	Nature and behavior of light	5. Polarization a. Newton argued that light has some properties different from sound. b. Part of Newton's argument is based on the polarization of light. c. Since light can be polarized, it is propagated by transverse waves.	 3 2 1	Cont.
C		6. Deficiencies of the wave model a. The wave model requires that light travel through an ether. b. Interference and diffraction of light require a wave model to explain these phenomena. c. Interaction of light with some atomic particles requires a particle model to explain this phenomenon.	 3 1 2	
B	Electric and magnetic fields	1. Electric charges and forces a. The lodestone and amber effect i. Electric and magnetic phenomena require that one body be attracted to another by other than gravitational force b. Gilbert does not accept Effluvium Theory i. The earth is a lodestone ii. A needle used on a sphere of lodestone formed meridian circles converging at opposite ends called "poles" iii. "Spheres of influence" become the basis for the modern field concept	 1 3 3 3	13%

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Electric and magnetic fields	iv. Attractive forces exist between many electrified and neutral forces.	1	Cont.
		v. Magnets have two oppositely located gains (poles) toward which only a few materials are attracted.	1	
		c. Electric charges and electric forces		
		i. William Gilbert was able to differentiate between conductors and insulators, thus physics was no longer limited to the amber effect.	3	
		ii. Benjamin Franklin explains deficiencies, excesses and normal supplies of "electric fluid" in terms of positive and negative.	3	
		iii. There are three rules governing electric nature of matter: - two kinds of electric charge - two ojects charged alike repel each other - two objects charged oppositely attract each other.	1	
		d. The Electric Force Law		
		i. Priestly repeats Franklin's experiments and compares results with Newton's conclusions of gravitational forces.	3	
		ii. Priestly proposes that forces exerted by charges vary inversely as the square of the distance -- a reasonable parallel to Newton's gravitational forces.	3	
		iii. Charles Coulomb provides direct experimental evidence for inverse square law with the torsion balance. $F_e \propto \frac{1}{R^2}$	1	

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Electric and magnetic fields	iv. Coulomb also demonstrates that the magnitude of the electric forces depends upon the magnitude of the charges. $F_c = \frac{Kq_1q_2}{R^2}$	1	Cont.
		e. The unit of charge		
		i. The unit of charge is derived from current units. To comply with SI units, the Coulomb is defined as that amount of charge passing a point in a wire in one second when the current is one ampere.	2	
		ii. The Coulomb is a relatively small amount of charge when in motion, but when at rest represents the charge on $\frac{1}{1.6 \times 10^{-19}}$ electrons.	2	
		f. Electrostatic induction		
		i. A charged body can influence the charge on another body.	1	
A		2. Forces and fields		
		a. Fields		
		i. To define a field it must be possible to assign a numerical value of field strength to every point in the field.	1	
		ii. Scalar fields can be illustrated by using intensity of light, sound, and/or temperature.	1	
		iii. Vector fields must have a magnitude and a direction at every point.	1	

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Electric and magnetic fields	iv. Physicists can use their feature of the field concept in three ways: - the value of a field at a point in space - the set of all values everywhere in space where the field exists - the region of space in which the field can be detected	1	Cont.
		b. Gravitational fields		
		i. The gravitational law can be rearranged - the field strength at any point is the ratio of the net gravitational force acting on a test body at that point to the mass of the test body	1	
		c. Electric fields similar to gravitational fields		
		i. The force at a point is similarly determined in an electric field except for the presence of two kinds of electric charges.		
		ii. The direction of vector $\vec{E}$ is the direction of the force exerted by the field on a positive test charge.	1	
		d. The smallest charge		
		i. Robert Millikan combined two force fields, gravitational and electric, to demonstrate that charges in nature are made up of whole numbered multiples of the smallest charge. $e = 1.6025 \times 10^{-19}$ Coulomb	1	

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.		e. The Law of Conservation of Charge i. Franklin concluded from his experiments that the net amount of electric charge in a closed system remains constant regardless of what reactions occur in the system.	1	Cont.
A	Electric and magnetic fields	3. Moving charges a. Electric currents i. Alessandro Volta produces steady electric currents -- far superior to leyden jars.	1	
		b. Electric potential difference, current and power i. Electric potential energy changes when work is done in moving an electric charge from one point to another in an electric field.	1	
		ii. Electrical potential difference is the ratio of the change in electric potential energy ΔEp of charge q to the magnitude of the charge. $V = \frac{\Delta Ep}{q}$	1	
		iii. Moving a charge in an electric field requires energy and work to be done. The work is measured in volts.	2	
		iv. Free from other forces, a charged particle in an electric field will accelerate and increase in kinetic energy.	2	
		v. The electron gun provides a stream of electrons with many applications.	3	

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
		vi. Electrons in conductors do not move freely and are governed by Ohm's Law and its parameters. $V = IR$	1	
		vii. Power is a measure of the rate of change of energy. $P = VI$	1	
		viii. Where Ohm's Law applies, power can be measured in terms of the resistance of the material through which a current flows. $P = I^2R \quad P = V^2/R$	2	
Cont.	Electric and magnetic fields	4. Moving charges and magnets		Cont.
		a. A magnetic field without a magnet		
		i. Christian Oersted discovered that electric current affects a compass needle by causing the needle to swing perpendicular to the wire carrying the current.	2	
		ii. It was the first instance in which a force seemingly did not act along a line connecting sources of forces.	2	
		iii. The left hand rule gives the direction of the magnetic field surrounding a current-carrying conductor.	1	
		b. Currents act on currents		
		i. The ampere is defined in terms of a force existing between two current-carrying wires.	1	
		c. Magnetic field and moving charges		
		i. The deflection of charged particles within a magnetic field demonstrates interaction of magnetic fields.	1	

PROGRAM COMPONENTS Cont.

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Electric and magnetic fields	ii. The amount and direction of deflection will depend upon the velocity of the particle, charge on the particle, and value of the magnetic field strength. $F = k \vec{B}_{\perp} q \vec{v}$	1	Cont.
		iii. If the magnetic field is strong enough, charged particles may become trapped as in Van Allen Radiation Belts.	1	
A	Electromagnetic Radiation	1. Electromagnetic Theory		8%
		a. Principles of electromagnetism as established by Oersted, Henry Ampère, and Faraday		
		i. An electric current in a conductor produces magnetic field lines that surround the conductor.	1	
		ii. A conductor moving across an external magnetic field has a current induced in itself.	1	
		b. Maxwell's mathematical model of magnetic induction		
		i. An electric field that changes with time generates a magnetic field.	1	
		ii. Displacement current is the rate at which the charge displacement changes.	2	
		iii. A changing electric field in space produces a magnetic field.	1	
		iv. A changing magnetic field in space produces an electric field.	1	

PROGRAM COMPONENTS Cont.

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Electromagnetic radiation	2. The propagation of electromagnetic waves a. Changing electric fields induce magnetic fields which in turn induce electric fields, setting up an unending sequence of events. i. Electric and magnetic fields varying with time can produce a disturbance that moves away from their source and can be detected as perpendicular electric and magnetic disturbances in neighboring regions.	1	Cont.
		b. Speed and propagation of waves depends upon stiffness and density of the medium. i. Using a mechanical model of the ether, Maxwell related stiffness to the electric field and density to the magnetic field.	2	
		ii. The ratio of these factors is the same for strengths of all fields and determines the wave speed.	2	
		iii. Light consists of the transverse undulations of the same medium which is the cause of electric and magnetic disturbances.	2	
		iv. Light, electric, and magnetic propagations occur at the same speed and unify the separate sciences, providing a path for the development of quantum machanics and relativity.	2	
A		3. Evidence for the Electromagnetic Spectrum a. Hertz investigated evidence of electromagnetic waves at various frequencies.		

PROGRAM COMPONENTS Cont.

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.		i. Hertz, using an induction coil as a propagator, detected electromagnetic waves with a wire conductor.	1	
		ii. Hertz demonstrated that electromagnetic waves have all the properties similar to those of light.	1	
		iii. Lebedev suggested that radiation can possibly exert pressure.	3	
A	Electromagnetic radiation	4. The electromagnetic spectrum		Cont.
		a. Energy and moving charges together produce radiation away from a source as an electromagnetic wave.		
		i. Radio waves are long and easily diffracted. These waves can be modulated by intensity (amplitude) or by variation (frequency).	2	
		ii. Radar and television detect waves of about 1 metre wave length and are subject to interference by reflection.	2	
		iii. Wavelengths of infrared or microwave radiation are in the range of 10^{-1} to 10^{-6} metres and are emitted by heated bodies.	2	
		iv. Wavelengths of electromagnetic radiation are sensitive to visual reception between 7×10^{-7} and 4×10^{-7} metres.	2	
		v. The ultraviolet region of the spectrum has waves slightly shorter than visible waves.	2	
		vi. X-rays are propagated by electrons stopping suddenly when hitting a metallic conductor.		

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.		- The maximum frequency is determined by the energy with which the electrons strike the target. - The energy is determined by voltage applied. - X-rays can produce interference patterns which can be used to determine crystal structure.	2	
		vii. Gamma radiation is emitted by unstable atomic nuclei of radioactive materials.	2	
C	Electromagnetic radiation	5. The ether concept a. Mechanical model is compared to mathematical model for transmission of electric and magnetic forces.		Cont.
		i. Experiments to detect motion relative to the ether failed. Michelson and Morley did not detect an ether wind.	1	
		ii. A hypothesis suggested that objects moving with the speed of light changed in size to make any relative motion undetectable.	3	
		iii. Einstein showed that equations of electromagnetism and mechanics can be written to fit the Principle of Relativity, which states that the same laws of mechanics apply in each of two frames of reference which have a constant velocity relative to each other.	2	

PROGRAM COMPONENTS Cont.

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Cont.	iv. Einstein conjectured that the speed of light is the same for all observers when moving through free space. This resolved the question of the ether moving relative to the motion of the observers.	2	Cont.
		v. The need for all-pervading ether was removed by Einstein.	2	
C	Structure of matter	1. Chemical nature of the atom		11%
		a. Dalton proposed an atomic theory which accounted for the Law of Conservation of Mass.	2	
		b. The Law of Definite Proportions could be explained by Dalton's theory.	2	
		c. Dalton's theory was also consistent with the Law of Multiple Proportions.	2	
		d. Dalton's interpretation of experimental facts made possible some conclusions concerning the nature of atoms.	2	
		e. Dalton's work produced the possibility of determining numerical values for atomic mass.	2	
		f. Elements have different atomic masses and different capacities for chemical combination.	2	
		g. The understanding of the atom was enhanced by discoveries in electrochemistry.		
		i. Volta's electric cell made it possible to study the process of electrolysis.	2	
		ii. The electrical behavior of chemical substances provided a means of decomposing compounds to elements important to industry.	2	

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.		h. Michael Faraday discovered two fundamental laws of electrolysis.		
		i. The amount of chemical change produced in electrolysis is proportional to the product of the current and the time.	2	
		ii. The amount of an element liberated from an electrolyte by a given amount of electricity depends on the element's atomic mass and its combining capacity.	2	
B	Struc-ture of matter	2. Electric nature of the atom		Cont.
		a. The periodicity in the properties of the elements led to the idea of atomic structure.	2	
		b. The discovery of cathode rays led to experiments which established their properties.		
		i. Rays with the same properties are produced independent of the nature of the cathode.	2	
		ii. Rays travel in straight lines perpendicular to the emitting surface.	2	
		iii. A magnetic field deflects the path of cathode rays.	2	
		iv. Cathode rays can cause some chemical reactions to occur which are indentical to the chemical reactions produced by light.	2	
		c. J. J. Thomson conducted a series of experiments which indicated that cathode rays are negatively charged particles.		
		i. The behavior of cathode rays in magnetic and electric fields can be predicted.	2	

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Structure of matter	ii. The ratio of the charge of a particle to its mass is denoted by q/m.	2	Cont.
		iii. Cathode rays from different materials all have a q/m value of 1.76×10^{11} coulombs/kilogram.	2	
		iv. Cathode rays from a part of all matter.	2	
		v. The electron is one of the elementary particles.	2	
		d. Robert Millikan measured the charge of the electron.		
		i. In Millikan's Oil Drop Experiment the electric force on a particle ($q\vec{E}$) is balanced by the force of gravity ($m\vec{g}$).	1	
		ii. The mass of a single electron may be determined knowing the charge, q_e and ratio, q_e/m.	1	
A		3. Quantum behavior of matter		
		a. Heinrich Hertz discovered the phenomenon of the photoelectric effect.		
		i. Photoelectric particles have the same properties as electrons.	2	
		ii. All substances exhibit the photoelectric effect.	2	
		iii. New ideas must be introduced to account for these experimental results.	2	
		iv. The quantum concept developed from explanations of the photoelectric effect.	2	
		v. Some photoelectric phenomena cannot be explained by classical electromagnetic theory.	2	

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Structure of matter	b. Einstein explained the photoelectric effect.		Cont.
		i. Einstein assumed that energy is not distributed evenly over an expanding wave front.	1	
		ii. Light energy comes in packets. Each packet is a quantum of energy.	1	
		iii. Einstein's photoelectric equation is upheld by experimental results.	1	
		iv. Millikan established a straight line relationship between the frequency of absorbed light and the maximum kinetic energy of the photoelectrons.	1	
		v. Max Planck introduced the quantum of energy concept.	1	
		vi. The photoelectric effect cannot account for other properties of light.	1	
		c. Roentgen's discovery of X-rays did not fit the accepted ideas about electromagnetic waves.		
		i. X-rays have several properties.	2	
		ii. X-rays act like electromagnetic radiation of very short wave length.	2	
		iii. X-rays have quantum properties.	2	
		iv. X-rays can be used in medical diagnosis.	2	
		d. Many models of the atom were devised at the end of the 19th century.		
		i. An atomic model was proposed by J. J. Thomson.	2	

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
A	Struc-ture of matter	4. Rutherford-Bohr model of the atom		Cont.
		a. An indication of atomic structure was provided by the emission and absorption of light by atoms.		
		i. Light from a radiating gas is a mixture of only a few definite colors.	2	
		ii. John Herschel suggested that each gas could be identified from its line spectrum.	2	
		b. The emission line spectrum of hydrogen is a converging series of specific colors.		
		i. Jakob Balmer provided an empirical relation which fits the emission spectrum of hydrogen.	1	
		ii. Improvements in techniques have allowed new regions of the spectrum to be explored.	1	
		c. Scattering experiments interpreted by Rutherford led to the concept of the nuclear atom.		
		i. The scattering experiment is important in nuclear physics.		
		ii. Geiger and Marsden conducted the scattering experiment which led to the modern model of the atom.	1	
		d. Scattering experiments made it possible to determine nuclear charge and size.		
		i. Each nucleus has a positive charge q, numerically equal to Zq_e.	1	
		ii. The size of the nucleus may be estimated from scattering experiments.	1	

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Structure of matter	e. Bohr introduced three postulates designed to account for the existence of stable electron orbits and discrete emission spectra.		Cont.
		i. If the electron orbits the nucleus of an atom, the energy loss will cause its collapse.	2	
		ii. A stable atom can only result for specific magnitudes of orbit radii.	2	
		iii. Emission or absorption of radiation corresponds to a transition between stationary states.	2	
		f. It is possible to calculate the size of the hydrogen atom using Bohr's model.		
		i. The atomic sizes calculated are similar to spacings observed in crystals.	3	
		g. The potential energy of the electron can be calculated using the Bohr model.	2	
		h. The Bohr model could be used to explain all emission and absorption lines in the hydrogen spectrum.		
		i. There is a correlation between experimental data and predicted wavelengths of the spectrum lines.	1	
		ii. Separate energy states correspond to different electron orbits.	1	
		i. Discrete energy states were confirmed by the Franck-Hertz experiment.		
		i. Atoms have excited stationary states with discrete energy values greater than the lowest energy states.	1	

PRIO-RITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
Cont.	Structure of matter	ii. a correlation exists between energy gained by atoms in collision and observed spectrum lines. j. Bohr found a way of relating his atomic model to the periodic table. i. Chemical and physical properties of an element depend upon electron arrangement. ii. Chemical behavior is related to atomic structure. iii. Examples may be taken from the periodic table to support the Bohr theory.	1 2 2 2	Cont.
C		5. Inadequacies of atomic models a. Discrepancies exist between theory and experiment. i. Only the spectrum of the hydrogen atom can be predicted accurately. ii. Electric and magnetic fields affect emission and absorption lines. iii. The relative intensity of spectral lines is difficult to predict. iv. Untestable concepts are required (orbitals). b. A better theory of atomic structure was necessary. i. Stationary states must be explained by using quantum concepts. ii. Useful theories use quantum concepts.	 2 2 2 2 2 2	Cont.

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
C	Modern physical theories	1. Some results of relativity theory		7%
		a. Experiments involving high-speed particles reveal differences between relativistic mechanics and Newtonian mechanics.	2	
		b. Relativistic mechanics suggest that the mass of a body should vary with speed according to the formula: $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$	1	
		c. Experiments provide evidence for the inadequacy of Newtonian physics for high-speed particles.	2	
		d. Einstein proposed that mass and energy are equivalent. $E = mc^2$	1	
A		2. Particle-like behavior of radiation		Cont.
		a. If a quantum has energy, then it also has momentum.	1	
		b. The Compton effect was a successful demonstration of the momentum of a quantum.	1	
		c. Photons act both like particles of matter and waves.	1	
A		3. Wave-like behavior of particles		
		a. Wave-particles dualism has been applied to electrons and other atomic particles.	2	
		b. Some wave properties of the electron can be measured.	1	
		c. De Broglie's relation can be applied to Bohr's angular momentum postulate for the electron in the hydrogen atom.	1	

PRIORITY RATING	CONCEPT		SUB-PRIORITY RATING*	EMPHASIS IN PER CENT
C	Modern Physical theories	4. Significance of mathematical atomic model a. Schrödinger developed an equation which defines the wave properties of electrons and predicts particle-like behavior. b. Quantum mechanics does not supply a physical model of the atom.	 2 2	Cont.
A		5. Heisenberg's uncertainty principle a. Measurements of events in nature can be made using reflected visible light. b. The wavelength of radiation has to be comparable to, or smaller than, the dimensions of an object to accurately locate it. c. It is difficult to locate atomic particles using photons because of the Compton effect. d. The more accurately the electron is located, the less accurately we know its velocity. e. The uncertainty principle can be expressed quantitatively.	 3 1 1 1 2	
B		6. Probability interpretation of quantum mechanics a. Schrödinger's wave equations give us the probabilities for finding particles. b. Wave amplitude may be used to represent the probability of an electron being at a particle location. c. The quantum theory gives a mathematical representation used to predict interaction with particles, fields, and radiation. d. Our ideas of waves and particles do not apply on the atomic scale. e. Einstein expressed his faith that there are more basic and deterministic laws yet to be found.	 2 2 2 1 3	