BASIC MECHANICAL PHYSICS CONCEPTS OF THE APPLIED SCIENCES OF PHYSICAL EDUCATION

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ABSTRACT

BASIC MECHANICAL PHYSICS CONCEPTS OF THE
APPLIED SCIENCES OF PHYSICAL EDUCATION

By

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Experience has shown that students of physical education have difficulty understanding basic concepts of the applies sciences. It is believed that much of the difficulty can be attributed to a lack of prerequisite knowledge of physics concepts which are thought to form a large part of the basic understandings needed. The purpose of this study was to develop the basic concepts of mechanical physics for the applied sciences by: identifying necessary concepts and categorizing those concepts in hierarchical organization.

Six criterion books, five on applied sciences and one freshman physics book, were used to obtain a list of basic concepts. These books were selected through questionnaires on the basis of use in the midwest district. The material from the books of the applied sciences was sorted on the basis of differentiation and duplication of mechanical physics concepts with the freshman mechanics physics book to aid in filling any gaps in material. The sorted statements were formed into a hierarchy of facts, concepts and generalizations.

The final format resulted in three generalizations being developed; force, motion and energy, under an overall generalization

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of work. The quantity of statements compiled is an indication of the extent to which a student must have a command of mechanical physics concepts to master the applied sciences.

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By

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To My Mother and Father

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CHAPTER 1

INTRODUCTION

Applied science presents a difficult barrier to many students majoring in physical education whose background preparation in mathematics, chemistry and physics is deficient. The basic concepts of these sciences compose a large portion of the introductory material for kinesiology, physiology of exercise and tests and measurements.

Experience has shown that students do not understand such basic concepts as: proportions, ratios, molecular movement, diffusion and acceleration. Therefore, instructors must take time in each class to teach the basic concepts before application is possible. This limits the amount of time available for application. If students had the background material prior to taking the applied sciences, this time loss could be decreased. Projecting this idea and cumulating the time loss in all three applied sciences would result in a significant saving.

It may appear to the instructor that the student is not mature enough to handle the materials of his class but, as pointed out by Gagne (6), it is actually a matter of readiness.

Prominent psychologists such as Gagne (6) and Piaget (10) have indicated a need for first obtaining basic concepts in cognitive development.

> . . . the production of genius is not on 'tricks' but on the learning of a great variety of specific capabilities (6).

> . . . if we thus admit the existence of a progressive structuring of reality by means of operations gradually constructed one after another or on the basis of one another, then the most likely hypothesis is that the memory code itself depends on the subject's operations . . . (10).

The idea of basic concepts goes by different terms. Frost (5) chose to use "common elements" in comprising a list of the different terms which exist to describe the primary step in the process of achieving mastery.

Psychologist	Common Elements
Gagne	capabilities
Ferguson	abilities
Olson (Bruner)	strategies
Piaget	operations
Harlow	learning sets

The need for the structuring of a course of basic concepts also was pointed out in terms of promoting learning and creative thinking by Bruner (1); developing the memory by Bruner (1) and Piaget (10); enhancing retention by Bruner (1), Gagne (6) and Piaget (10); and achieving mastery by Bruner (1), Frost (5), Gagne (6) and Piaget (10).

A study by Tagatz, Lemke and Meinke (12), on the relationship between conceptual learning and curricular achievement, stated that the two were highly related.

Repetition of material from one class to the next can be an inhibiting factor to those students who already understand the material as pointed out by Gagne (6).

> . . . the highly successful pupil may show a slackening of interest when success comes too easily, when deliberate pace and repetition take the edge off excitement of the new and unknown.
>
> A student is ready to learn something new when he has mastered the prerequisities; that is, when he has acquired the necessary capabilities through preceding learning.

It is believed that basic concepts can be drawn from the applied sciences which will establish a basis for these background understandings.

> Assuming certain prerequisite abilities necessary for concept attainment, which function in a cumulative manner, the educator should be able to subdivide a specific intellectual task into its subordinate or fractional concepts or units necessary for mastery (5).

Through an understanding of the basic concepts of the applied sciences, the student would be better prepared to apply them to physical education activities.

> If the individual is to engage in problem solving to acquire a new higher order rule, he must first have acquired some other simpler rules.
>
> The acquisition of knowledge is a process in which every new capability builds on a foundation established by previously learned capabilities (6).

Hence, to supply the student with the background understandings needed for application and retention, and ultimately to allow for more application time in the applied sciences, the basic concepts for the applied sciences should be developed.

Purpose

The purpose of this study was to develop the basic concepts of mechanical physics for the applied sciences by identifying necessary concepts and categorizing those concepts in a hierarchical organization.

The ultimate goal of developing basic concepts for the applied sciences was to construct a course outline aimed at the correction of known deficiencies. Many basic concepts taught in kinesiology and physiology of exercise are identical. The duplication in these courses could be avoided through a basic concepts course. Course time in the applied sciences then could be devoted to immediate application of the basic concepts to physical education activities which would help to promote learning, memory and creative thinking in the application courses (1).

Each phase of the study has its own purpose as follows:

Identification--This phase was an attempt to compose a list of those concepts indicated by the literature as being basic knowledge needed for the applied sciences.

Categorization--The purpose of this phase was two fold: (a) to organize the concepts into a meaningful format and (b) to see if these concepts would tend to fall into a few broad categories. The facts, concepts and generalizations format was chosen to allow for more than one possible approach in organizing the concepts into a hierarchical form and later into a sequence of material.

> The attainment of new capabilities by human learners requires a systematic plan for the acquiring of prerequisite discriminations, concepts, or rules. Learned capabilities become most readily generalizable when they are soundly based on previously mastered entities (6).

Nature of the Study

Related literature comprised the source data for development of the basic concepts. Criterion books of two types were used.

Six criterion books, five on applied sciences and one physics book, were used to obtain a list of basic concepts. These books were selected through questionnaires on the basis of use to determine what students were required to learn in: (a) kinesiology and physiology of exercise in physical education programs and (b) freshman mechanics in physics departments. The material from the books of the applied sciences was sorted on the basis of: (a) differentiation of concepts from their applications, (b) differentiation of physics concepts from other basic science concepts, and (c) duplication of concepts. The freshman mechanics book was used to aid in filling any gaps in material. That is, if the books in the applied sciences assumed the reader had knowledge of certain concepts, then it follows that they must also have assumed the reader had knowledge of the underlying principles on which these assumed concepts were built. Therefore, the mechanics book provided those concepts which may have been assumed known in the applied science books as well as their underlying principles.

Scope of the Study

This study is only one stage of what should become a much broader plan. Some ideas which could be pursued follow.

The concepts should be extended to include chemistry concepts. A supplementary section for mathematics deficiencies also should be included.

A body of knowledge should be designed to show all relationships between concepts and give examples of applications.

A course could be designed to test the content material. Tests should be developed to determine the extent to which students understand these concepts prior to and after completion of such a course. A class of this type also needs a laboratory section. Many people must have the opportunity to visualize the application of a concept before they can master it. Perhaps not all of the concepts could be formed into a laboratory situation but those that can should be presented.

There would be other alternative uses for the content material. One possibility would be implementation into units of instruction at other grade levels.

CHAPTER 2

METHODS

Identification Phase

The procedures followed in identifying the basic physics concepts of the applied sciences were as follows:

First, to identify current kinesiology and physiology of exercise textbooks in use and those recommended for reference, a questionnaire was sent to the department heads of thirty-three colleges and universities of the midwest district for distribution to the instructors of these courses (Appendix A). This indirect approach of contacting the instructors was used because of the inability to find resource materials which contained instructor's names and courses taught.

The colleges and universities were selected on a basis of the number of physical education majors earning a bachelor's degree from 1969 to 1970. Together, these colleges and universities represented 71% of the total of earned bachelor's degrees conferred in physical education in the midwest district (7).

Responses from one kinesiology and one physiology of exercise instructor from both the men's and women's departments of each university constituted 100% return. Four responses from each university, a total of 132, were possible. However, if the men's and women's departments were consolidated and one instructor taught both kinesiology and physiology of exercise, then one response counted as four.

When 78% (103) of the responses were received, an index of use score was assessed for each book by the following method.

On the questionnaire, books were indicated as "adopted text" or "reference." The category of "adopted text" was given an index-of-use weight of two and the "reference" category a weighting of one on the assumption that an adopted text would be used more often. The weight value of each category was then divided by the number of books indicated on each questionnaire. Again, an assumption of use was made: that one book would be allotted more time than two, in which case the time would be shared between the two. For example, if a questionnaire indicated two adopted texts, they would both receive a 1.00 "index value"; if four references were indicated, each would receive a 0.25 "index value" (Table 1).

On completion of the tally, the number of total points was summated for each book to yield an "index of use" score. These scores were then summated in descending order until over 50% of the total of the scores was achieved. Criterion books whose scores comprised this 50% were selected to be used in identifying the basic physics concepts. Kinesiology and physiology of exercise texts were selected separately (Tables 1 and 2).

These books were read and any physics-related statements listed. The task was to differentiate the physics concepts from the course material. The statements then were grouped by concept. Bueche's Principles of Physics was referred to for any additional statements or

Table 1. Index of Use Scores for Kinesiology Texts.

	Adopted			Reference								
Index Value--→	2	1	.66	1	.50	.33	.25	.20	.17	.14	.12	Index of Use
Barham Thomas		3		1	.50	.33		.20	.34	.14	.12	5.63
Broer	6	1						.20		.14	.12	7.46
Bunn					.50			.40	.17		.12	1.19
Cooper Glassow	14	4		2	2.50	1.32	.75	1.60	1.19	.28	.24	27.88*
Dyer								.20				0.20
Dyson									.17	.14	.12	0.43
Ecker	2											2.00
Haye								.20	.17	.28	.12	0.77
Jensen Schultz		3	.66		1.50	.66	.50	.60	.85	.42	.12	8.31
Kelly					1.50	.99	.50	1.20	.68	.42	.12	5.41
Kranz							.25					0.25
Logan McKinney	4	1				.33	.25					5.58
Mac-Conaill					.50	.66		.60	.68	.28	.12	2.84
Plagen-hoef										.14		0.14
Rasch Burke	12	4	.66		3.50	2.31	1.00	1.20	.85	.56	.12	26.20*
Scott	2	1					.25				.12	3.37
Steind-ler					.50							0.50
Thompson	4	2	.66			.33	.75	.20	.68	.28	.12	9.35
Tricker Tricker					.50					.14		0.64
Wells	46	8			1.50	1.65	.25	.60	.34	.42	.24	59.00*
Williams Lissner		1		1			.50	.80	1.02	.28	.12	4.72
											Total	171.87

Table 2. Index of Use Scores for Physiology of Exercise Texts.

	Adopted				Reference							
Index Value-->	2	1	.66	.20	1	.50	.33	.25	.20	.17	.14	Index of Use
Astrand Rodahl	4	2			1		.99		.60	.51	.56	9.66
Clayton								.25				0.25
Davis Logan					1		.33	.25	.20		.14	1.92
deVries	38	3		.20		.50	.33		.60	.85	.28	43.76*
deVries (lab)											.14	0.14
Falls, Wallis, Logan				.20			.33	.25	.40	.85	.56	2.59
Guyton	2											2.00
Johnson											.14	0.14
Jokl							.33		.20	.34	.14	1.01
Karpovich Sinning	14	2		.20		.50	1.32	.50	.60	.68	.42	20.22*
Matthews Fox	6	1		.20	1	1	.66	.75	1.00	.34	.42	12.37
Morehouse Miller	6				1	1	1.65	.75	.60	.68	.56	12.24
Ricci						.50		.25	.80			3.46
Sloan												
											Total	109.76

concepts which were needed for further clarification or understanding. These included any concepts or underlying principles which were assumed by the criterion books of the applied sciences to be known by the student. Also, in cases where the physics book stated an idea more clearly than the applied science book, that wording was considered in making the final statement.

Bueche was selected for use on the basis of a questionnaire sent to the physics departments of the same thirty-three colleges and universities (Appendix B). On the basis of an 88% (28) return, Bueche was the physics book most often used in physics courses designed for freshman liberal arts students. It was adopted by six universities with 1.42 being the average use.

Categorization Phase

It was this writer's belief that these apparently diffuse and complex learnings could be simplified into a few primary concepts. The individual concepts were grouped into increasingly broader categories and these categories sorted according to their relationship to a primary concept.

The physics book was used here to assist by supplying the understandings needed to master the concepts derived from the other criterion books.

Format

The format contains three levels of specificity: facts, concepts and generalizations. A fact is a statement of truth which, when combined with other facts, helps to establish a concept. A generalization is a broad statement which encompasses or shows the relationship between two or more concepts. These definitions do not imply that a statement cannot serve at more than one level of specificity or that all concepts are at the same level of specificity.

The concepts exist in a hierarchy. To understand how this hierarchy is structured, consider the following diagram.

```
                  Generalization
              Concept 3       Concept 4
               .Fact D
              .
             .  Fact E.
            .          .
           .    Face F  .
          .              .
        Concept 1    Concept 2
          Fact A ---- Fact A
          Fact B      Fact C
```

As can be seen from the dashed line, a fact can be used to build more than one concept and from the dotted lines that concepts can in turn act as facts to build other concepts. The same is true for generalizations, of course; they can be combined to form broader generalizations.

The format constructed actually consists of three hierarchical structures which develop three generalizations which then are used as concepts to form one all encompassing generalization.

CHAPTER 3

RESULTS

Below is a topic outline to aid the reader in following the progression of concepts under each of the three generalizations.

WORK

I. Force

  A. Scalar and Vector Quantities

    1. Magnitude and direction

      a. mass

      b. velocity (see II B. 2b)

      c. acceleration (see II B. 2)

    2. Resultant

      a. solution of vector problems

      b. basic trignometric rules

  B. Internal and External Forces

    1. Buoyancy

    2. Centrifugal force and centripetal force

    3. Friction

    4. Gravitational force

      a. weight

        1. gravitational constant

        2. center of gravity

b. line of gravity

5. Pressure

6. Tensile force

II. Motion

A. Kinds of Motion

1. Rectilinear

2. Curvilinear including projectiles

3. Rotary

a. oscillations

b. pendulums

4. Flow

a. pressure gradient

b. current

c. potential difference

d. laws which govern flow

B. Newton's Laws of Motion

1. Law of inertia

a. stability

b. unbalanced force

2. Acceleration

a. mass

b. velocity and speed

c. momentum

d. conservation of momentum

e. rotational analog

f. angular-motion equations

3. Action and reaction

C. Levers

1. Angular motion of

2. Mechanical advantage

3. Classes of

4. Modifications of

III. Energy

A. Conservation

1. Potential energy

2. Kinetic energy

3. Heat

B. Measurement

C. Unit of Work

D. Power

E. Efficiency

The facts under each concept are labeled by the letter f and numbered, but not to imply a sequence.

Generalizations, Concepts and Facts

Work is an application of force which displaces a unit of matter.

I. Force is a utilization of energy expenditure in the form of a push or a pull which has the potential to alter motion.

II. Motion is the change in position of a unit of matter from one point in space to another initiated through the application of force.

III. Energy is the ability to do work.

I. Force is a utilization of energy expenditure in the form of a push or a pull which has the potential to alter motion.

A. Two quantitative measures are dealt with in mechanical physics; scalar and vector. (11p.141)

f1. Scalar quantities have only magnitude. (11p.141)

f2. Vector quantities have both magnitude and direction. (11p.141, 147)

f3. Scalar quantities can be added arithmetically, whereas vector quantities should be added vectorially for maximum information. (2p.3) (11p.141, 147) (13p.95)

f4. Area, distance, mass, volume, speed, time and weight are examples of scalar quantities. (11p.141)

f5. Acceleration, displacement, velocity, momentum and force are examples of vector quantities. (11p.141)

f6. A vector is a tipped line segment (→) whose length represents its magnitude and whose orientation in space its direction; also, an arrow or ray. (11p.141) (13p.92)

1. An applied force can be expressed as a vector quantity having both magnitude and direction. (11p.157)

f1. An applied force can be graphically represented as a vector, a tipped line segment whose length represents its magnitude and whose orientation in space its direction. (11p.141) (13p.92) f2. The line of force is an imaginary line indicating the direction of the applied force of which the vector segment is a part. (2p.169)

f3. The magnitude of a force is an expression of its relative size. (11p.141) (13p.92)

f4. The magnitude of an applied force can be measured by the product of the mass and the acceleration of the object acted upon. (2p.49, 175) (3p.13) (11p.5, 149, 524)

f5. The equation, F = ma, expresses the relationship between the average force applied and the mass and resulting acceleration of the object as described by Newton's second law. (11p.5, 149, 524)

f6. Mass is a constant representing the amount of matter composing an object. (11p.127)

f7. The greater the mass of an object, the greater the intensity of force required to change its state of motion. (2p.49) (3p.13)

f8. Velocity is the displacement of an object per unit of time. (2p.23) (11p.145)

f9. Forces can be added by taking two at a time, the final solution of which is known as the resultant. (2p.3) (11p.141, 147) (13p.95)

a. Mass is a constant representing the amount of matter composing an object. (11p.127) f1. The mass of an object is directly proportional to the force required for acceleration and inversely proportional to the magnitude of the acceleration produced. (2p.49)

f2. The mass of an object becomes a direct measure of its inertia. (2p.49)

f3. Inertia is the resistive property of matter to be accelerated. (2p.49) (3p.152) (11p.140)

f4. Inertia increases in direct proportion to the mass of an object. (2p.49) (3p.13)

f5. Mass can be measured by the quotient of the weight of an object divided by the gravitational constant at the place the weight measurement was taken.

$$m = \frac{W}{g} \qquad \text{(11p.127)}$$

f6. The greater the mass of an object, the greater the intensity of force required to change its state of motion. (2p.49) (3p.13)

f7. Mass is a scalar quantity. (11p.141)

b. Velocity is the displacement of an object per unit of time (see Section II B. 2b).

c. The resulting magnitude of the acceleration due to a change in the state of motion of an object is directly proportional to the magnitude of the applied force and inversely proportional to the mass of the object (see Section II B. 2).

2. A resultant force is the final vector solution of two or more summed forces. (2p.3) (11p.141, 147) (13p.95)

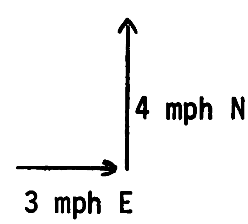
   f1. A vector is a tipped line segment (→) whose length represents its magnitude and whose orientation in space its direction; an arrow or ray. (11p.141) (13p. 92)

   f2. Vectors can be added in any order. (2p.5)

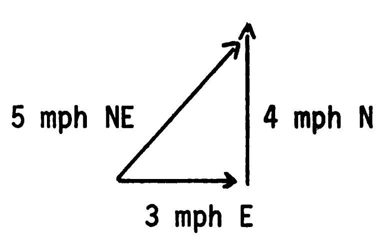
   f3. Applied forces should be added vectorially for maximum information. (2p.3) (11p.141, 147) (13p.95)

   f4. Applied forces are added vectorially by taking two at a time. (11p.143)

   f5. Forces can be added graphically by converting each to a common scale and connecting them tip to tail. (11p.143) (13p.95)



   f6. The resultant is expressed graphically by connecting the tail of the first summed vector with the tip of the last by a new vector which points in the direction of the tip of the last vector. (2p.6)



f7. The resultant vector only points in one direction. (2p.6)

f8. The resultant magnitude of two forces will not be their arithmetic sum unless applied in the same direction. (13p.95)

f9. The resultant direction of two forces is dependent upon the angle of application of each force and is best determined vectorially. (11p.95)

f10. The resultant direction of two forces will be halfway between them only if the two forces are of equal magnitude. (13p.95)

a. In the solution of vector problems, those in which the resultant is unknown are solved by the composition of vectors and those in which the components are the unknowns are solved by the resolution of vectors. (11p. 142)

f1. A vector component is one of any number of vectors which are added together, end to end, to obtain a resultant force. (2p.4)

f2. Vectors can be added in any order. (1p.5)

f3. Applied forces should be added vectorially for maximum information. (2p.3) (11p.141, 147) (13p.95)

f4. A resultant is the final vector solution of two or more summed forces. (2p.3) (11p.141, 147) (13p.95)

f5. In the composition of vectors the rectangular-component trignometric method makes use of basic trignometric rules. (2p.9) (3p.266) (11p.142) (13p.98)

f6. Vectors are added by the component method by resolving each vector into its sine and cosine components and adding those components to find the composite resultant components. (2p.8)

f7. Given its trignometric components, the Pythagorean theorem is used to find the resultant's magnitude and the tangent is used to find the resultant's direction. (1p.9) (13p.142)

f8. The statement of the parallelogram of forces which governs the solution of vectorial problems is based upon Newton's observation that a moving object, when acted upon by two independent forces simultaneously, moved along a diagonal equal to the vector sum of the two independent forces. (11p.5) (13p.95)

1. The solution of vector problems makes use of some basic trignometric rules. (2p.9) (3p.266) (11p.142) (13p.98)

   f1. The Pythagorean theorem states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides. (3p.266) (11p.142) (13p.98)

   f2. The sine of an acute angle of a right triangle is equal to the ratio of the magnitude of the side opposite the angle to the magnitude of the hypotenuse. (2p.267) (11p.142)

f3. The cosine of an acute angle of a right triangle is equal to the ratio of the magnitude of the side adjacent to the angle to the magnitude of the hypotenuse. (13p.98)

f4. The tangent of an acute angle of a right triangle is equal to the ratio of the magnitude of the side opposite the angle to the magnitude of the adjacent side. (2p.8) (3p.267)

B. The applied sciences deal with only some of the internal and external forces.

f1. Buoyancy is the push of a liquid in resistance to being displaced by an object. (3p.252) (8p.305)

f2. Centrifugal force is the pull outward from the center of the circle acting upon a body other than the one traveling in the circle. (2p.157)

f3. Centripetal force is the pull toward the center of the circle acting upon the traveling body to turn it into a circular path. (2p.151)

f4. Compression is a push which causes a decrease in volume. (2p.198) (11p.23)

f5. Drag is the resistive pull of a fluid on an object moving through it. (4p.344) f6. Friction is the resistive force of one object to another object sliding across its surface. (2p.59) (3p. 296) (4p.149)

f7. Gravitational force is the constant attraction each particle of matter has for every other particle of matter. (3p.165, 296) (11p.123)

f8. Momentum is the impulse an object has due to its motion. (11p.63)

f9. Pressure is the push of matter in a perpendicular direction over a unit area of a container. (2p.118)

f10. Tensile force is the resistive pull of an object being stretched. (2p.195) (11p.23)

f11. Tension is the force with which a rope or another constraining material pulls on an object. (2p.3)

1. Buoyancy is the push of a liquid in resistance to being displaced by an object. (3p.252) (8p.305)

   f1. An object immersed in water is buoyed up by a force equal to the product of the density of water and the quantity displaced. (3p.252) (8p.305) (13p.112)

   f2. Floating is the state of being buoyed up by a force equal to the weight of the object before it's immersed. (3p.251)

   f3. Floating is the act of displacing an equivalent weight of liquid before immersion. (3p.251) f4. Archimedes is accredited with the first statement on the principle of buoyancy. (3p.252) (8p.305)

f5. The center of buoyancy is the point at which an object is balanced in a liquid. (13p.112)

f6. Density is the mass per unit volume. (8p.305)

f7. The density of water is one gram per cubic centimeter. (8p.305)

f8. Specific gravity is the density of a substance relative to the density of water. (2p.201) (3p.252)

f9. Specific gravity can be calculated by use of the equation:

$$\text{spec. gr.} = \frac{\text{dry weight of object}}{\text{loss in weight in water}}$$

(3p.252) (4p.228)

2. Centrifugal force is equal in magnitude but opposite in direction to centripetal force. (11p.157) (13p.58)

f1. Centrifugal force is the pull outward from the center of the circle acting upon a body other than the one traveling in the circle. (2p.157)

f2. Centripetal force is the pull toward the center of the circle acting upon the traveling body to turn it into a circular path. (2p.151)

f3. Centrifugal and centripetal force can both be expressed by the same formula:

$$F = m\frac{v_t^2}{r} = \frac{wv_t^2}{gr}$$

where v_t^2 is the tangential velocity and r is the radius of the cirle. (11p.157)

f4. Centripetal force can be displayed as tension in a line pulling a rotating object toward the center of rotation. (11p.157) (13p.38)

f5. Centripetal force acts at right angles to an object's otherwise straight course. (13p.38)

3. Friction is the resistive force of one object to another object sliding across its surface. (2p.59) (3p.296) (4p.149)

f1. Frictional force works to retard motion. (2p.58) (3p. 290)

f2. The magnitude of frictional force (f) can be determined by the product of the coefficient of friction (μ) and the perpendicular force with which the supporting object pushes against the supported object (N or normal force).

$f = \mu N$ (2p.58, 59) (3p.290)

f3. The coefficient of friction varies from surface to surface. (2p.59)

f4. The coefficient of friction is termed static just prior to motion and dynamic or kinetic for an object already in motion. (2p.59) (3p.290)

f5. Frictional force increases with courseness of the surface of either object and application of an external force. (3p.290) (13p.19) f6. Frictional force is greatest just prior to the onset of motion. (2p.59) (3p.290)

f7. Frictional force is dissipated as heat.

f8. Gas molecules are considered as supporting surfaces which yield frictional resistance. (2p.60)

f9. An object is not considered as freely falling unless the frictional force is negligible. (2p.60)

4. Gravitational force is the constant attraction each particle of matter has for every other particle of matter. (3p.165, 296) (11p.123)

f1. The magnitude of the gravitational force that one particle of matter has for another is directly proportional to the distance between the two particles. (2p.164) (11p.123)

f2. The magnitude of the gravitational force that one spherical body has for another can be expressed by the formula

$$F = G \frac{m_1 m_2}{d^2}$$

where F is the attractive force of one sphere for another, G is the proportionality constant, m is the mass of the sphere and d is the distance between the centers of the two spheres. (2p.65)

f3. Gravitational force is unidirectional for a sphere; that is, toward the center of the particle. (11p.123) (13p.141) f4. Because the earth is not a true sphere, being that it is flattened at the poles and bulges at the equator, the gravitational force varies from place to place on its surface because the distance to the center varies. (11p.125)

f5. The gravitational force is slightly less at the equator because the distance to the earth's center is greater. (11p.125)

f6. The mass of the earth is so great relative to an individual and the distance so close that no significant errors are produced in practical problems by assuming the force of gravity is unidirectional; toward the earth's center. (11p.123)

f7. Gravitational force can be considered as acting at one central area of an object, the center of gravity or mass, since the force of gravity attracts every particle of the object toward the earth's center. (11p.123)

f8. As long as the gravitational force is uniform, the center of gravity coincides with the center of mass. (2p.166)

f9. An object's weight has no influence on the gravitational force which is constant. (3p.265) (11p.126)

f10. Weight is a measure of the magnitude by which an object is pulled toward the earth's center. (2p.11) (11p.164)

a. Weight is a measure of the magnitude by which an object is pulled toward the earth's center. (2p.11) (11p.164)

f1. The magnitude of an applied force can be measured by the product of the mass and the acceleration of the object acted upon. (2p.49, 175) (3p.13) (11p.5, 149, 524)

f2. Weight is expressed as the product of the mass of the object and the acceleration due to gravity.

$$W = mg \qquad (11p.127)$$

f3. The weight of an object varies from place to place on the earth's surface in direct proportion to the change in acceleration due to gravity. (3p.165) (11p.127)

f4. It can be shown that $m = \frac{W}{g}$ and both mass and $\frac{W}{g}$ are constants. (2p.48) (11p.127)

f5. The acceleration due to gravity (g) is an expression of the acceleration due to gravity of a freely falling object in the absence of resistive forces. (11p. 126)

f6. The center of gravity of an object is the point at which the mass of the object is considered to be concentrated. (11p.123) (13p.9)

1. The acceleration due to gravity (g) is an expression of the acceleration due to gravity of a freely falling object in the absence of resistive forces. (11p.126)

f1. In most practical computations, the gravitational constant may be considered to be 32.2 ft./sec.^{2} (3p.267) (11p.126) (13p.136)

f2. The acceleration of 32 ft./sec.^{2} expresses that a falling object's velocity increases at a rate of 32 ft./sec. during each second. (3p.267) (11p.126) (13p.136)

f3. The acceleration due to gravity is always toward the earth's center. (2p.65) (3p.4)

f4. Either the time or distance of an object's fall can be calculated by use of the formula:

$$d = \tfrac{1}{2}gt^2$$

where g is the acceleration due to gravity, d is the distance and t is the time. (11p.126)

f5. Falling objects travel 16.1 ft. in the first second, 48.3 ft. in the second second and so on. (3p.265) (11p.126)

f6. Falling objects reach a maximum velocity of 120 mph after a fall from a height of about 482 ft. at sea level. (3p.265) (5p.126)

2. The center of gravity of an object is the point at which the mass of the object is considered to be concentrated. (11p.123) (13p.9)

f1. The center of gravity has no physical reality but is merely a mathematical construct used to simplify computations. (11p.123) f2. The center of gravity of a solid object, symmetrically shaped and of uniform density, is located at its geometric center. (3p.165) (11p. 124)

f3. The center of gravity does not always fall within the physical dimensions of the object. (11p.125)

f4. The center of gravity moves with the motion of the object. (11p.129)

b. The line of gravity is an imaginary line passing through an object's center of gravity in line with the pull toward the earth's center. (11p.127)

f1. The base of support is the area of contact with another surface. (11p.127)

f2. As long as the line of gravity falls within an object's base of support it remains in balance. (11p.128)

f3. In a theoretically perfect balanced position, the line of gravity falls through the geometric center of the base of support. (11p.127)

5. Pressure is the push of matter in a perpendicular direction over a unit area of a container. (2p.118)

f1. Gas molecules colliding with the walls of a container give rise to a pressive force. (2p.118)

f2. A high pressure area will seek a lower pressure area. (11p.302) f3. The low pressure area around the lungs allows the atmospheric pressure within the lungs to overcome the natural contractile tendency of the lung tissue. (11p.302)

f4. A fluid moving through a constricted area decreases its pressure on the sides of the container. (11p.43)

f5. Pressure can be expressed by the formula:

$$P = \frac{F}{A}$$

where F is the force perpendicular to the area, A. (2p.203)

f6. Pascal's principle states that a pressure applied to a confined fluid is transmitted to every particle of the fluid. (2p.705)

f7. Decreasing the number of molecules per unit of volume decreases the pressure. (8p.255)

6. Tensile force is the resistive pull of an object being stretched. (2p.195) (11p.23)

f1. Strain is an expression of the magnitude of a tensile force. (2p.196) (3p.287)

f2. Strain can be expressed by the formula:

$$S = \frac{\Delta L}{L}$$

where S is the strain, ΔL is the change in length from L, the original length. (2p.196) (3p.289) f3. Strain has no units of measure because it is the proportion of two lengths; therefore, the units cancel each other. (2p.196)

f4. According to Hooke's law, stress is proportional to strain. (2p.196) (3p.290)

f5. Stress is force per unit of area over which the force is applied. (2p.195) (3p.289)

f6. There are five major kinds of stress which tend to deform an object; tension, compression, bending, twisting (torque) and shearing. (3p.289)

f7. Stress has units of measurement such as; $lbs./ft.^2$, $lbs./in.^2$, N/cm^2, etc. (2p.195)

II. Motion is the change in position of a unit of matter from one point in space to another initiated through the application of force.

A. The resulting kind of motion of an object subjected to a force is dependent upon the line of force at impact relative to the center of gravity of the object. (11p.130)

f1. Rectilinear motion of an object is the result of an unopposed force applied directly in line with the object's center of gravity or equal distance above and below the center of gravity simultaneously. (3p.277) (13p.34)

f2. An object remains in rectilinear motion unless compelled to change its path by some external nonzero force. (13p. 34) f3. Rectilinear motion can result from application of force above or below the center of gravity if compensating for a resistive force. (13p.35)

f4. Rotary motion of an object is the result of a force applied above or below the object's center of gravity.

f5. Curvilinear motion of an object is the result of limiting the object's path by applying a secondary force or using a confined pathway, i.e., a circular track. (13p. 35)

f6. A force applied to an object at a point other than its center of gravity results in rotary motion about its center of gravity as well as displacement in the direction of the force. (11p.130) (13p.35)

1. Rectilinear motion is the equal displacement of every mass particle of an object along a straight line. (11p. 136) (13p.31)

   f1. Rectilinear motion of an object is the result of an unopposed force applied directly in line with the object's center of gravity or equal distance above and below the center of gravity simultaneously. (3p. 277) (13p.34)

   f2. Rectilinear motion is referred to by some sources as translatory motion. (11p.136)

   f3. Measuring the progression of an object by the movements of its center of gravity through space is the most beneficial technique because the object's velocity and acceleration can also be calculated. (11p.40)

f4. If the sum of all angles of rotation of two or more rotary forces acting on an object in the same direction is zero, the result will be rectilinear motion. (11p.162) (13p.32)

f5. Rectilinear motion can be directed horizontally or vertically or have both horizontal and vertical components. (3p.277)

f6. The more directly horizontal (backward) from its center of gravity an object pushes against another surface, the more it contributes to the rectilinear (forward) motion of the object. (13p.422)

f7. The major differences between rectilinear motion of the body in the water as opposed to on land are imposed by the medium (water) through which it moves. (13p.111)

a. The major differences between rectilinear motion of the body in the water as opposed to on land are imposed by the medium (water) through which it moves. (13p.111)

f1. Rectilinear motion through water must account for buoyancy more than for the force of gravity as on land. (13p.111)

f2. Swimming is the act of producing rectilinear motion to propel the body through water by minimizing the resistance and applying force advantageously. (13p.112) f3. As the supporting surface against which to push, water provides less resistance than land. (13p.111, 112)

f4. As the medium through which the body moves, water becomes the major source of resistance. (13p.111, 112)

f5. According to Karpovich, skin resistance, eddy resistance and wave-making resistance are the three factors of water resistance. (3p.253)

f6. A horizontal rather than a vertical position during swimming takes the greatest advantage of buoyancy and reduces the resistance imposed by the water. 13p.111)

f7. The body moves through water in the direction opposite to that of the applied force. (13p.113)

f8. Streamlining is the act of positioning a body in a manner which offers the smallest surface area in the direction of the intended motion with the purpose of reducing resistance. (13p.112)

f9. Cavitation is the suction effect on a body moving rapidly through a fluid which opposes the motion. (13p.113)

f10. Cavitation is caused by a low pressure area behind a body moving through a fluid created by whirls and eddies produced by sudden and quick movements. (13p. 112, 113) f11. Drag is the resistive pull of a fluid on an object moving through it. (4p.344)

f12. The amount of drag does not increase in proportion to the body's speed but as the velocity squares. (4p.344)

f13. Useless motions add to the resistance of the swimmer. (13p.112)

2. Curvilinear motion is the progression of an object in a circular path or a path other than a circle or straight line, i.e., a parabola. (11p.136) (13p.32)

f1. Curvilinear motion of an object is the result of limiting the object's path by applying a secondary force or using a confined pathway, i.e., a circular track. (13p.35)

f2. Gravity pulls projectiles into a parabolic path when other resistive forces such as air resistance are neglected. (3p.237) (11p.136, 158) (13p.32)

f3. Characteristics of a projectile working against air resistance may cause variable and irregular curvilinear motion. (11p.136)

f4. Centripetal force acts to accelerate the object into a circular path and produce radial acceleration. (11p.157)

f5. Radial acceleration is the rate at which centripetal force pulls an object toward the center of a circle. (11p.156)

a. Gravity pulls projectiles into a parabolic path when other resistive forces such as resistance are neglected. (3p.237) (11p.136, 158) (13p.32)

f1. A projectile is a freely falling object which was initially propelled by a force into the air. (2p.74)

f2. A projectile would maintain its motion in a straight line with the velocity at which it was propelled were it not for the resistive forces of gravity, air and friction. (11p.149)

f3. The force of gravity works to accelerate the projectile vertically down. (2p.76)

f4. The final horizontal displacement of a projectile can be calculated from the following formula if air resistance is ignored.

$$R = \frac{v^2 \sin 2\theta}{g} \qquad \text{when } h_o = 0.$$

where R is the horizontal range, v is the original (initial) velocity of the object, θ is the angular projection, g is the acceleration due to gravity, and h_o is the original height. (3p.236) (11p.138)

f5. To increase the time which a projectile remains in the air, the angle of projection is moved upward or increased. (2p.77)

f6. Range is the horizontal distance between the point of propulsion and the point of landing. (3p.271) f7. Maximum range is obtained with an angle of projection of 45° when the original height is zero because the value of sin 2Θ is greatest at 45°. (3p.270) (11p.139)

f8. The height reached during flight can be calculated from the formula:

$$h = \frac{(v \sin\Theta)^2}{g} \qquad \text{when } h_o = 0$$

where h is the height, v is the original (initial) velocity, Θ is the angular projection, g is the acceleration due to gravity, and h_o is the original height. (11p.139)

f9. Maximum height for any projectile can be reached when the angle of projection is 90° because the value of Θ is greatest at 90°. (11p.139)

f10. The time from projection to landing can be calculated from the formula:

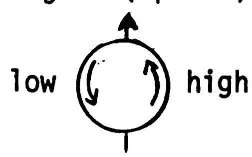
$$t = \frac{2v \sin\Theta}{g} \qquad \text{when } h_o = 0$$

where t is the time, v is the original (initial) velocity, Θ is the angular projection, g is the acceleration due to gravity, and h_o is the original height. (11p.139)

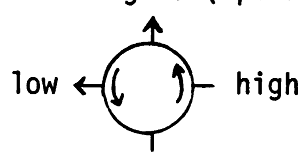
b. Characteristics of a projectile working against air resistance may cause variable and irregular curvilinear motion. (11p.136) f1. Air resistance has the greatest effect on projectiles that are large, light, rough, irregular in shape or moving at fast speeds. (2p.278) (11p. 140, 159) (13p.131)

f2. Air resistance least affects projectiles that are small, heavy, smooth, of uniform shape or moving at moderate speeds. (3p.278) (11p.159) (13p.138)

f3. As a projectile spins it increases the speed of the air flow and therefore decreases the pressure on the side that spins away from the direction of flight while it decreases air flow speed and increases pressure on the side that spins toward the direction of flight. (3p.278) (11p.158)



f4. As a projectile spins the opposing pressures to opposite sides of the projectile create a force at right angles to the direction of flight resulting in a displacement to the side that spins away from the direction of flight. (3p.279) (11p.157, 158)



f5. Gyroscopic action is the stabilizing effect of spin against tumbling and other erratic motion of a projectile. (11p.159) f6. The projectile's speed is relative to that of the air flow. (11p.158)

f7. Air resistance varies in direct proportion to the square of the velocity so, for an object moving twice as fast as another object, the air resistance against it is not twice but four times as great. (11p.140)

f8. A head wind will decrease an object's speed and a tail wind will increase it. (11p.159)

c. Centripetal force acts to accelerate an object into a circular path and produce radial acceleration. (11p.157)

f1. Centripetal force can be displayed as tension in a line pulling a revolving object toward the center of revolution. (11p.159) (13p.38)

f2. As an object revolves its direction and therefore its velocity, a vector quantity, is changing even though the speed, a numerical value, is not. (2p. 152, 153)

f3. Radial acceleration can be calculated from use of the equation:

$$a_r = \frac{v_t^2}{r}$$

where a_r is the radial acceleration, v_t is the instantaneous tangential velocity and r is the radius of the circle. (11p.157) f4. The magnitude of centripetal force can be calculated by use of the formula:

$$F = \frac{v_t^2}{r} = \frac{wv_t^2}{gr} \qquad \text{(11p.157)}$$

f5. As the mass and velocity of an object increase so does the centripetal force needed to move it into a circular path as can be demonstrated by increased tension in a line holding an object in a circular path. (2p.156)

f6. As the radius of a circular path decreases, the centripetal force required to keep an object in it increases. (2p.156)

f7. As the radius of a circular path decreases, even though the velocity of the object remains constant, the angular speed increases. (2p.156)

3. Rotary motion is progression of a rigid object in a circular path or part of a circular path about a center of mass. (13p.33, 35)

f1. Rotary motion of an object is the result of a force applied above or below the object's center of gravity.

f2. A body of matter tends to maintain its state of rest, or uniform motion, in a straight line unless acted upon by an applied force (law of inertia). (3p.295) (11p.4) (13p.36)

f3. A force applied to an object at a point other than its center of gravity results in rotary motion about its center of gravity as well as displacement in the direction of the force. (11p.130) (13p.35)

f4. A force couple is a pair of forces equal in magnitude but opposite in direction working on separate lines parallel to one another causing rotation. (13p.95)

f5. The measurements of the motion about the object's center of gravity can be expressed and calculated by use of the rotational analogs of the rectilinear motion formulas. (2p.178)

f6. Repetitive angular movements usually display oscillations. (13p.53)

a. Repetitive angular movements usually display oscillations. (13p.53)

f1. Equivalent forces applied at equivalent time intervals result in oscillatory motion. (13p.35)

f2. Oscillations in the body are usually the result of maintaining a balanced position. (11p.132)

f3. Amplitude is characteristic of oscillations. (11p.132)

f4. A pendulum is permitted only oscillatory motion. (13p.35)

b. A pendulum is permitted only oscillatory motion. (13p.35)

f1. The force of gravity produces the motion of a pendulum, assisting the downward motion and opposing the upward motion. (13p.117) f2. The upward motion of a pendulum is dependent upon the momentum developed during the downward motion. (13p.117)

f3. Amplitude is the maximum displacement of the body from its position of equilibrium which occurs during one oscillation. (2p.273)

f4. The period of vibration, or simply the period, is the time it takes to make one oscillation. (2p.273)

f5. The period is dependent upon the length of the pendulum. (13p.117)

f6. The period is not affected by the weight of the pendulum. (13p.117)

f7. Frequency is the number of complete oscillations per unit of time. (2p.273)

f8. The speed of a pendulum is the greatest at the point in the arc when the length of the pendulum aligned with the force of gravity. (13p.117)

f9. At the height of its arc of the upward swing, a pendulum reaches a point of zero velocity as the force of gravity and the momentum of the mass are balanced. (13p.117, 120)

4. Flow is the motion of a liquid or gas under the influence of a distorting force (an applied force). (2p.198)

f1. The molecules of a liquid or gas are in constant motion. (2p.192)

f2. A fluid is a substance which flows.

f3. Compared to gas molecules, those of a liquid are closer together and move with a slower velocity. (4p.129)

f4. Liquids vary little with temperature, the shape of their container and have a definite volume. (4p.129)

f5. Gas molecules move with a high velocity and are farther apart than liquid molecules. (4p.129)

f6. Gases have no definite volume or shape, taking the shape and volume of their container, and vary easily with temperature. (4p.129)

f7. As gas fills a container the collision of the gas molecules with the walls of the container creates a pressure. (2p.191)

f8. The laws which govern the flow of liquids also govern the flow of gases. (4p.108)

f9. The flow of a fluid is brought about by a pressure gradient. (4p.86)

f10. Current is the rate of fluid flow. (2p.362)

a. The flow of a fluid is brought about by a pressure gradient. (4p.86)

  f1. A pressure is the push of matter in a perpendicular direction over a unit area of a container. (2p.118)

  f2. A pressure gradient is the difference in pressure between two areas which brings about a flow of fluid while overcoming resistance. (2p.205) (4p.86)

  f3. The natural direction of flow is always from an area of high pressure to an area of low pressure. (4p.86) f4. Pascal's principle states that a pressure applied to a confined fluid is transmitted to every particle of the fluid. (2p.705)

f5. The magnitude of the pressure gradient can be obtained from the product of the volume of blood flow and the resistance.

$$\text{Press. grad.} = \text{vol.} \times R$$

(4p.89)

f6. The resistance to flow is the sum of all forces opposing the flow. (4p.88)

f7. The relationship between the pressure gradient, volume of blood flow and the resistance can be rearranged to give a formula to find the magnitude of the resistance.

$$R = \frac{\text{press. grad.}}{\text{vol.}}$$

where the volume of flow is expressed by the flow rate in ml./sec. (4p.89, 93)

f8. A pressure increase increases the resistance. (8p.187)

f9. A decrease in resistance allows the fluid to flow freely and the pressure to decrease. (8p.222)

f10. Viscosity is a measure of a fluid to resist flow. (2p.199) (4p.88)

f11. The greater the resistance to flow, the greater the viscosity of the fluid. (4p.88)

f12. Pressure is directly proportional to tension. (4p.69) f13. The law of La Place states that tension is equivalent to the product of pressure and the radius of the cylinder.

Tension = press. x radius (4p.69)

b. Current is the rate of fluid flow. (2p.362)

f1. Factors affecting the volume of fluid flow confined to a vessel can be given by Poiseuille's Law.

$$\text{Vol. of blood flow} = \frac{\text{press. x vessel d}}{\text{vessel l x viscosity}}$$

$$F = \frac{\Delta P \pi r^4}{lV}$$

$$\Delta P \propto F$$

where d is the diameter of the vessel and l is the length. (4p.89)

f2. Flow rate increases with an increase in pressure or diameter of the vessel. (4p.92)

f3. Flow rate decreases with an increase in vessel length or viscosity of the fluid. (4p.88, 89, 92)

f4. If the vessel diameter doubles, the flow rate is decreased. (4p.92)

f5. The flow is usually nonturbulent, but restrictions, obstructions and other resistances can cause the flow to eddy thereby creating noise. (4p.80)

c. A potential difference causes an electrical current to flow. (2p.358) f1. An ion is an atom which has either lost or gained an electron leaving it with either a positive or a negative charge, respectively.

f2. Like charges (same polarities) repel each other. (2p.331)

f3. Unlike charges (opposite polarities) attract each other. (2p.331)

f4. A current is the amount of flow of positive charges. (2p.361)

f5. The current of flow is from the area of high potential to that of low potential. (2p.359)

f6. A positive charge yields a high potential opposed to a negative charge of low potential. (2p.359)

f7. The potential difference between two points is the work required to carry a unit positive change from one to the other. (2p.347)

f8. Action potentials are small bioelectrical currents produced by changes in ionic concentration gradients. (11p.68)

f9. Conduction is the process of carrying a wave of depolarization along a fiber or wire to transmit an impulse. (8p.11) (11p.98)

f10. The electrical activity increases linearly with the conduction velocity. (11p.85)

f11. An action potential and wave of depolarization are all-or-none processes. (8p.11)

d. The laws which govern the flow of liquids also govern the flow of gases. (4p.108)

f1. Gas pressure is the collision of gas molecules perpendicular in direction over a unit area of a container. (4p.129)

f2. Boyle's Law states that the pressure of a gas is inversely proportional to the volume under a constant temperature. (4p.129)

f3. Gay-Lussac's Law states that the pressure of a gas is directly proportional to the temperature with a constant volume. (4p.129)

f4. As the temperature increases, the motion of gas molecules increases, more frequent collisions result and therefore the pressure increases. (4p.129)

f5. The Law of Partial Pressures states that in a mixture of gases each gas exerts a part of the total pressure in proportion to its concentration. (4p.129)

f6. Henry's Law states that the quantity of gas that will dissolve in a liquid is directly proportional to its partial pressure, with temperature constant. (4p.129)

f7. The partial pressure of a gas is proportional to its volume percent in the mixture; therefore, if the volume percent is known, the product of it and the total pressure will give the partial pressure for that gas. (8p.166) f8. Partial pressure was usually expressed in millimeters of mercury (mmHg) but more recently in Torr units; 1 Torr = 1 mmHg. (8p.166)

f9. Hydrostatic pressure is the increasing pressure in a vertical column of liquid due to the weight of the liquid. (4p.90)

f10. Hydrostatic pressure is present in any vertical column or tube containing liquid because as the height increases the weight of the liquid increases. (4p.90)

B. Newton's three laws of motion express relationships between applied forces and their effect upon matter. (11p.4)

f1. A body of matter tends to maintain its state of rest, or uniform motion, in a straight line unless acted upon by an applied force (law of inertia). (3p.295) (11p.4) (13p.36)

f2. The resulting magnitude of the acceleration due to a change in the state of motion of an object is directly proportional to the magnitude of the applied force and inversely proportional to the mass of the object (law of momentum). (3p.295) (11p.4) (13p.36)

f3. For every action there is a reaction equal in magnitude and opposite in direction (law of interaction). (3p.207) (11p.5) (13p.37)

1. A body of matter tends to maintain its state of rest, or uniform motion, in a straight line unless acted upon by

an applied force (law of inertia). (3p.295) (11p.4) (13p.36)

f1. Equilibrium is a state of rest or uniform motion in which the resultant of all forces (and sum of all torques) acting upon a body is zero. (2p.15, 170) (11p.130) (13p.86)

f2. Forces with a resultant of zero are considered to be balanced. (2p.12)

f3. To maintain a state of equilibrium, every force which comes into action must be counteracted by an opposing force. (3p.73) (11p.149)

f4. A body in uniform motion without any forces acting upon it is considered to be in equilibrium. (2p.45)

f5. Stability is the state of alleviating unbalanced forces to achieve a state of equilibrium or using them advantageously to control motion. (11p.130)

f6. To set a body in motion or change its state of motion requires the application of an unbalanced force. (3p.295) (11p.140) (13p.30)

a. Stability is the state of alleviating unbalanced forces to achieve a state of equilibrium or using them advantageously to control motion. (11p.130)

f1. To maintain a state of equilibrium every force which comes into action must be counteracted by an opposing force. (3p.73) (11p.149) f2. To set a body in motion, an applied force must move the line of gravity outside the base of support. (11p.128)

f3. The degree of stability is directly related to the size of the base of support. (3p.180) (11p.129) (13p.15, 110)

f4. The degree of stability is directly related to the height of the center of gravity. (3p.180) (13p.17)

f5. The degree of stability is inversely related to the distance between the line of gravity and the center of the base of support. (3p.180) (13p.17)

f6. Maximum stability of a segmented body is achieved when the center of gravity of each segment is aligned vertically over the center of the base of support. (13p.19)

f7. The ability to resist an impact and maintain stability can be improved by moving the line of gravity and/or increasing the base of support in the direction of the oncoming force. (3p.296) (13p.18)

f8. Balance is the continuous process of adjusting for applied forces to keep the line of gravity within the base of support.

f9. Balance is lost if the line of gravity falls outside of the base of support. (11p.128)

f10. Oscillations are the result of the process of balancing. (11p.132)

b. To set a body in motion or change its state of motion requires the application of an unbalanced force. (3p.295) (11p.140) (13p.30)

f1. To set a body in motion requires an applied force whose magnitude is greater than any resistance to the body, i.e., inertia. (13p.30)

f2. Inertia is the resistive property of matter to be accelerated. (2p.49) (3p.152) (11p.140)

f3. The magnitude of force required to set a body in motion can be expressed by the formula:

$$F = ma \qquad (2p.175)\ (11p.5,\ 149)$$

f4. When an object is moved, the most common resistance overcome is the force of gravity. (11p.169) (13p.30)

f5. The velocity of a body in motion remains constant unless acted upon by a force. (13p.36)

f6. Motion is not visually perceived unless a change in velocity or direction takes place in either the object or the viewer. (4p.37)

f7. Movement of an entire object takes place when the base of support changes. (3p.164)

2. The resulting magnitude of the acceleration due to a change in the state of motion of an object is directly proportional to the magnitude of the applied force and inversely proportional to the mass of the object. (3p.295) (11p.4, 149) (13p.36)

f1. The relationship between force (F) and acceleration (a) can be expressed by

$$F \propto ma$$

where $\propto$ is read as "is directly proportional to." (2p.47) (11p.523)

f2. To convert the statement of proportionality, $F \propto ma$, into a statement of equality requires the inclusion of a constant (k) to give $F = kma$, where $k = 1$ upon the correct selection of either force or mass units. (2p.47) (11p.524)

f3. Mass is a constant representing the amount of matter composing an object. (11p.127)

f4. Average acceleration is the rate of change in the velocity of an object expressed in units of time.

$$\bar{a} = \frac{v - v_o}{t}$$

where v_o is the original (initial) velocity, v is the terminal velocity and t is the time over which the change took place. (2p.26) (11p.146)

f5. An object when increasing its velocity is said to be accelerating and when decreasing its velocity is said to be decelerating. (2p.26)

f6. Velocity is the displacement of an object per unit of time.

$$\bar{v} = \frac{s}{t} \qquad \text{(2p.23) (11p.145)}$$

f7. Velocity is a vector quantity. (2p.26) (11p.141, 145)

f8. Being the sum of two vector quantities divided by time, acceleration is a vector quantity. (2p.26) (11p.141)

f9. Constant acceleration occurs when the increase of the speed and velocity of an object is uniform over time. (2p.27) (11p.146)

f10. During constant acceleration, the average velocity is the average of the original (initial) and final velocities.

$$\bar{v} = \frac{v + v_o}{2} \qquad (2p.27)$$

f11. During constant acceleration, the plot of acceleration against time is a horizontal straight line with a magnitude equal to the slope of velocity plotted against time which is a straight line. (11p.146)

f12. Four equations can be mathematically derived for use in the solution of problems involving constant acceleration from equations previously known. (2p.30) (11p. 146)

<u>Known</u>	<u>Derived</u>
$\bar{v} = \frac{s}{t}$	$s = \bar{v}t$
$\bar{a} = \frac{v - v_o}{t}$	$v = v_o + at$
$\bar{v} = \frac{1}{2}(v + v_o)$	$2as = v^2 - v_o^2$
	$s = v_o t + \frac{1}{2}at^2$

a. Mass is a constant representing the amount of matter composing an object. (11p.127)

f1. The mass of an object is directly proportional to the force required for acceleration and inversely proportional to the magnitude of the acceleration produced. (2p.49)

f2. The mass of an object becomes a direct measure of its inertia. (2p.49)

f3. Inertia is the resistive property of matter to be accelerated. (2p.49) (3p.152) (11p.140)

f4. Inertia increases in direct proportion to the mass of an object. (2p.49) (3p.13)

f5. Mass can be measured by the quotient of the weight of an object divided by the gravitational constant at the place the weight measurement was taken.

$$m = \frac{W}{g} \qquad \text{(11p.127)}$$

f6. The greater the mass of an object, the greater the intensity of force required to change its state of motion. (2p.49) (3p.13)

f7. Mass is a scalar quantity. (11p.141)

b. Velocity is the displacement of an object per unit of time. (2p.23) (11p.145)

f1. The magnitude of average velocity can be measured by the formula:

$$\bar{v} = \frac{s}{t}$$

where $\bar{v}$ is the average velocity, s is a displacement vector and t is the time taken. (2p.23) (11p.145)

f2. Displacement is the directed change in position of an object as measured along an arbitrary x-axis.

$$s = x_t - x_o$$

where s is the displacement, x_t is the terminal point on the scale and x_o is the original (initial) point on the scale. (11p.145)

f3. Displacement is a vector quantity. (11p.141, 145)

f4. Distance (d) is the length of a traversed path.

$$d = |x_t - x_o|$$

where d is the distance, x_t is the terminal point on the scale, x_o is the original (initial) point on the scale and $|\ |$ is the absolute value of the quantity within. (11p.145)

f5. Distance is a scalar quantity and is always positive. (11p.141, 145)

f6. For an object traveling in a constant direction along a straight line the displacement (s) is equivalent to the distance (d) traveled. (2p.23)

f7. If the original (initial) position has a higher scale value than the terminal position, then the displacement and velocity values will be negative. (11p.145) f8. As the time interval approaches an insignificantly small value in relationship to the interval of interest, the average velocity is considered to be instantaneous. (2p.26) (11p.145)

f9. Under uniform (constant) velocity, average velocity and instantaneous velocity are equal. (11p.146)

f10. The magnitude of the instantaneous velocity is equal to the instantaneous speed. (2p.26)

1. Speed (u) is the distance traveled per unit of time of a mass body after an application of force. (4p.351) (11p.119) (13p.78)

f1. Average speed can be measured by use of the formula:

$$\bar{u} = \frac{d}{t}$$

where $\bar{u}$ is the average speed, d is the distance and t is the time taken. (2p.23)

f2. Instantaneous speed is the limiting value computed as the time interval approaches a relatively minute quantity. (2p.26)

f3. The speed of an object is proportional to the magnitude of the applied force. (4p.351) (11p.119) (13p.78)

f4. To produce speed in an object, the magnitude of the applied force must be greater than the resistive forces opposing it. (4p.351) f5. Speed is a measure of movement at a constant rate. (4p.351)

c. Momentum is the change in motion of a mass body. (11p.149)

f1. The change in motion is proportional to the magnitude and in the direction of the applied force (law of momentum). (2p.111) (11p.5)

f2. The magnitude of momentum can be calculated by use of the formula:

$$\text{momentum} = mv$$

where m is the mass of the body and v is the velocity. (11p.149)

f3. Momentum can be derived from the equations for force and acceleration through substitution.

$$F = ma$$

$$a = \frac{v - v_o}{t}$$

$$F = \frac{mv - mv_o}{t} \qquad \text{(11p.149)}$$

f4. Substituting momentum into the equation for force redefines force as a change in momentum over a unit of time. (11p.150)

f5. The change in momentum of a body is equivalent to the impulse applied. (2p.109)

f6. The magnitude of force acting on an object over a unit of time can be calculated by the impulse-momentum equation.

$$Ft = mv - mv_o$$

where Ft is the impulse, mv is the terminal momentum and mv_o is the original (initial) momentum. (2p.109) (11p.150)

d. The principle of the conservation of momentum applies for angular motion as well as linear motion. (11p.155)

f1. Angular momentum can be calculated by the product of rotational inertia and angular velocity.

$$\text{angular momentum} = I\,\omega$$

(11p.527)

f2. The symbol $\mathcal{J}$ is also used by some sources as the symbol for rotational inertia. (11p.155, 527)

f3. The angular momentum of a system is constant until acted upon by an outside force. (2p.184) (11p.155)

e. The rotational analog for extended rigid bodies of the relationship F = ma is $\tau = I\alpha$. (2p.178)

f1. Angular acceleration (α) is the rotational analog of rectilinear acceleration (a) for extended rigid bodies. (2p.175, 178) (11p.156)

f2. Angular acceleration is related to linear acceleration by the formula:

$$\alpha r = a \qquad \text{(2p.176)}$$

f3. Angular acceleration can be expressed by the formula:

$$\alpha = \frac{\omega - \omega_o}{t}$$

where α is the angular acceleration, ω is the angular velocity, and t is the time. (11p.147)

f4. Angular acceleration and angular velocity are expressed in radians/sec.^{2} and radians/sec., respectively. (11p.147)

f5. In rotary motion the concepts of torque and rotational inertia are analogous to the concepts in rectilinear motion of force and mass, respectively. (2p.175) (3p.172) (11p.153)

f6. Torque is the turning effect of an applied force about a center of rotation, axis or pivot point. (2p.168) (11p.153)

f7. The magnitude of torque can be measured by the product of the force and the perpendicular distance from the line of force to the center of rotation.

$$\tau = Fr$$

where τ (tau) is the torque, F is the force and r is the perpendicular distance. (2p.168, 169) (3p.46) (11p.153)

f8. The perpendicular distance from the line of force to the center of rotation can be referred to as the lever arm and is often expressed by one of the following symbols; l, d or r. (2p.169) (3p.46) (11p.153)

f9. The rotational inertia depends on both the mass and the perpendicular distance and is referred to as the moment of inertia.

$$I = mr^2 \qquad (2p.176, 178)$$

f10. Substituting into Newton's equation for force, the rotational analog can be derived.

$$\alpha r \text{ for } a \rightarrow F = mr\alpha$$

$$Fr = \tau \text{ (torque) } \therefore$$

$$\tau = mr^2\alpha \text{ in rad./sec.}^2$$

$$I = mr^2$$

$$\tau = I\alpha$$

(2p.176) (11p.154)

f11. The moment of inertia for a small object is approximately the product of the mass of the object and the square of the distance from the center of rotation. (11p.154)

f. Rectilinear motion equations can be converted into analogous angular motion equations by substituting θ, ω and α for s, v and a respectively. (2p.149)

f1. The angular distance (θ) through which a rotating object travels is measured in units of radians or, sometimes, degrees. (2p.146) (11p.147)

f2. A radian is a measure equal to the angle at the center of a circle subtended by (opposite) an arc on the circle equal in length to the radius of the circle or 57.3°. (3p.51) (11p.148)

f3. One complete revolution is equal to 2π radians or $\theta = 360°$. (2p.146) f4. The length of the arc of a circle can be calculated by the product of the angular distance in radian units and the radius of the circle.

$$s = \theta r$$

where s is the length or the arc. (2p.147)

f5. Average angular velocity is calculated by use of the formula:

$$\bar{\omega} = \frac{\theta}{t}$$

where ω (omega) is the angular velocity, θ is the angular distance and t is the time taken. (2p.147) (3p.51) (11p.147)

f6. Angular velocity (ω) can be expressed by the ratio of an angular unit to a unit of time such as; degrees per second, revolutions per minute, radians per second or others. (2p.147)

f7. As the unit of time approaches zero or a limiting value, the angular velocity approximates the instantaneous speed.

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta \Theta}{\Delta t}$$

where Δ (delta) is read as "the change in." (2p.148)

f8. Average angular acceleration can be calculated from the equation:

$$\bar{\alpha} = \frac{\omega - \omega_o}{t}$$

where α (alpha) is the angular acceleration, ω (omega) is the average acceleration and t is the time taken. (2p.149)

f9. With uniform angular acceleration, as with uniform rectilinear acceleration, the average angular velocity can be calculated by use of the formula:

$$\bar{\omega} = \tfrac{1}{2}(\omega - \omega_o)$$

f10. Each of the basic linear equations has an analogous angular equation as follows:

KNOWN

Linear	Angular
$\bar{v} = \frac{s}{t}$	$\bar{\omega} = \frac{\theta}{t}$
$\bar{a} = \frac{v - v_o}{t}$	$\alpha = \frac{\omega - \omega_o}{t}$
$\bar{v} = \tfrac{1}{2}(v + v_o)$	$\bar{\omega} = \tfrac{1}{2}(\omega + \omega_o)$

DERIVED

Linear	Angular
$s = \bar{v}t$	$\theta = \bar{\omega}t$
$v = v_o + at$	$\omega = \omega_o + \alpha t$
$2as = v^2 - v_o^2$	$2\alpha\theta = \omega^2 - \omega_o^2$
$s = v_o t + \tfrac{1}{2}at^2$	$\theta = \omega_o t + \tfrac{1}{2}\alpha t^2$

(2p.150)

3. To every action there is a reaction equal in magnitude and opposite in direction (law of interaction). (3p.207) (11p.5) (13p.37)

f1. Newton dealt with only two bodies when stating his third law. (2p.47)

f2. An action is a force applied by one object against another. (2p.45)

f3. A reaction is the resulting force by an object in equal opposition to a force applied by another object. (2p.45)

f4. The more directly horizontal (backward) from its center of gravity that an object pushes against another surface, the more it contributes to the rectilinear (forward) motion of the object. (13p.422)

f5. Momentum is the change in motion of a mass body. (11p. 149)

f6. The law of conservation of momentum states that the total momentum after the collision of bodies is exactly equal to the total momentum before collision. (11p.151)

f7. The total momentum in an isolated system is constant. (2p.110)

f8. The angle of incidence is the line of force at which a moving body collides with a surface relative to the line of force or a perpendicular to the line of force of the surface at impact.

f9. The angle of rebound is the line of force at which a colliding body is propelled away from the surface with which it collides.

f10. The angle of rebound is affected by the amount of spin, direction of spin, area of contact, coefficient of restitution, and degree of penetration of the two colliding surfaces causing it to differ from the angle of incidence. (11p.158)

C. A lever is a rigid bar that revolves about a fulcrum while it transmits and modifies one applied force to gain a mechanical advantage to move an opposing resistive force. (3p.32) (11p.164) (13p.69)

f1. The mechanical advantage is a statement of the output relative to the input. (13p.82)

f2. There are three classes of levers depending upon the relative positions of the force, axis and resistance. (3p.33) (11p.165) (13p.35)

f3. The wheel and axle and pulley are lever modifications. (11p.171)

f4. A fulcrum is the fixed point around which a lever revolves. (3p.32) (11p.164) (13p.69)

f5. The resistance to the applied force may be the weight of the lever itself. (3p.32) (13p.69)

f6. The angle of application is the angle formed by the line of the resistive force and the lever. (13p.71)

f7. The angle of pull (or push) is the angle formed by the line of the applied force and the lever. (4p.25) f8. The resistance and the applied force can both be represented by a single point on the lever, the mid-point of the area over which it is applied. (13p.71)

f9. The torque of the resistive force or the applied force has an exact relationship to their distance from the fulcrum. (13p.70)

f10. The resistance-arm includes the perpendicular distance from the line of the applied resistance and the fulcrum. (3p.33) (11p.164) (13p.72)

f11. The force arm includes the perpendicular distance from the line of the applied force and the fulcrum. (2p.168) (3p.32, 33) (11p.164) (13p.72)

f12. When force is applied to a lever, its motion is angular with all points moving in an arc of a circle a distance proportional to the distance from the fulcrum. (11p.164) (13p.31, 35)

1. When a force is applied to a lever its motion is angular with all points moving in an arc of a circle a distance proportional to the distance from the fulcrum. (11p.164) (13p.31, 35)

   f1. The further away from the fulcrum of a lever, the faster the point moves. (3p.43, 45) (11p.164)

   f2. As a lever rotates about its fulcrum, each point forms a concentric circle with a radius equivalent to its distance from the fulcrum. (11p.136) f3. As the radius of a given lever shortens, the angular velocity and the angular acceleration of the lever's end are increased. (3p.45) (11p.149) (13p.11)

2. The mechanical advantage is a statement of the output relative to the input. (13p.82)

f1. The mechanical advantage of a lever can be calculated by the ratio of the force arm to the resistance arm. (11p.164) (13p.82)

f2. The force and resistance will be in balance when the product of the force and force arm equals the product of the resistance and resistance arm.

$$f \times fa = r \times ra$$

where the rotary components of f and r are applied at 90° to the lever. (2p.43) (11p.165) (13p.73)

f3. An imbalance between the force and the resistance causes the lever to move. (11p.165)

f4. The product of the force and force arm represents a force torque and the product of the resistance and resistance arm a resistance torque.

$$f \times fa = \text{force torque}$$

$$r \times ra = \text{resistance torque}$$

(11p.165) (13p.94)

f5. The mechanical advantage of a wheel and axle can be calculated by the ratio of the radius of the wheel to that of the axle.

$$MA = \frac{R}{r} \qquad (13p.83)$$

f6. A fixed single pulley changes only the direction at which a force is applied, not its magnitude. (13p.83)

f7. Efficiency is low when the stabilizing force is greater than the rotary force causing the motion. (11p.169)

3. Levers are divided into three classes depending upon the relative positions of the force, fulcrum and resistance. (3p.43) (11p.165, 166) (13p.72, 73)

f1. A first class lever has the fulcrum positioned between the force and resistance. (11p.165) (13p.72)

f2. In a first class lever, the fulcrum can be positioned to divide the lever into equal halves between the force arm and resistance arm. (13p.72)

f3. The first class lever is used to balance a weight and a force, gaining neither force nor direction. (3p.43) (11p.165) (13p.70)

f4. First class levers can sacrifice force to gain speed. (11p.165)

f5. A second class lever has the resistance positioned between the fulcrum and the force. (11p.166) (13p.72)

f6. In a second class lever, the length of the force arm coincides with the total length of the lever, therefore favoring force. (3p.43) (13p.72, 73)

f7. A second class lever gains force at the expense of speed and distance. (3p.43) (13p.73) f8. A second class, and sometimes a first class, lever transmits an applied force over a large distance and modifies it to a force of larger magnitude transmitted a shorter distance and thus gains a mechanical advantage. (3p.32) (11p.164) (13p.69)

f9. The wheel and axle is a form of a second class lever. (11p.171)

f10. A third class lever has the force positioned between the fulcrum and the resistance. (11p.166) (13p.72)

f11. In a third class lever, the length of the resistance arm coincides with the total length of the lever, therefore favoring speed and distance. (3p.43) (13p. 72, 73)

f12. A third class lever gains speed and distance at the expense of force. (3p.43) (13p.73)

4. The wheel and axle and pulley are lever modifications. (11p.171)

f1. The radius of the wheel may be considered to be the force arm of a lever. (13p.78)

f2. The larger the radius of the wheel the greater the force magnification. (13p.78)

f3. The force can be applied to either the wheel rim or the axle. (13p.78)

f4. The wheel and axle is a form of a second class lever. (11p.171) f5. A pulley is a wheel with a rope running part way around it. (3p.84) (13p.81)

f6. A pulley can act to change the direction of the applied force and/or the resulting motion. (3p.84) (11p.171) (13p.81)

f7. The resistance always is positioned at 90° to the pulley. (8p.115)

f8. The only pulley represented in the body is the fixed single pulley. (13p.81)

III. Energy is the ability to do work. (4p.145)

A. The law of the conservation of energy holds that energy is neither created nor destroyed when converted from one form to another. (4p.145)

f1. Energy takes different forms such as; mechanical energy, chemical energy, heat, potential energy and kinetic energy. (3p.80) (4p.145) (11p.47, 49, 85, 516)

f2. Energy can be transformed from one form to another. (4p.145) (11p.49)

f3. Some of the energy which goes into a system does not appear as work but is dissipated as heat. (3p.81) (11p.85)

f4. The energy used to move an object which does not add to the force adds to the distance (and vice versa). (11p.164)

f5. The magnitude of force can be reduced by increasing the surface area over which it is applied. (11p.532)

1. Potential energy is the amount of work an object is capable of doing by virtue of its position, state, or arrangement. (2p.92) (13p.120)

   f1. Potential energy is referred to as stored energy. (4p.145) (11p.42)

   f2. Potential energy with respect to the earth's gravitational field can be estimated by the following formula:

   $$\text{Potential energy} = wh = mgh$$

   (2p.92)

   f3. Potential, or stored, energy can be converted to other energy forms (3p.8) (11p.42)

   f4. Energy is required to store energy. (11p.73)

2. Kinetic energy is the amount of work an object is capable of doing by virtue of its motion. (11p.90) (13p.137)

   f1. Kinetic energy is related to the mass and velocity of the moving object by the following relationship:

   $$\text{kinetic energy} = \tfrac{1}{2}mv^2$$

   (13p.137, 519)

   f2. The magnitude of kinetic energy can be estimated by the product of the force and the distance over which it is applied.

   $$\text{kinetic energy} = Fd$$

   $$\tfrac{1}{2}mv^2 = Fd \qquad \text{(11p.519)}$$

f3. Since the amount of work done is the product of the force and the distance over which it is applied, kinetic energy can be equated with work done.

$$\text{Work} = Fd = \tfrac{1}{2}mv^2 = \text{kinetic energy}$$

(3p.80) (4p.145) (11p.86, 531)

3. Heat can be transferred by one of four means; conduction, convection, radiation or evaporation (vaporization). (4p.176) (8p.246)

f1. Conduction is the process of heat exchange by contact. (4p.269)

f2. Convection is the process of heat transfer by the flow of a fluid. (4p.269)

f3. Radiation is the process of heat transfer by way of electromagnetic waves. (4p.269)

f4. Evaporation, or vaporization, is the process of changing a liquid into a gas through heating. (4p.269)

f5. Friction can generate heat energy. (2p.96)

B. Energy can be measured. (11p.172)

f1. For the human body, the ratio of the carbon dioxide expired to the oxygen inspired is known as the respiratory quotient.

$$\text{R.Q.} = \frac{CO_2}{O_2}$$

(3p.80) (4p.160) (8p.80) (11p.172)

f2. Energy expended can be expressed in calories. (8p.123) (11p.173) f3. A kilocalorie is the heat required to raise the temperature of one kilogram of water one degree centigrade in the range 0 to 100°C. (2p.242) (4p.145)

f4. Some conversions to horsepower are:

1 hp = 33,000 ft.lbs./min. (4562.4 kg.m./min.), 10.7 cal./min. or 2.1 liters O_2/min. (11p.173)

f5. Intensity is a measure of the amount of energy expended in a given unit of time. (4p.74) (11p.243)

f6. A change in speed requires an expenditure of energy. (8p.126) (11p.487)

f7. Energy increases in a linear relationship to the load carried. (8p.129)

C. A unit of work is the amount required to exert one unit of force through one unit of distance. (4p.144) (8p.103) (11p.87) (13p.97)

f1. The energy expended during dynamic work can be expressed by the following formula:

$$W_d = Fd$$

where W_d is the dynamic work, F is the force and d is the displacement in the direction of the force. (3p.80) (11p.172)

f2. The units in which work is expressed is dependent upon the units of force and displacement employed, such as; gram-centimeters, foot-pounds, kilogram-meters, foot-tons, etc. (3p.80) (11p.87) f3. Mechanical work can be converted to calories.

3086 ft.lbs. = 1 cal.

426.7 kg.m. = 1 cal. (11p.173)

f4. An underload is a resistance value less than the optimal load and an overload is a value greater than the optimal load. (4p.328)

f5. Technically, no work is accomplished unless the load is moved. (11p.88)

f6. The energy expended during static work can be expressed by the following formula:

$$W_s = Ft$$

where W_s is the static work, F is the force and t is the time the force was sustained. (11p.172)

f7. Work for lifting can be calculated by the product of the weight of the load and the height to which it is raised. (8p.137)

f8. A distinction is made between lifting a load, positive work, and lowering a load, negative work. (4p.346) (8p.103) (11p.87)

f9. Work accomplished in aquatic locomotion under constant water speed can be estimated by use of the formula:

$$W = Rd = Fd$$

where W is the work, R is the water resistance, d is the distance and F is the propelling force. (8p.131)

f10. Work done by the pressure of fluid can be expressed by the formula:

$$\text{Work} = \text{pressure} \times \text{volume moved}$$

(4p.69)

f11. Except for static work, time is not a relevant factor in the concept or work. (4p.144)

D. Power is the rate at which work is done. (11p.174) (13p.383)

f1. Power can be calculated by the ratio of work to the time required to do the work.

$$P = \frac{W}{t} \qquad (11p.174)$$

f2. Power is usually expressed in horsepower (550 ft.lb./sec.). (4p.144) (11p.174)

f3. Power is a combination of strength and speed. (4p.145)

f4. Strength is the ability to overcome a resistance. (11p. 174)

f5. As the weight of the load increases, the speed of lifting decreases. (8p.18) (11p.88)

E. Efficiency is the degree to which the energy expended appears as useful work. (8p.382)

f1. Mechanical efficiency, in general, can be expressed as the ratio of work production to energy input expressed as a percentage.

$$\text{Gross Efficiency} = \frac{\text{Work done} \times 100}{\text{Gross energy used}}$$

(4p.69) (8p.113)

f2. Efficiency remains constant with an increase in speed because it is proportional to the rate of increase in energy demand. (4p.341)

f3. Friction decreases mechanical efficiency. (8p.382)

f4. Work efficiency is the ratio of useful work output to useful work input. (11p.174) (13p.382)

a. Work efficiency is the ratio of useful work output to useful work input. (11p.174) (13p.382)

f1. Physiological work efficiency is usually expressed as a percentage from the formula:

$$W.E. = \frac{W \times 100}{O_2 \times \text{(approx.) } 15{,}000 \text{ ft.lbs.}}$$

where W.E. is the work efficiency, W is the work expressed in ft.lbs. and O_2 is the oxygen consumed expressed in liters. (11p.174) (13p.382)

f2. Useful work varies with the applied load. (11p.88)

f3. Friction decreases mechanical efficiency. (8p.382)

f4. The efficiency for a machine follows the same formula of output to input.

$$\text{Eff.} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Work done by machine}}{\text{Work done on machine}}$$

(4p.339)

f5. Servomechanisms utilize small forces to control larger forces. (8p.37)

REFERENCES

REFERENCES

1. Bruner, Jerome S. The Process of Education. Cambridge: Harvard University Press, 1960.

2. Bueche, F. Principles of Physics. New York: McGraw-Hill (2nd. ed.), 1972.

3. Cooper, John M. and Ruth B. Glassow. Kinesiology. Saint Louis: C.V. Mosby Co., 1972.

4. deVries, Herbert A. Physiology of Exercise for Physical Education and Athletics. Dubuque: Wm. C. Brown Co., 1969.

5. Frost, Joe L., and B. Thomas Rawland. Curricula For the Seventies. Boston: Houghton Mifflin Co., 1960.

6. Gagne, Robert M. The Conditions of Learning. New York: Holt, Rinehart and Winston, 1970.

7. Hooper, Mary Evans (ed.). Higher Education Earned Degrees Conferred: 1969 - 1970 Institutional Data. Washington, D.C.: U.S. Government Printing Office, 1970.

8. Karpovich, Peter V. and Wayne E. Sinning. Physiology of Muscular Activity. Philadelphia: W.B. Saunders Co., 1971.

9. Ohles, John F. "Interest and Learning," Education, 89:249-52, February, 1969.

10. Piaget, Jean. On the Development of Memory and Identity. Eleanor Duckwork (trans.). Barre: Clark University Press with Barre Pub., 1968.

11. Rasch, Philip J. and Roger K. Burke. Kinesiology and Applied Anatomy. Philadelphia: Lea & Febiger (4th ed.), 1971.

12. Tagatz, Glenn E., Elmer A. Lemke, and Dean L. Meinke. "The Relationship Between Conceptual Learning and Curricular Achievement," The Journal of Experimental Education, 38:70-75, 1969.

13. Wells, Katherine F. Kinesiology. Philadelphia: W.B. Saunders Co. (4th ed.), 1969.

APPENDICES

APPENDIX A

Questionnaire and Follow-up Letters for the Applied Sciences

Miss Paula D. Serra
Room 131
Women's Intramural Building
Michigan State University
East Lansing, Mich. 48823

Dear

I am attempting to compile a list of current kinesiology and physiology of exercise textbooks being used or recommended to students in the mid-west district.

Enclosed you will find copies of a questionnaire with return envelope attached. The questionnaire is designed to take only a few minutes to complete.

It would be of great assistance to me if you would see that each faculty member of your department who teaches either a kinesiology or a physiology of exercise course receives one questionnaire with the attached envelope.

Your aid in this distribution will be very much appreciated.

Sincerely,

Paula D. Serra

Dear Instructor:

I would like to identify current kinesiology and physiology of exercise textbooks in use and those recommended for reference. It would be helpful if you would complete the following checklist and return the list to me in the enclosed envelope. Your response will be very much appreciated.

Sincerely,

Paula D. Serra

University______________________________

Course Taught: _____ Kinesiology _____ Phys. of Exercise

Department: _____ Men's _____ Women's

KINESIOLOGY

Adopted Text	Reference	
☐	☐	Barham, Jerry N. and William L. Thomas. Anatomical Kinesiology: A Programmed Text. Toronto: MacMillan Co., 1969.
☐	☐	Cooper, John M., and Ruth B. Glassow. Kinesiology. St. Louis: C.V. Mosby Co., 1972.
☐	☐	Haye, Anna Scott. Fundamentals of Movement - a study guide for students and teachers. Palo Alto: The National Press, 1961.
☐	☐	Jensen, Clayne R., and Gordon W. Schultz. Applied Kinesiology. New York: McGraw-Hill Book Co., 1970.
☐	☐	Kelly, David L. Kinesiology: Fundamentals of Motor Description. Englewood Cliffs: Prentice-Hall, Inc., 1971.
☐	☐	MacConaill, M.A., and J.V. Basmajian. Muscles and Movements - a basis for human kinesiology. Baltimore: Williams and Wilkins Co., 1969.

Adopted Text | Reference

☐ ☐ Rasch, Philip J., and Roger K. Burke. Kinesiology and Applied Anatomy. Philadelphia: Lea and Febiger, 1967.

☐ ☐ Thompson, Clem W. Manual of Structural Kinesiology. St. Louis: C.V. Mosby Co., 1969.

☐ ☐ Wells, Katherine F. Kinesiology. Philadelphia: W.B. Saunders Co., 1969.

☐ ☐ Williams, Marian, and Herbert B. Lissner. Biomechanics of Human Motion. Philadelphia: W.B. Saunders, 1962.

PHYSIOLOGY

☐ ☐ Astrand, Per Olof, and Kaare Rodahl. Textbook of Work Physiology. New York: McGraw-Hill, 1970.

☐ ☐ Davis, Elwood Craig, and Gene A. Logan. Biophysical Values of Muscular Activity. Dubuque: W.C. Brown Co., 1969.

☐ ☐ deVries, Herbert A. Physiology of Exercise. Dubuque: W.C. Brown Co., 1969.

☐ ☐ Falls, Harold B., Earl L. Wallis, and Gene A. Logan. Foundations of Conditioning. New York: Academic Press, 1970.

☐ ☐ Jokl, Ernst. Physiology of Exercise. Springfield: Thomas, 1969.

☐ ☐ Karpovich, Peter, and Wayne Sinning. Physiology of Muscular Activity. Philadelphia: W.B. Saunders, 1971.

☐ ☐ Matthews, Donald K., and Edward L. Fox. Physiological Basis of Physical Education and Athletics. Philadelphia: W.B. Saunders Co., 1971.

☐ ☐ Morehouse, Clarence, and Augustus Miller. Physiology of Exercise. St. Louis: C.V. Mosby Co., 1967.

☐ ☐ Ricci, Benjamin. Physiological Basis of Human Performance. Philadelphia: Lea and Febiger, 1967.

Adopted Text | Reference

☐ ☐ Sloan, Archibald. Physiology for Students and Teachers of Physical Education. London: Edward Arnold, 1970.

OTHERS

Comments:

Miss Paula D. Serra
Room 131
Women's Intramural Building
Michigan State University
East Lansing, Mich. 48823

Dear

In June I sent you copies of a questionnaire to be distributed to your kinesiology and physiology of exercise instructors. The initial response was much better than I anticipated considering it was the summer term. However, I have still not reached the percentage necessary to progress with my work and must again ask for your assistance.

Below is a resume of the responses I have received from your university. It would be of great assistance to me if you would provide me with feedback on the information which I have not yet received.

Sincerely,

Paula D. Serra

- -

University ____________________________

Course	Dept.	Received
Kinesiology	Men's	______
	Women's	______
Physiology	Men's	______
	Women's	______

Received

_____ Kinesiology responses but the department is unknown.

_____ Physiology responses but the department is unknown.

Comments:

Miss Paula D. Serra
Room 131
Women's Intramural Building
Michigan State University
East Lansing, Mich. 48823

Dear

In June I sent you copies of a questionnaire to be distributed to your kinesiology and physiology of exercise instructors. The initial response was much better than I anticipated considering it was the summer term. However, I have still not reached the percentage necessary to progress with my work and must again ask for your assistance.

My records show that your university has not yet responded. I am certain that this is either due to the summer term or lack of contacting you. To assist me would you please complete the bottom portion of this letter, returning it to me in the enclosed envelope, and urge your instructors to respond when convenient.

Sincerely,

Paula D. Serra

- -

University ___________________________

Department _____ Men's _____ Women's

_____ I have received your questionnaires.

_____ I have distributed your questionnaires to the appropriate instructors.

_____ Faculty are away for the summer.

Comments:

APPENDIX B

Questionnaire for Physics

Room 105
Women's Intramural Bldg.
Michigan State University
East Lansing
Michigan 48823

Dear Sir:

I am working on a thesis which requires the use of freshman physics books.

Could you please help me identify those texts being used in the midwest district by recording below the information for the textbook used in your freshman level general (offered for liberal arts majors) physics course. Enclosed is a return envelope for your response.

Your assistance will be very much appreciated.

Sincerely yours,

Miss Paula D. Serra

- -

Author	Title	Publisher	Date