DOCUMENT RESUME

ED 031 415 24 SE 007 463

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Development and Evaluation of Instructional Aids in a Technical Physics Course for Industrial Technology Students. Final Report.

Saint Louis Junior Coll. District, Florissant Valley Community Coll., Ferguson, Mo.
Spons Agency-Office of Education (DHEW), Washington, D.C. Bureau of Research.
Bureau No-BR-8-F-062
Pub Date Jun 69
Grant-OEG-6-9-008062-0040-010
Note-114p.
EDRS Price MF-$0.50 HC-$5.80
Descriptors-Audiovisual Aids, *College Science, Community Colleges, *Curriculum Development, Evaluation, *Instruction, Instructional Materials, *Physics, *Technical Education
Identifiers-Ferguson, Florissant Valley Community College, Missouri

In order to study the effectiveness of programed material in problem solving, four programed lessons were constructed and administered by audio-tape, 35mm slides, and a printed manual. The details of these programs, as well as the tests to evaluate them, are described. An outline is presented of a multi-media approach to technical physics of which these programs are a part. Evidence is given which indicates that the programs may have improved the student's problem solving ability, however, no statistical significance between means for the methods was found. Evidence is also given which indicates that the difficulty that students encountered in solving problems might be due to reading difficulties. (BC)

FINAL REPORT

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SUMMARY

In order to study the effectiveness of programmed material in problem solving, four programmed lessons were constructed and administered by an audio-tape and 35 mm slide presentation and also by printed manual. The details of these programs, as well as the tests to evaluate them, are described. An outline is presented of a multi-media approach to technical physics of which these programs are a part. Evidence is given which indicates that the programs may have improved the student's problem solving ability; however no statistical significance between means for the methods was found. Evidence is also given which indicates that the difficulty that students have in solving problems might be in reading rather than in mathematics.

INTRODUCTION

The recent increase in the number of two-year colleges and technical institutions has caused great concern for educators about the teaching of physics in two-year curricula. Because of the wide range in ability, and the vastly different needs of the students in these technical programs, the "standard" physics course is not appropriate for the industrial engineering technology student. This is evidenced most recently by a national meeting of leaders in the field of technical education which was held at Florissant Valley Community College and sponsored by the Commission on College Physics, an agency of the National Science Foundation. The most significant single outcome of this meeting was that a different approach to the teaching of physics in the two-year college is urgently needed.

This present project was undertaken as an attempt to introduce a multi-media approach to technical physics with special emphasis on problem solving and the reporting of laboratory measurements and experiments.

METHOD

The technical physics course at Florissant Valley Community College was redesigned into modular or weekly units, a list of which is shown in Appendix A. An outline of a typical weekly unit is shown in Appendix B. Laboratory experiments, reading assignments and problems were an integral part of each unit. Laboratory experiments or measurements, as well as programmed problem solving lessons, which are mentioned in the unit outline, were done in an open lab situation. This means that the student came to the lab for experiments or programmed problem solving lessons any time during the week. The laboratory exercises emphasized measurements and units, as well as an analysis of the errors involved. Each lab exercise was written in the form shown in Appendix C. At the end of all but a few of the weekly units a ten minute quiz was given to the student. A sample quiz which followed unit three, on the laws of motion, is shown in Appendix D. No evaluation of this modular approach was attempted; however student comments about it were unanimously favorable.

The major portion of this project involved the development and evaluation of three programmed problem solving lessons. Problem solving is a major objective for technology students for several reasons. One reason is that problem solving provides the student with the practice he needs in identifying physical quantities, and the units associated with the instruments used to measure those quantities. The author felt that an attempt should be made to determine a means of improving the student's problem solving ability, as well as to identify the precise difficulty which students have in problem solving. In view of these objectives, programmed problem solving lessons were developed to be administered by two different methods to two groups of students. The two methods chosen were a written programmed manual and an audio-visual form of the same manual which synchronized an audio tape with 35mm slide presentations.

Approximately twenty-eight technology students enrolled in the author's technical physics course (or college physics) for engineering technology students were divided randomly into two groups. One group was to complete the programmed lesson by means of the written manual and the other by the A-V method. Because of student withdrawals the final group sizes were reduced to ten in the written group and twelve in the A-V group. The programmed materials used in this project, as well as the evaluative tests, are described in detail in the following section.

PROGRAMMED LESSONS

Four separate programmed problem-solving lessons were developed, each of which required from thirty to forty-five minutes to complete. The topics of the lessons corresponded to the unit topic for that week. The topics were:

1. Newton's Laws of Motion - Part I
2. Newton's Laws of Motion - Part II
3. Circular Motion
4. Rotational Motion

The written (printed) manuals were constructed first, from which the A-V materials were later made. The three programs (four lessons) are shown in Appendix E. The format that was used for each lesson included three to four problems, each a little more difficult than the previous one. Each problem in a lesson consisted of the following basic sequence of multiple choice questions.

1. Statement of problem with appropriate diagram.
2. What is unknown?
3. What is known?
4. What equation or equations relate the unknown to the knowns?
5. What would be the rearranged or combined equations?
6. What would be the equation after substitution of the knowns?
7. What would be the simplified equation?
8. What would be the result?

The questions in the finished manual were printed on one side of a page only, with the answer to the previous question at the top of each page. At the back of each manual is an answer sheet which was used to evaluate which of the steps in the problems presented the most difficulty to the students. This answer sheet also contains the problem statement and diagram to which the student could refer as he considered his answer. The student was provided with a formula and glossary sheet to which he could also refer during the lesson. This sheet is shown in Appendix F.

Each of the questions printed in the manuals was photographed on 35mm film, from which white print on black background transparencies were made. For the last lesson on rotational motion, soft colored backgrounds were used, and the students indicated their approval of them in a questionnnaire to be described later. A script was written for each lesson; it not only asked the questions presented on each slide, but also provided additional comments which were appropriate to a given question. This script was recorded on high quality stereo recording equipment by the audio-visual department of the Instructional Resources Division at Florissant Valley Community College. The voice was that of a professional announcer. The 35mm slides were then synchronized to the audio tape using an appropriate signal on the second channel of the stereo tape. As the A-V group began one of the lessons, they were given the same answer sheets from the back of the printed manuals that the written group had. These answer sheets contained the problem statements to which the student could refer during the lesson. The A-V group was provided the same formula sheet (Appendix F) that was given to the written group.

The effectiveness of the programs and the two methods of presentation were measured by means of pre and post tests designed in the manner of the programmed lessons (as shown in Appendix G). These tests are quite similar to each other, in that they each contain ten multiple choice problems which were carefully designed to test the student's ability in each of the areas of problem-solving that are presented in the programmed lessons.

Two of the questions require a complete solution to the problem. One asks only for the unknown while three ask for the known information in the problem. Two of the questions ask the student to combine two or more formulas, and the remaining two involve units only. As a supplementary evaluation procedure, a questionnaire was given to all students in the program at the time of the post test. This questionnaire is shown in Appendix H.

RESULTS

The primary method of evaluation for the project was by means of the scores on the pre and post tests. These scores (shown in Table I) represent the mean number of correct answers out of ten questions, expressed in percent. Also shown are the standard deviations (S.D.) and the sample numbers (N).

TABLE I

GROUP TEST SCORES

	WRITTEN		A-V	
	PRE	POST	PRE	POST
Mean	49	56	61	64
S.D.	20.2	20.6	18.0	17.1
N.	10	10	12	12

Those questions with more than one answer were considered correct if the student chose one-half or more of the correct answers. As is indicated in the table, the mean scores of both the written and A-V groups did increase from the pre test to the post test. However, the relatively large standard deviation indicates that this increase in mean scores would not be statistically significant. A standard t-test for comparison of the means of the two different samples was computed using as samples the pre and post test scores for both the written and A-V groups. In both cases the values of t gave probabilities greater than .05. The relatively high scores on both pre and post tests for the A-V group seemed to indicate that the scores were not randomly selected from the same normal population. However, a t-test of significance indicated that the means were not significantly different at the .05 level. A second method of evaluation involved the number of incorrect answers on the answer sheet at the back of each lesson. This number of incorrect answers was found to gradually decrease over the four lessons.

The programs were also evaluated by means of the questionnaire in Appendix H. Each of the questions on it have five levels of response. In order to find the overall response by the groups, a graduated weighting scale was used ranging from +2 for strongly agree, +1 for mildly agree, zero for not sure, -1 for mildly disagree to -2 for strongly disagree. The results are shown in Table II.

TABLE II
RESULTS OF QUESTIONNAIRE

QUESTION	WEIGHTED RESPONSE
Do you feel that the programs were a help to you in problem solving?	+1.04
Did the problems have too much detail	-.86
Were the problems generally too difficult?	-.95
Were the programs too long?	-1.27
Did you like the colored slides better than the black and white slides? (A-V group only)	+1.50

Of the comments which were made at the bottom of the questionnaire, not one was unfavorable toward the programs. Of all the responses to question one on the questionnaire, not one had a weight less than zero (not sure).

As an attempt to identify the difficulty which students have in problem-solving, a tabulation of the number of incorrect answers was made from the answer sheets of each lesson. This tabulation indicated that students have the most difficulty identifying the known or given information in a problem. The next most difficult task is to choose from a list of formulas, which one applies to a particular problem. The algebra and arithmetic in the problems gave the students relatively little trouble.

CONCLUSIONS

The fact that the mean scores on post tests were higher than pre tests for both groups, although not significantly so, might indicate that this course, including the programmed lessons would improve a student's problem solving ability. It is highly improbable that both means would show an increase just by chance.

The results of the questionnaire by itself would also indicate that the programs were successful. The lack of statistical significance in mean comparisons, probably due to the low sample number, indicates that for these students the written and A-V methods are equally effective. The results of a tabulation of incorrect answers on the answer sheets of each lesson would indicate that students enter physics courses with reading deficiencies rather than mathematics deficiencies, as is commonly believed. These programs will be available at Florissant Valley Community College as part of a multi-media approach to technical physics.

APPENDIX A

COURSE OUTLINE

UNIT	TOPIC	CHAPTER*
1	Background Mathematics and Trigonometry	1,2
2	Linear Motion and Kinematics	3,4
3	Newton's Laws of Motion	5
4	Friction	6
5	Statics	7
6	Circular Motion	8
7	Work and Energy	9
8	Momentum	10
9	Rigid Body Motion	11
10	Power, Efficiency and Simple Machines	12
11	Elastic Forces	13,15
12	Fluid Mechanics	14
13	Thermometry and Heat	17
13	Thermal Properties of Gases	18
15	First and Second Laws of Thermodynamics	19
16	Thermal Properties of Liquids and Solids	20

*Chapter number in Modern Technical Physics, Beiser, Addison Wesley, Reading, Mass. 1966

APPENDIX B

WEEKLY UNIT OUTLINE

Monday

(1) Introduction to physical phenomena related to this week's topic (20 min.).

(2) Discuss results of above and from these, design experiments that will lead to a physical law or relationship which governs the phenomena of this week's topic (30 min.).

Wednesday

(1) Do in class key experiment and/or have film, transparency, etc., to show the relationship of the variables in question (25 min.).

(2) Discuss the results and units, formulate the law or relationship and extend to more complicated situations (25 min.).

Thursday Problem solving session (optional to student) (50 min.).

Friday

(1) Lecture on conclusions and extension of this week's unit as well as tie in with previous units (25 min.).

(2) Hand out notes and assignment (including problems) for next week along with test on this week's unit. Collect solved problems.

(3) Test on unit (10 min.).

Open lab and programmed audio-visual learning session (90 min.) at the student's convenience.

APPENDIX C

LABORATORY REPORT

EXPERIMENT________________________ NAME__________________________

PURPOSE:

METHOD AND DIAGRAM:

DATA:

CALCULATIONS:

DISCUSSION OF RESULTS AND ERROR ANALYSIS:

A P P E N D I X D

TECH PHYSICS
WEEKLY QUIZ

NAME ______________________

T F 1. If an object is moving in a straight line with uniform velocity then there must be a net force acting on it to produce that motion.

T F 2. A freight train moves because the locomotive pulls harder on the cars of the train than the cars pull on the locomotive.

3. Newton's law of inertia says that if a body is in motion in a straight line; then

1) it will eventually come to rest.
2) the forces acting on it will keep it in a straight line.
3) it will stay in constant motion in a straight line until a force acts on it.

4. The weight of a body is

1) the same thing as its mass.
2) the same everywhere in the solar system.
3) the same for all objects that are the same size.
4) the gravitational force that the earth exerts on it.

5. The unit of force in the British system of units is

1) pounds
2) slugs
3) kilograms
4) newtons

6. The unit of mass in the MKS system is

1) pounds
2) slugs
3) kilograms
4) newtons

7. If an object weighs 16 pounds its mass is

   1) 32 slugs
   2) 16 slugs
   3) 1/2 slugs
   4) 2 slugs

8. If an object rests on a frictionless horizontal surface and if a force acting on it in a horizontal direction is doubled, the acceleration will

   1) be halved.
   2) be in the opposite direction to the force.
   3) be doubled
   4) remain constant

9. If a net force of one newton acts on an object of mass one kilogram then the acceleration will be

   1) 1 m/sec^2
   2) 2 m/sec^2
   3) 9.8 m/sec^2
   4) .5 m/sec^2

10. If an object of mass ten slugs is accelerated uniformly at one foot per second per second then the force acting on it is

   1) 32 lb.
   2) 10 lb.
   3) 3.2 lb.
   4) 1 lb.

A P P E N D I X   E

PROGRAMMED PROBLEM SOLVING LESSON

NEWTON'S LAWS OF MOTION

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Florissant Valley Community College
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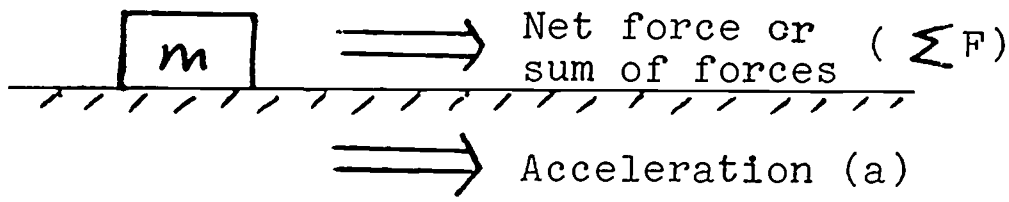
Fall, 1968

R

Newton's Second Law of Motion

$$\sum F = ma$$



Acceleration is in the same direction as the force.

A

Problem:

What acceleration is necessary to increase the velocity of an object from 6 m/sec to 10m/sec in 2 seconds?

E-c

Unknown: a

Known: $F_{pull} = 10$ lb. ,

$m = 1$ slug

Equations relating unknown to knowns are:

1) $\Sigma F = ma$
2) $w = mg$
3) $d = 1/2\ at^2$
4) $v = v_o + at$
5) $\Sigma F = F_{pull}$
6) $N = W$
7) $\Sigma F = W$

A-a

Unknown is:

1) a
2) *****
3) *****
4) *****
5) *****

E-d

Unknown: a
Known: $F_{pull} = 10$ lb, $m = 1$ slug
Equations: $\Sigma F = ma$, $\Sigma F = F_{pull}$

Rearranging equations to solve for unknown:

1) $a = \Sigma F \times m$

2) $a = \frac{F_{pull}}{m}$

3) $a = \frac{\Sigma F}{F_{pull}}$

4) $a = \frac{F_{pull}}{ma}$

5) $a = \frac{m}{F_{pull}}$

A-b

Unknown: a

Known information is:

1) *****
2) *****
3) $v_o = 6$ m/sec
4) *****
5) $v = 10$ m/sec
6) *****
7) $t = 2$ sec

E-e

Unknown: a
Known: $F_{pull} = 10$ lb, $m = 1$ slug
Equations: $\Sigma F = ma$, $\Sigma F = F_{pull}$
Rearranged equations: $a = \frac{F_{pull}}{m}$

Substituting knowns into equation:

1) $a = \frac{1 \text{ slug}}{1 \text{ lb.}}$
2) $a = \frac{1 \text{ slug}}{10 \text{ lb.}}$
3) $a = \frac{10 \text{ lb.}}{1 \text{ slug}}$
4) $a = 10$ lb. x slugs
5) $a = \frac{1 \text{ lb.}}{10 \text{ slugs}}$

A-c

Unknown: a
Known: v_o = 6 m/sec , v = 10 m/sec , t = 2 sec

Equation relating unknown to knowns is:

1) *****
2) *****
3) $a = \frac{v-v_o}{t}$
4) *****
5) *****

E-f

Unknown: a
Known: F_{pull} = 10 lb, m = 1 slug
Equations: $\Sigma F = ma$, $\Sigma F = F_{pull}$
Substituted equation: $a = \frac{10 \text{ lb}}{1 \text{ slug}}$

Simplifying units:

1) a = 10 lb/slug
2) a = .1 ft/sec^2
3) a = 10 ft/sec^2
4) a = 10 lb

A-d

Unknown: a

Known: v_o = 6 m/sec; v = 10 m/sec, t = 2 sec

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

Substituting knowns into equation:

1) *****
2) *****
3) $a = \frac{10 \text{ m/sec} - 6 \text{ m/sec}}{2 \text{ sec}}$
4) *****
5) *****

E-g

Unknown: a

Known: F_{pull} = 10 lb

Equations: $\Sigma F = ma$, $\Sigma F = F_{pull}$

Substituted equation: $a = \frac{10 \text{ lb}}{1 \text{ slug}}$

Answer: $a = 10 \text{ ft/sec}^2$

A-e

Unknown: a
Known: v_o = 6 m/sec, v = 10m/sec, t = 2 sec
Equation: $a = \frac{v - v_o}{t}$
Substituted equation: $a = \frac{10\ m/sec - 6\ m/sec}{2\ sec}$

Simplifying:

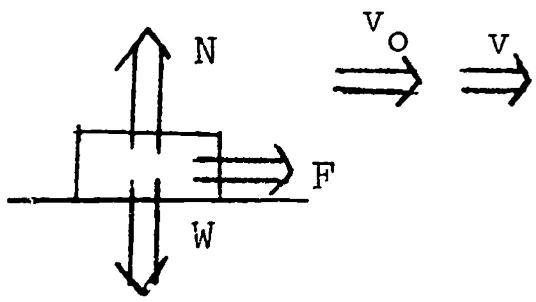
1) *****
2) *****
3) *****
4) *****
5) $a = \frac{4\ m/sec}{2\ sec}$

F

Problem:

What force would be necessary to increase the velocity of an object of mass 2 slugs from 4 ft/sec to 8 ft/sec in 2 seconds?

Diagram:



A-f

Unknown: a

Known: v_o-6 m/sec, v = 10 m/sec,

t = 2 sec

Simplified equation: $a = \frac{4\ m/sec}{2\ sec}$

Simplifying:

1) *****
2) $a = 2\ m/sec^2$
3) *****
4) *****
5) *****

F-a

Unknown is:

1) a
2) m
3) v
4) ΣF
5) t
6) v_o

A-g

Unknown: a

Known: v_o = 6 m/sec, v = 10 m/sec, t = 2 sec

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

Substituted equation: a

$$a = \frac{10 \text{ m/sec} - 6 \text{ m/sec}}{2 \text{ sec}}$$

Answer: $a = 2 \text{ m/sec}^2$

F-b

Unknown: ΣF

Known information is:

1) m = 2 slugs
2) v = 8 ft/sec
3) w = 2 slugs
4) v = 4 ft/sec
5) v_o = 4 ft/sec
6) m = 4 slugs
7) v_o = 8 ft/sec
8) t = 2 sec

B

Problem:

What is the mass of a 320 lb. object?

F-c

Unknown: ΣF
Known: $m = 2$ slugs , $v = 8$ ft/sec
$v_o = 4$ ft/sec , $t = 2$ sec

Equations relating unknown to knowns are:

1) $d = 1/2\ at^2$
2) $\Sigma F = ma$
3) $v = \frac{d}{t}$
4) $v^2 = {v_o}^2 + 2ad$
5) $v = v_o + at$
6) $a = \frac{v - v_o}{t}$
7) $w = mg$
8) $\Sigma F = w$

B-a

Unknown is:

1) F
2) m
3) v
4) a
5) N
6) w

F-d

Unknown: ΣF
Known: $m = 2$ slugs, $v = 8$ ft/sec,
$v_o = 4$ ft/sec, $t = 2$ sec

Equations: $\Sigma F = ma$, $a = \frac{v-v_o}{t}$

Combininb equations to solve for unknown:

1) $m = \frac{\Sigma F}{a}$

2) $\Sigma F = v_o + at$

3) $\Sigma F = m \frac{v-v_o}{t}$

4) $\Sigma F = \frac{m}{v_o + at}$

5) $\Sigma F = mv_o + mat$

B-b

Unknown: m

Known information is:

1) $m = 320$ slugs
2) $m = 320$ lb
3) $g = 32$ ft/sec^2
4) $w = 320$ lb
5) $g = 9.8$ m/sec^2
6) $w = 32$ lb
7) $\Sigma F = 320$ lb

F-e

Unknown: ΣF
Known: $m = 2$ slugs, $v = 8$ ft/sec,
$v_o = 4$ ft/sec, $t = 2$ sec
Equation: $\Sigma F = ma$, $a = \frac{v - v_o}{t}$

Combined equations: $\Sigma F = m \frac{v - v_o}{t}$

Substituting knowns into equation:

1) $\Sigma F = \frac{4 \text{ ft/sec} - 8 \text{ ft/sec}}{2 \text{ sec}}$

2) $\Sigma F = 2 \text{ slugs} \times \frac{8 \text{ ft/sec} - 4 \text{ ft/sec}}{2 \text{ sec}}$

3) $\Sigma F = 2 \text{ slugs} \times \frac{4 \text{ ft/sec} - 8 \text{ ft/sec}}{2 \text{ sec}}$

4) $\Sigma F = \frac{2 \text{ slugs}}{2 \text{ sec}} \times 8 \text{ ft/sec} - 4 \text{ ft/sec}$

B-c

Unknown: m

Known: g = 32 ft/sec   w = 320 lb

Equation relating unknown to knowns is:

1) $\Sigma F = ma$
2) $d = 1/2\ at^2$
3) $w = mg$
4) $m = \frac{\Sigma F}{g}$
5) $m = \frac{\Sigma F}{a}$

F-f

Unknown: ΣF

Known: m = 2 slugs, v = 8 ft/sec

v_o = 4 ft/sec, t = 2 sec

Equation: $\Sigma F = m\ \frac{v - v_o}{t}$

Substituted equation:

$$\Sigma F = 2 \text{ slugs} \times \frac{8 \text{ ft/sec} - 4 \text{ ft/sec}}{2 \text{ sec}}$$

Simplifying:

1) $\Sigma F = 2 \text{ slugs} \times \frac{2 \text{ ft/sec}}{2 \text{ sec}}$
2) $\Sigma F = 2 \text{ slugs} \times \frac{8 \text{ ft/sec}}{2 \text{ sec}}$
3) $\Sigma F = 2 \text{ slugs} \times \frac{4 \text{ ft/sec}}{2 \text{ sec}}$
4) $\Sigma F = 2 \text{ slugs} \times 2 \text{ ft/sec}$

B-d

Unknown: m
Known: $g = 32$ ft/sec^2, $w = 320$ lb
Equation: $w = mg$

Rearranging equation to solve for unknown:

1) $m = gw$

2) $m = \frac{g}{w}$

3) $m = \frac{v}{t}$

4) $m = \frac{F}{a}$

5) $m = \frac{w}{g}$

F-g

Unknown: ΣF
Known: $m = 2$ slugs, $v = 8$ ft/sec, $v_o = 4$ ft/sec, $t = 2$ sec

Simplified equation:
$\Sigma F = 2 \text{ slugs} \times \frac{4 \text{ ft/sec}}{2 \text{ sec}}$

Simplifying:

1) $\Sigma F = 4$ slug - ft/sec

2) $\Sigma F = 8$ slug - ft/sec^2

3) $\Sigma F = 4$ slug - ft/sec^2

4) $\Sigma F = 4$ slug - ft

B-e

Unknown: m
Known: g = 32 ft/sec^2, w = 320 lb
Equation: w = mg
Rearranged equation: m = $\frac{w}{g}$

Substituting knowns into equation:

1) m = $\frac{320}{1}$ lb - ft/sec^2

2) m = .1 lb - ft/sec^2

3) m = $\frac{320 \text{ lb}}{32 \text{ ft/sec}^2}$

4) m = $\frac{32 \text{ lb}}{320 \text{ ft/sec}^2}$

5) m = 10 lb - ft/sec^2

F-h

Unknown: ΣF
Known: m = 2 slugs, v = 8 ft/sec,
v_o = ft/sec, t = 2 sec
Simplified equation: ΣF = 4 slug - ft/sec^2

Simplifying units:

1) ΣF - 4 ft - lb
2) ΣF = 4 lb - ft/sec^2
3) ΣF = 4 ft/sec^2
4) ΣF = 4 lb

B-f

Unknown: m

Known: g = 32 ft/sec, w =320 lb

Equation: w = mg

Substituted equation: $m = \frac{320 \text{ lb}}{32 \text{ ft/sec}^2}$

Simplifying:

1) m = 10 lb
2) m = .1 lb
3) $m = 10 \frac{\text{lb}}{\text{ft/sec}^2}$
4) $m = 1 \frac{\text{lb}}{\text{ft/sec}^2}$
5) $m = 32 \frac{\text{lb/sec}^2}{\text{ft}}$

F-1

Unknown: ΣF

Known: m = 2 slugs, v = 8 ft/sec, v_o = 4 ft/sec, t = 2 sec

Equations: $\Sigma F = ma$, $a = \frac{v - v_o}{t}$

Substituted equation:

$$\Sigma F = 2 \text{ slugs} \times \frac{8 \text{ ft/sec} - 4 \text{ ft/sec}}{2 \text{ sec}}$$

Answer: $\Sigma F = 4$ lb

B-g

Unknown: m
Known: $g = 32\ ft/sec^2$, $w = 320\ lb$

Simplified equation: $m = 10\ \frac{lb}{ft/sec^2}$

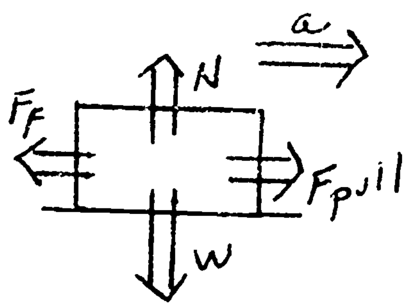
Simplifying units:

1) $m = 10\ lb$
2) $m = 10\ slugs$
3) $m = 10\ \frac{slugs}{sec^2}$
4) $m = 10\ ft/sec^2$

G

Problem:
What acceleration would an object weighing 32 lb have if it were pulled on a rough surface with a 4 lb force? The opposing frictional force is 2 lb.

Diagram:



B-h

Unknown: m
Known: $g = 32\ ft/sec^2$, $w = 320\ lb$

Equation: $m = \frac{w}{g}$

Substituted equation: $m = \frac{320\ lb}{32\ ft/sec^2}$

Answer: **m = 10 slugs**

G-a

Unknown is:

1) ΣF
2) w
3) N
4) a
5) F_f

C

Problem:

What is the weight of an object which has a mass of 10 kilograms?

G-b

Unknown: a

Known information is:

1) $g = 9.8\ m/sec^2$
2) $F_f = 2$ lb
3) $F_{pull} = 2$ lb
4) $g = 32\ ft/sec^2$
5) $w = 32$ lb
6) $F_f = 4$ lb
7) $F_{pull} = 4$ lb

C-a

Unknown is:

1) a
2) F
3) m
4) w
5) v
6) t

G-c

Unknown: a
Known: F_f = 2 lb, g = 32 ft/sec^2,
w = 32 lb, F_{pull} = 4 lb

Equations relating unknown to knowns are:

1) $F_f = F_{pull}$
2) $a = \frac{v - v_0}{t}$
3) $\Sigma F = ma$
4) $w = mg$
5) $d = 1/2\ at^2$
6) $\Sigma F = F_{pull} + F_f$
7) $\Sigma F = F_{pull} - F_f$
8) $\Sigma F = F_{pull}$

C-b

Unknown: w

Known information is:

1) $g = 9.8\ m/sec^2$
2) $m = 10\ n$
3) $w = 10\ kg$
4) $g = 32\ ft/sec^2$
5) $m = 10\ kg$
6) $w = 32\ kg$

G-d

Unknown: a

Known: $F_f = 2$ lb, $g = 32\ ft/sec^2$, $w = 32$ lb, $F_{pull} = 4$ lb

Equation:

$$\Sigma F = ma,\ w = mg,\ \Sigma F = F_{pull} - F_f$$

Combining equations to solve for unknown:

1) $\Sigma F = mg$
2) $w = ma$
3) $F_{pull} - F_f = ma$
4) $\Sigma F = \frac{w}{g}a$
5) $F_{pull} - F_f = \frac{w}{g}a$

C-c

Unknown: w
Known: $g = 9.8$ m/sec^2, $m = 10$ kg

Equation relating unknown to knowns is:

1) $d = 1/2\ at^2$
2) $w = mg$
3) $m = \frac{\Sigma F}{a}$
4) $N = mg$
5) $\Sigma F = ma$

G-e

Unknown: a
Known: $F_f = 2$ lb, $g = 32$ ft/sec^2,
$w = 32$ lb, $F_{pull} = 4$ lb
Equations: $\Sigma F = ma$, $w = mg$,
$\Sigma F = F_{pull} - F_f$
Combined Equations: $F_{pull} - F_f = \frac{w}{g}a$

Rearranging equation to solve for unknown:

1) $a = \frac{\Sigma F}{m}$
2) $a = \frac{w}{F_{pull}} - F_f$
3) $a = \frac{F_{pull} - F_f}{\frac{w}{g}}$
4) $a = \frac{F_{pull} - F_f}{m}$
5) $a = (F_{pull} - F_f)\frac{w}{g}$

C-d

Unknown: w
Known: $g = 9.8\ m/sec^2$, $m = 10\ kg$
Equation: $w = mg$

Substituting knowns into equation:

1) $w = 10\ kg \times 9.8\ m/sec^2$

2) $w = \frac{10\ kg}{9.8\ m/sec^2}$

3) $w = 32\ kg \times 9.8\ m/sec^2$

4) $w = \frac{10\ kg}{32\ ft/sec^2}$

5) $w = \frac{9.8}{10}\ \frac{kg}{m/sec^2}$

G-f

Unknown: a
Known: $F_f = 2\ lb$, $g = 32\ ft/sec^2$,
$w = 32\ lb$, $F_{pull} = 4\ lb$

Equations: $\Sigma F = ma$, $w = mg$, $\Sigma F = F_{pull} - F_f$

Rearranged equation: $a = \frac{F_{pull} - F_f}{\frac{w}{g}}$

Substituting knowns into equation:

1) $a = \frac{2\ lb - 4\ lb}{32}$

2) $a = \frac{\frac{4\ lb - 2\ lb}{32\ ft/sec^2}}{32\ lb}$

3) $a = \frac{4\ lb - 2\ lb}{\frac{32\ lb}{32\ ft/sec^2}}$

4) $a = \frac{4\ lb - 2\ lb}{32\ lb \times 32\ ft/sec^2}$

5) $a = \frac{2\ lb - 4\ lb}{\frac{32\ ft\ lb}{32\ ft/sec^2}}$

C-e

Unknown: w
Known: $g = 9.8\ m/sec^2$, $m = 10\ kg$
Equation: $w = mg$
Substituted equation: $w = 10\ kg \times 9.8\ m/sec^2$

Simplifying:

1) $w = 9.8\ kg\ m/sec^2$
2) $w = 980\ kg\ m/sec^2$
3) $w = 198\ kg\ m/sec^2$
4) $w = 98\ kg\ m/sec^2$

G-g

Unknown: a
Known: $F_f = 2\ lb$, $g = 32\ ft/sec^2$
$w = 32\ lb$, $F_{pull} = 4\ lb$

Equation: $a = \dfrac{F_{pull} - F_f}{\frac{w}{g}}$

Substituted equation: $a = \dfrac{4\ lb - 2\ lb}{\frac{32\ lb}{32\ ft/sec^2}}$

Simplifying:

1) $a = 4 \dfrac{lb}{\frac{lb}{ft/sec^2}}$

2) $a = 2 \dfrac{lb}{\frac{lb}{ft/sec^2}}$

3) $a = 1 \dfrac{lb}{ft/sec^2}$

4) $a = 2 \dfrac{lb}{ft/sec^2}$

5) $a = 1 \dfrac{lb}{\frac{lb}{ft/sec^2}}$

C-f

Unknown: w
Known: $g = 9.8\ m/sec^2$, $m = 10\ kg$
Simplified equation: $w = 98\ kg\ m/sec^2$

Simplifying units:

1) $w = 98j$
2) $w = 98n$
3) $w = 98\ m/sec^2$
4) $w = 98\ kg$

G-h

Unknown: a
Known: $F_f = 2\ lb$, $9 = 32\ ft/sec^2$, $w = 32\ lb$, $F_{pull} = 4\ lb$
Simplified equation: $a = 2 \frac{lb}{\frac{lb}{ft/sec^2}}$

Simplifying units:

1) $a = 2 \frac{lb}{ft/sec^2}$
2) $a = 2 \frac{ft\text{-}lb}{sec^2}$
3) $a = 2\ ft/sec^2$
4) $a = 2\ lb$

C-g

Unknown: w
Known: $g = 9.8\ m/sec^2$, $m = 10\ kg$
Equation: $w = mg$
Substituted Equation: $w = 10\ kg \times 9.8\ m/sec^2$

Answer: $w = 98\ n$

G-i

Unknown: a
Known: $F_f = 2\ lb$, $g = 32\ ft/sec^2$

$w = 32\ lb$, $F_{pull} = 4\ lb$

Equations: $\Sigma F = ma$, $w = mg$,

$\Sigma F = F_{pull} - F_f$

Substituted equation: $a = \dfrac{4\ lb - 2\ lb}{\dfrac{32\ lb}{32\ ft/sec^2}}$

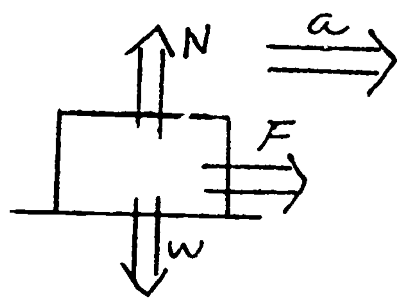
Answer: $a = 2\ ft/sec^2$

D

Problem:

What force is necessary to give an object weighing 9.8 newtons an acceleration of 3 m/sec^2?

Diagram:

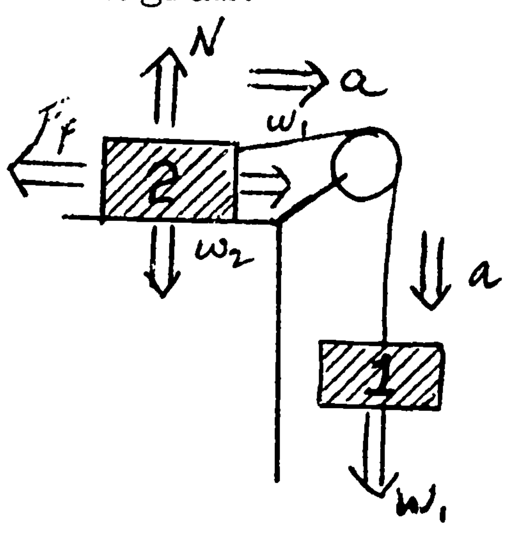


Problem:

Two objects of 10 kg mass each are held together by a thin rope. The total mass of the two objects is $m_1 + m_2 = 20$ kg. Object No. 1 hangs vertically from a small pulley. A frictional force of 8 newtons resists the motion of object No. 2 on the horizontal surface. Find the acceleration of the objects. The rope transmits force from one object to the other and the pulley changes the direction of that force.

H

Diagram:



D-a

Unknown is:

1) v

2) a

3) N

4) w

5) m

6) ΣF

H-a

Unknown is:

1) m_2

2) F_f

3) a

4) $\frac{a}{m}$

5) F_{pull}

6) w_1

7) m_1

D-b

Unknown: ΣF

Known information is:

1) $F = 9.8n$
2) $m = 9.8n$
3) $g = 9.8\ m/sec^2$
4) $w = 9.8n$
5) $a = 9.8\ m/sec^2$
6) $a = 3\ m/sec^2$

H-b

Unknown: a

Known information is:

1) $m_2 = 20$ kg
2) $m_1 = 10$ kg
3) $g = 9.8\ m/sec^2$
4) $g = 980\ m/sec^2$
5) $F_f = 8n$
6) $m_1 = 8n$
7) $m_1 + m_2 = 20$ kg
8) $F_f = 10$ kg
9) $w = 10$ kg
10) $w = 8n$

D-c

Unknown: ΣF
Known: $g = 9.8\ m/sec^2$, $w = 9.8n$,
$a = 3\ m/sec^2$

Equations relating unknown to knowns are:

1) $N = W$
2) $\Sigma F = ma$
3) $\Sigma F = mg$
4) $w = mg$
5) $a = \frac{v - v_o}{t}$
6) $d = 1/2\ at^2$
7) $v^2 = v_o^2 + 2ad$

H-c

Unknown: a
Known: $m_1 = 10\ kg$, $g \doteq 9.8\ m/sec^2$,
$F_f = 8n$, $m_1 + m_2 = 20\ kg$

Equations relating unknown to knowns are:

1) $\Sigma F = w_1 + F_f$
2) $\Sigma F = (m_1 + m_2)a$
3) $v = \frac{d}{t}$
4) $d = 1/2\ at^2$
5) $\Sigma F = w_1 - F_f$
6) $m_1 = \frac{g}{w_1}$
7) $a = \frac{v - v_o}{t}$
8) $w_1 = m_1 g$
9) $\Sigma F = (m_1 - m_2)a$

D-d

Unknown: ΣF
Known: $g = 9.8\ m/sec^2$, $w = 9.8n$,
$a = 3\ m/sec^2$
Equations: $\Sigma F = ma$, $w = mg$

Rearranging equations to solve for unknown:

1) $\Sigma F = mg$

2) $\Sigma F = \frac{w}{a}$

3) $\Sigma F = (\frac{w}{g})a$

4) $\Sigma F = ma$

5) $\Sigma F = (\frac{m}{g})a$

H-d

Unknown: a
Known: $m_1 = 10\ kg$, $g = 9.8\ m/sec^2$, $F_f = 8n$,
$m_1 + m_2 = 20\ kg$
Equations: $\Sigma F = (m_1 + m_2)a$, $\Sigma F = w_1 - F_f$,
$w_1 = m_1 g$

Combining equations to solve for unknown:

1) $m_1 g = (m_1 + m_2)a$

2) $\Sigma F = m_1 g - F_f$

3) $m_1 g - F_f = (m_1 + m_2)a$

4) $(m_1 + m_2)g = (m_1 + m_2)a$

5) $w_1 - F_f = (m_1 + m_2)g$

D-e

Unknown: ΣF
Known: $g = 9.8\ m/sec^2$, $w = 9.8n$,
$a = 3\ m/sec^2$

Equations: $\Sigma F = ma$, $w = mg$
Rearranged equations: $\Sigma F = (\frac{w}{g})a$

Substituting knowns into equation:

1) $\Sigma F = \frac{9.8n}{9.8\ m/sec^2} \times 3\ m/sec^2$

2) $\Sigma F = \frac{9.8n}{3\ m/sec^2} \times 9.8\ m/sec^2$

3) $\Sigma F = \frac{3\ m/sec^2}{9.8n} \times 9.8\ m/sec^2$

4) $\Sigma F = \frac{9.8\ m/sec^2}{9.8n} \times 3\ m/sec^2$

H-e

Unknown: a
Known: $m_1 = 10\ kg$, $g = 9.8\ m/sec^2$,
$F_f = 8n$, $m_1 + m_2 = 20\ kg$

Equations: $\Sigma F = (m_1 + m_2)a$, $\Sigma F = w_1 - F_f$,
$w_1 = m_1 g$

Combined equation: $m_1 g - F_f = (m_1 + m_2)a$

Rearranged equation to solve for unknown:

1) $a = \frac{m_1 g - F_f}{m_1 + m_2}$

2) $a = \frac{w_1 - F_f}{m_1 + m_2}$

3) $a = \frac{w_1}{m_1 g - F_f}$

4) $a = \frac{m_1 g + F_f}{m_1 g + m_2 g}$

D-f

Unknown: ΣF

Known: $g = 9.8\ m/sec^2$, $w = 9.8n$, $a = 3\ m/sec^2$

Equation: $\Sigma F = ma$, $w = mg$

Substituted equation:

$$\Sigma F = \frac{9.8n}{9.8\ m/sec^2} \times 3\ m/sec^2$$

Simplifying:

1) $\Sigma F = 30 \frac{n - m/sec^2}{m/sec^2}$

2.) $\Sigma F = .3\ n - m/sec^2$

3) $\Sigma F = 3 \frac{n - m/sec^2}{m/sec^2}$

4) $\Sigma F = 29.4 \frac{n - m/sec^2}{m/sec^2}$

H-f

Unknown: a

Known: $m_1 = 10kg$, $g = 9.8\ m/sec^2$, $F_f = 8n$, $m_1 + m_2 = 20\ kg$

Equations: $\Sigma F = (m_1 + m_2)\ a$, $\Sigma F = w_1 - F_f$, $w_1 = m_1 g$

Rearranged equation: $a = \frac{m_1 g - F_f}{m_1 + m_2}$

Substituting knowns into equation:

1) $a = \frac{10n - 8n}{20\ kg}$

2) $a = \frac{20\ kg \times 9.8\ m/sec^2 - 8n}{20\ kg}$

3) $a = \frac{10kg \times 9.8\ m/sec^2 - 8n}{10n}$

4) $a = \frac{10kg \times 9.8\ m/sec^2 - 8n}{20kg}$

5) $a = \frac{10\ kg \times 9.8\ m/sec^2 - 10n}{20\ kg}$

D-g

Unknown: ΣF
Known: $g = 9.8\ m/sec^2$, $w = 9.8n$, $a = 3\ m/sec^2$

Simplified equation: $\Sigma F = 3\ \frac{n - m/sec^2}{m/sec^2}$

Simplifying units:

1) $\Sigma F = 3\ n - m/sec^2$

2) $\Sigma F = 3\ kg$

3) $\Sigma F = 3\ n/sec^2$

4) $\Sigma F = 3\ n$

H-g

Unknown: a
Known: $m_1 = 10\ kg$, $g = 9.8\ m/sec^2$,
$F_f = 8\ n$, $m_1 + m_2 = 20\ kg$
Equations: $\Sigma F = (m_1 + m_2)a$, $F = w_1 - F_f$,
$w_1 = m_1 g$

Substituted equation:

$$a = \frac{10\ kg \times 9.8\ m/sec^2 - 8n}{20\ kg.}$$

Simplifying:

1) $a = \frac{980\ kg - m/sec^2 - 8n}{20\ kg}$

2) $a = 4.5\ m/sec^2 - 8n$

3) $a = \frac{98\ kg - m/sec^2 - 8n}{20\ kg}$

4) $a = \frac{9.8\ m/sec^2 - 8n}{10\ kg}$

D-h

Unknown: ΣF
Known: $g = 9.8\ m/sec^2$, $w = 9.8n$,
$a = 3\ m/sec^2$

Equation: $\Sigma F = (\frac{w}{g})a$

Substituted equation:

$$\Sigma F = \frac{9.8n}{9.8\ m/sec^2} \times 3\ m/sec^2$$

Answer: $\boxed{\Sigma F = 3n}$

H-h

Unknown: a
Known: $m_1 = 10kg$, $g = 9.8\ m/sec^2$,
$F_f = 8n$, $m_1 + m_2 = 20\ kg$

Simplified equation: $a = \frac{98\ kg - m/sec^2 - 8n}{20\ kg}$

Simplifying units:

1) $a = \frac{90\ kg - m/sec^2}{20\ kg}$

2) $a = \frac{98n}{20kg}$

3) $a = \frac{94\ kg - m/sec^2}{10\ kg}$

4) $a = \frac{98\ kg - m/sec^2}{20\ kg}$

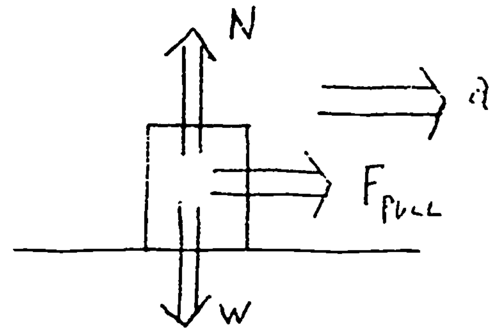
5) $a = \frac{90\ kg-}{20\ kg}$

E

Problem:

A ten pound force pulls an object of mass 1 slug. What would be the resulting acceleration?

Diagram:



H-i

Unknown: a

Known: $m_1 = 10\,kg$, $g = 9.8\ m/sec^2$

$F_f = 8n$, $m_1 + m_2 = 20\ kg$

Simplifying:

1) $a = 45\ m/sec^2$

2) $a = 4.5\ m/sec^2$

3) $a = 9\ m/sec^2$

4) $a = 4.5\ kg$

5) $a = 4\ m/sec^2$

E-a

Unknown is:

1) F_{pull}

2) m

3) v

4) a

5) N

H-j

Unknown: a

Known: $m_1 = 10$ kg, $g = 9.8$ m/sec^2,
$F_f = 8$n, $m_1 + m_2 = 20$ kg

Equations: $\Sigma F = (m_1 + m_2)a$, $\Sigma F = w_1 - F_f$,
$w_1 = m_1 g$

Substituted equation:

$$a = \frac{10 \text{ kg} \times 9.8 \text{ m/sec}^2 - 8\text{n}}{20 \text{ kg}}$$

Answer: $a = 4.5$ m/sec^2

E-b

Unknown: a

Known information is:

1) $F_{pull} = 10$ lb

2) $a = 3$ ft/sec^2

3) $m = 3$ slugs

4) $m = 1$ slug

5) $a = 1$ ft/sec^2

6) $F_{pull} = 1$ lb

7) $\Sigma F = 0$

H-k

The acceleration of both objects is:

1) the same

2) the same in direction but different in magnitude.

3) zero

4) the same in magnitude but different in direction

Answer Sheet

Name ______________________

A. What acceleration is necessary to increase the velocity of an object from 6 m/sec to 10 m/sec in 2 seconds?

A-a 1_X_, 2___, 3___, 4___, 5___.

b 1___, 2___, 3_X_, 4___, 5_X_

6___, 7_X_.

c 1___, 2___, 3_X_, 4___, 5___.

d 1___, 2___, 3_X_, 4___, 5___.

e 1___, 2___, 3___, 4___, 5_X_.

f 1___, 2_X_, 3___, 4___, 5___.

B. What is the mass of a 320lb object?

B-a 1___, 2___, 3___, 4___, 5___.

b 1___, 2___, 3___, 4___, 5___,

6___, 7___.

c 1___, 2___, 3___, 4___, 5___.

d 1___, 2___, 3___, 4___, 5___.

e 1___, 2___, 3___, 4___, 5___.

f 1___, 2___, 3___, 4___, 5___.

g. 1___, 2___, 3___, 4___.

C. What is the weight of an object which has a mass of 10 kilograms?

C-a 1___, 2___, 3___, 4___, 5___,

6___.

b 1___, 2___, 3___, 4___, 5___,

6___.

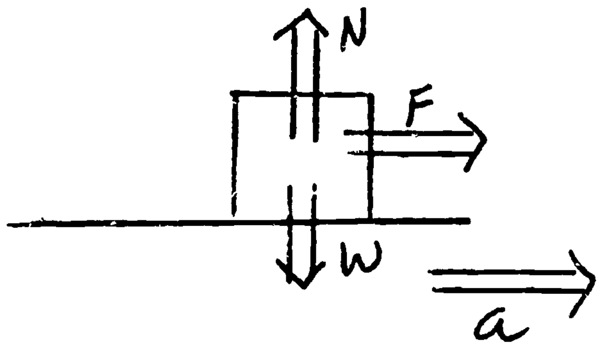
c 1___, 2___, 3___, 4___, 5___.

d 1___, 2___, 3___, 4___, 5___.

e 1___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___.

D. What force is necessary to give an object weighing 9.8 newtons an acceleration of 3 m/sec^2?



D-a 1___, 2___, 3___, 4___, 5___, 6___.

b 1___, 2___, 3___, 4___, 5___, 6___.

c 1___, 2___, 3___, 4___, 5___, 6___, 7___.

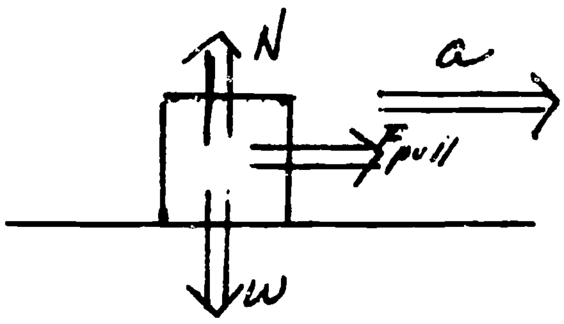
d 1___, 2___, 3___, 4___, 5___.

e 1___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

E. A ten pound force pulls an object of mass 1 slug. What would be the resulting acceleration?



E-a 1___, 2___, 3___, 4___, 5___.

b 1___, 2___, 3___, 4___, 5___, 6___, 7___.

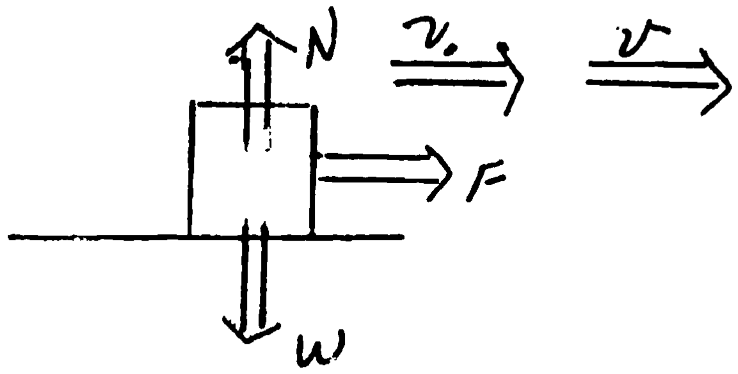
c 1___, 2___, 3___, 4___, 5___, 6___, 7___.

d 1___, 2___, 3___, 4___, 5___.

e 1___, 2___, 3___, 4___, 5___.

f 1___, 2___, 3___.

F. What force would be necessary to increase the velocity of an object of mass 2 slugs from 4 ft/sec to 8 ft/sec in 2 seconds?



F-a 1___, 2___, 3___, 4___, 5___, 6___.

b 1___, 2___, 3___, 4___, 5___, 6___, 7___, 8___.

c 1___, 2___, 3___, 4___, 5___, 6___, 7___, 8___.

d 1___, 2___, 3___, 4___, 5___.

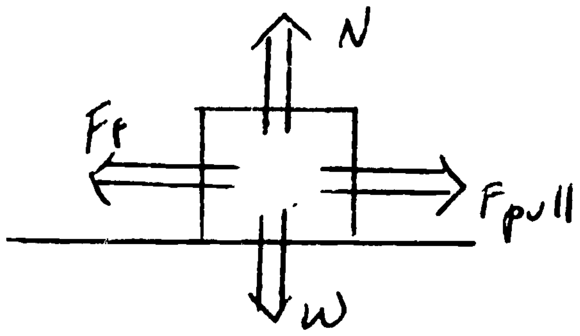
e 1___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___.

G. What acceleration would an object weighing 32 lb have if it were pulled on a rough surface with a 4 lb. force? The opposing frictional force is 2 lb.



G-a 1___, 2___, 3___, 4___, 5___,

b 1___, 2___, 3___, 4___, 5___,
6___, 7___.

c 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___.

d 1___, 2___, 3___, 4___, 5___.

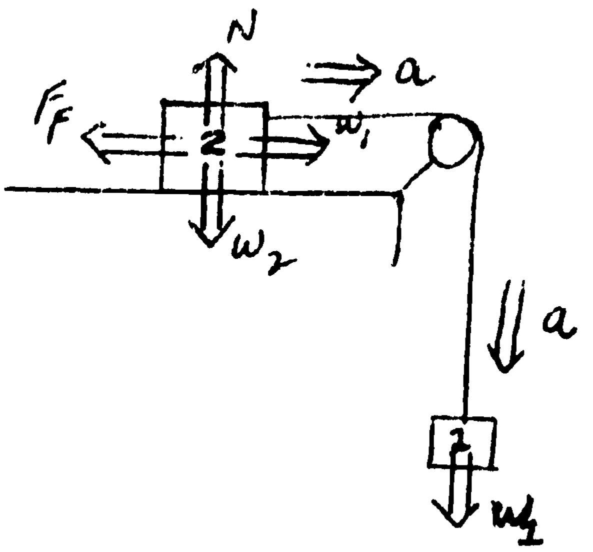
e 1___, 2___, 3___, 4___, 5___.

f 1___, 2___, 3___, 4___, 5___.

g 1___, 2___, 3___, 4___, 5___.

h 1___, 2___, 3___, 4___.

H. Two objects of 10 kg mass each are held together by a thin rope; the total mass of the system being $m_1 + m_2 = 20$ kg. Object number 1 hangs vertically from a small pulley as shown. A frictional force of 8 newtons resists the motion of object number 2 on the horizontal surface. Find the acceleration of the objects. The rope transmits a force from one object to the other and the pulley changes the direction of that force.



H-a 1___, 2___, 3___, 4___, 5___,
6___, 7___.

b 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___, 9___, 10___.

c 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___, 9___.

d 1___, 2___, 3___, 4___, 5___.

e 1___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___, 5___

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___, 5___.

i 1___, 2___, 3___, 4___. 5___.

k 1___, 2___, 3___, 4___.

PROGRAMMED PROBLEM SOLVING LESSON

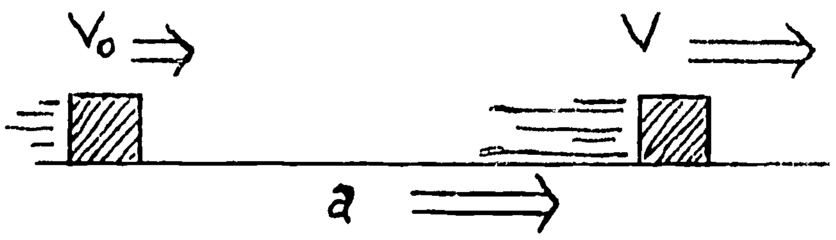
CIRCULAR MOTION

Physics Department
Florissant Valley Community College
3400 Pershall Road
Ferguson, Missouri 53135

Fall, 1968

A

LINEAR MOTION

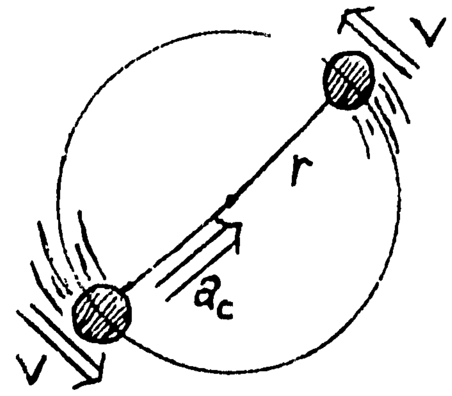


Speed Changes
Direction Same

Linear Acceleration

$$a = \frac{V - V_o}{t}$$

CIRCULAR MOTION

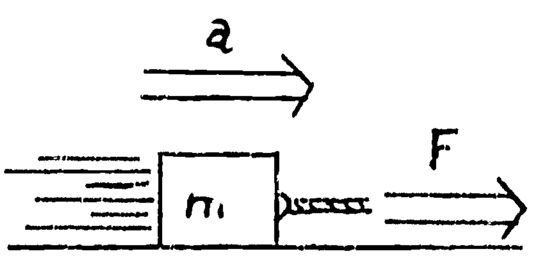


Speed Same
Direction Changes

$a_c = \frac{V^2}{r}$ centripetal acceleration

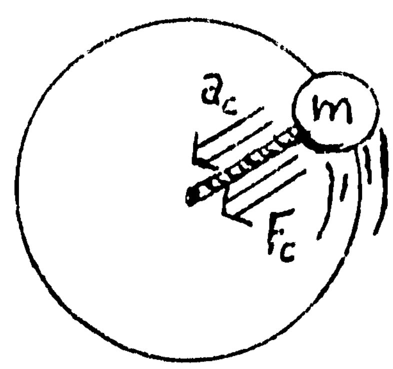
A-a

LINEAR MOTION



$F = ma$

CIRCULAR MOTION



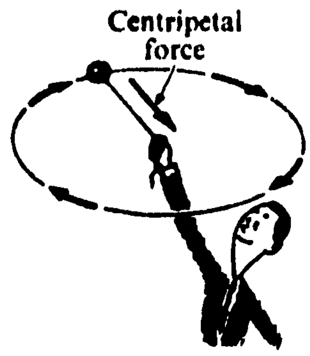
$F_c = ma_c$

A-b

Problem:

A man swings a 4 lb. ball (mass = 1/8 slug), attached to a rope, in a circle of radius 3 feet around his head. It is traveling at a constant speed of 12 ft/sec.
a) What is the centripetal acceleration of the ball?
b) What is the centripetal force on the ball?

Diagram:



Unknown is: B-a

1) F_c

2) m

3) W

4) r

5) a

6) v

A-c

Unknown in part a) is:

1) m
2) w
3) F_c
4) a_c
5) v
6) r

B-b

Unknown: r

Known information is:

1) F_c = 3200 lb
2) a_c = 27 mi/hr
3) m = 3200 lb
4) F_c = 800 lb
5) v = 40 ft/sec
6) w = 3200 lb
7) r = 800 ft
8) g = 32 ft/sec^2

A-d

Unknc .vn is: a_c

Known information is:

1) r = 8 ft
2) m = 4 lb
3) v = 12 ft/sec
4) r = 4 ft
5) v = 3 ft/sec
6) r = 3 ft
7) m = 8 slugs

B-c

Unknown: r

Known: F_c = 800 lb, v = 40 ft/sec, w = 3200 lb. g = 32 ft/sec^2

Equations relating unknown to knowns are:

1) $w = mg$
2) $a = \frac{v - v_o}{t}$
3) $F_f = ma$
4) $F_c = m\frac{v^2}{r}$
5) $v = \frac{r}{t}$
6) $r = 1/2\ at^2$

A-e

Unknown is: a_c

Known: $v = 12$ ft/sec, $r = 3$ ft

Equation relating unknown to knowns is:

1) $\sum F = ma_c$

2) $w = mg$

3) $a_c = \frac{v - v_0}{t}$

4) $a_c = \frac{v^2}{r}$

B-d

Unknown: r
Known: $F_c = 800$ lb, $v = 40$ ft/sec, $w = 3200$ lb, $g = 32$ ft/sec^2

Equation: $F_c = m \frac{v^2}{r}$, $w = mg$

Combining equations to solve for unknown:

1) $F_c = w \frac{v^2}{r}$

2) $w = F_c \frac{v^2}{r}$

3) $F_c = \frac{m^2 v^2}{r}$

4) $F_c = \frac{w}{g} \frac{v^2}{r}$

5) $w = \frac{m}{g} \frac{v^2}{r}$

A-f

Unknown: a_c

Known: $v = 12$ ft/sec, $r = 3$ ft

Equation: $a_c = \frac{v^2}{r}$

Substituting knowns into equation:

1) $a_c = \frac{12 \text{ ft/sec}}{3 \text{ ft}}$

2) $a_c = \frac{144 \text{ ft}^2/\text{sec}^2}{3 \text{ ft}}$

3) $a_c = \frac{144 \text{ ft}^2/\text{sec}^2}{9 \text{ ft}^2}$

4) $a_c = \frac{12 \text{ ft/sec}}{9 \text{ ft}^2}$

B-e

Unknown: r

Known: $F_c = 800$ lb, $v = 40$ ft/sec,
$w = 3200$ lb, $g = 32$ ft/sec^2

Equations: $w = mg$, $F_c = m\frac{v^2}{r}$

Combined equation: $F_c = \frac{w}{g}\frac{v^2}{r}$

Rearranging equation to solve for unknown:

1) $r = \frac{wv^2}{gF_c}$

2) $r = \frac{gF_c}{wv^2}$

3) $r = \frac{w}{g} F_c v^2$

4) $r = \frac{wg}{F_c v^2}$

Unknown: a_c

Known: $v = 12$ ft/sec, $r = 3$ ft

Equation: $a_c = \frac{v^2}{r}$

Substituted equation: $a_c = \frac{144 \text{ ft}^2/\text{sec}^2}{3 \text{ ft}}$

Simplifying:

1) $a_c = 48 \frac{\text{ft}^2/\text{sec}^2}{\text{ft}}$

2) $a_c = 12 \frac{\text{ft}^2/\text{sec}^2}{\text{ft}}$

3) $a_c = 44 \quad \text{sec}^2$

4) $a_c = 30 \frac{\text{ft}^2\ \text{sec}^2}{\text{ft}}$

Unknown: r

Known: $F_c = 800$ lb, $v = 40$ ft/sec, $w = 3200$ lb
$g = 32$ ft/sec^2

Equation: $F_c = \frac{w}{g} \frac{v^2}{r}$

Rearranged equation: $r = \frac{w\ v^2}{g\ F_c}$

Substituting knowns into equation:

1) $r = \frac{800 \text{ lb} \times 40 \text{ ft/sec}}{32 \text{ ft/sec}^2 \times 3200 \text{ lb.}}$

2) $r = \frac{3200 \text{ lb} \times 1600 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2 \times 800 \text{ lb}}$

3) $r = \frac{3200 \text{ lb} \times 40 \text{ ft/sec}}{32 \text{ ft/sec}^2 \times 800 \text{ lb}}$

4) $r = \frac{3200 \text{ lb} \times 1600 \text{ ft/sec}}{32 \text{ ft/sec}^2 \times 800 \text{ lb}}$

A-h

Unknown: a_c

Known: $v = 12$ ft/sec, $r = 3$ ft

Simplified equation: $a_c = 48 \frac{ft^2/sec^2}{ft}$

Simplifying units:

1) $a_c = 48\ ft^2/sec^2$
2) $a_c = 48\ ft^3/sec^2$
3) $a_c = 48\ ft/sec^2$
4) $a_c = 48\ ft/sec$

B-g

Unknown: r

Known: $F_c = 800$ lb, $v = 40$ ft/sec, $w = 3200$ lb, $g = 32\ ft/sec^2$

Equation: $r = \frac{w\ v^2}{g\ F_c}$

Substituted equation: $r = \frac{3200\ lb \times 1600\ ft^2/sec^2}{32\ ft/sec^2 \times 800\ lb}$

Simplifying:

1) $r = 400 \frac{lb\text{-}ft^2/sec^2}{ft/sec^2\text{-}lb}$
2) $r = 300 \frac{lb\text{-}ft^2/sec^2}{ft/sec^2\text{-}lb}$
3) $r = 200 \frac{lb\text{-}ft^2/sec^2}{ft/sec^2\text{-}lb}$
4) $r = 100 \frac{lb\text{-}ft^2/sec^2}{ft/sec^2\text{-}lb}$

A-i

Unknown: a_c

Known: $v = 12$ ft/sec, $r = 3$ ft

Equation: $a_c = \frac{v^2}{r}$

Substituted equation: $a_c = \frac{144 \text{ ft}^2/\text{sec}^2}{3 \text{ ft.}}$

Answer: $a_c = 48 \text{ ft/sec}^2$

B-h

Unknown: r

Known: $F_c = 800$ lb, $v = 40$ ft/sec,
$w = 3200$ lb, $g = 32 \text{ ft/sec}^2$

Simplified equation: $r = 200 \frac{\text{lb-ft}^2/\text{sec}^2}{\text{ft/sec}^2\text{-lb}}$

Simplifying units:

1) r = 200 ft/sec

2) r = 200 ft

3) r = 200 lb-ft

4) $r = 200 \text{ ft/sec}^2$

A-j

Answer: $a_c = 48 \text{ ft/sec}^2$

The direction of this acceleration is:

1) In the same direction as the velocity.
2) Toward the center of the circle.
3) Away from the center of the circle.
4) Downward, toward the earth.

B-i

Unknown: r

Known: $F_c = 800 \text{ lb}$, $v = 40 \text{ ft/sec}$,
$w = 3200 \text{ lb}$, $g = 32 \text{ ft/sec}^2$

Equation: $r = \frac{w\ v^2}{g\ F_c}$

Substituted equation: $r = \frac{3200 \text{ lb} \times 1600 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2 \times 800 \text{ lb}}$

Answer: $r = 200 \text{ ft}$

A-k

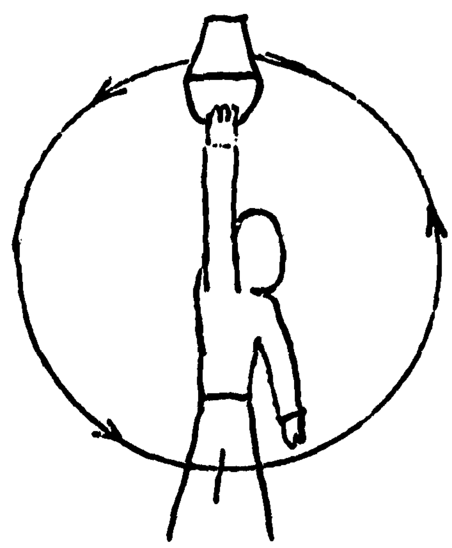
Answer: $a_c = 48 \text{ ft/sec}^2$

Direction: Toward the Center of the Circle

C

Problem:

A pail of water is swung in a vertical circle of radius four feet. What is the minimum time for one revolution so that the water doesn't spill?



A-1

Unknown in part b) is:

1) m
2) w
3) F_c
4) a_c
5) v
6) r

C-a

Unknown is:

1) r
2) v
3) w
4) m
5) t
6) a_c

A-m

Unknown: F_c

Known information is:

1) a_c = 12 ft/sec
2) a_c = 48 ft/sec^2
3) v^2 = 48 ft/sec^2
4) m = 4 lb
5) m = 1/8 slug
6) r = 4 ft

C-b

Unknown: t

Known information is:

1) v = 4 ft/sec
2) r = 4 ft
3) g = 9.8 m/sec^2
4) d = 4 ft
5) g = 32 ft/sec^2
6) a_c = 4 ft/sec^2

A-n

Unknown: F_c

Known: $a_c = 48$ ft/sec^2,
$m = 1/8$ slug

Equation relating unknown to knowns is:

1) $F_c = ma_c$
2) $w = mg$
3) $m = \frac{F_c}{g}$
4) $a_c = \frac{g}{w} F_c$

C-c

Unknown: t

Known: $r = 4$ ft, $g = 32$ ft/sec^2

Equation relating unknown to knowns are:

1) $F_f = ma$
2) $F_c = m \frac{v^2}{r}$
3) $v = \frac{r}{t}$
4) $t = 1/2\ a_c t^2$
5) $F_c = mg$ (at top)
6) $v_{av} = \frac{2\pi r}{t}$

A-o

Unknown: F_c

Known: $a_c = 48 \text{ ft/sec}^2$, $m = 1/8$ slug

Equation: $F_c = ma_c$

Substituting knowns into equation:

1) $F_c = \frac{48 \text{ ft/sec}^2}{8 \text{ slugs}}$

2) $F_c = 8 \text{ slugs} \times 48 \text{ ft/sec}^2$

3) $F_c = 1/8 \text{ slug} \times 48 \text{ ft/sec}^2$

4) $F_c = 1/8 \text{ slug} \times \frac{1}{48 \text{ ft/sec}^2}$

C-d

Unknown: t

Known: $r = 4$ ft, $g = 32 \text{ ft/sec}^2$

Equations: $F_c = m \frac{v^2}{r}$, $F_c = mg$ (at top),

$V_{av} = \frac{2\pi r}{t}$

Combining equation for unknown:

1) $mg = m \frac{2\pi r^2}{t^2}$

2) $mg = m \frac{4\pi^2 r}{t^2}$

3) $mg = m \frac{4\pi^2 r^2}{t^2}$

4) $mg = m \frac{2\pi}{t^2}$

A-p

Unknown: F_c

Known: $a_c = 48\ ft/sec^2$, $m = 1/8$ slug

Equation: $F_c = m\ a_c$

Substituted equation: $F_c = 1/8\ slug \times 48\ ft/sec^2$

Simplifying:

1) $F_c = 8$ slug - ft/sec^2
2) $F_c = 12$ slug-ft/sec^2
3) $F_c = 6$ slug - ft/sec
4) $F_c = 6$ slug - ft/sec^2

C-e

Unknown: t

Known: $r = 4$ ft, $g = 32\ ft/sec^2$

Equation: $F_c = m \frac{v^2}{r}$, $F_c = mg$, $v = \frac{2\pi r}{t}$

Combined equation: $mg = m \frac{4\pi^2 r}{t^2}$

Rearranging equation to solve for unknown:

1) $t^2 = 4\pi^2 rg$
2) $t^2 = 4\pi^2 mrg$
3) $t^2 = \frac{4\pi^2 r}{g}$
4) $t^2 = \frac{4\pi^2 r^2}{g}$

A-q

Unknown: F_c

Known: a_c = 48 ft/sec^2, m = 1/8 slug

Simplified equation: F_c = 6 slug-ft/sec^2

Simplifying Units:

1) F_c = 6 lb
2) F_c = 6 slugs
3) F_c = 6 ft/sec^2
4) F_c = 6 ft-lb

C-f

Unknown: t

Known: r = 4 ft, g = 32 ft/sec^2

Equation: $mg = m\frac{4\pi^2 r}{t^2}$

Rearranged equation: $t^2 = \frac{4\pi^2 r}{g}$

Simplifying for unknown:

1) $t = 2\pi\sqrt{\frac{r}{g}}$

2) $t = \frac{2\pi r}{\sqrt{g}}$

3) $t = 4\pi^2\sqrt{\frac{r}{g}}$

4) $t = 4\pi\sqrt{\frac{r}{g}}$

A-r

Unknown: F_c

Known: $a_c = 48$ ft/sec^2, m = 1/8 slug

Equation: $F_c = ma_c$

Answer: $F_c = 6$ lb

C-g

Unknown: t
Known: r = 4 ft, g = 32 ft/sec^2
Rearranged and simplified equation: $t = 2\pi\sqrt{\frac{r}{g}}$

Substituting knowns into equation:

1) $t = 2 \times 3.14 \times \sqrt{\frac{4 \text{ ft}}{9.8 \text{ m/sec}^2}}$

2) $t = 3.14 \times \sqrt{\frac{4 \text{ ft}}{32 \text{ ft/sec}^2}}$

3) $t = 2 \times 3.14 \times \sqrt{\frac{4 \text{ ft}}{32 \text{ ft/sec}^2}}$

4) $t = 2 \times \sqrt{\frac{3.14 \times 4 \text{ ft}}{32 \text{ ft/sec}^2}}$

A-s

Answer: $F_c = 6$ lb

The direction of this force is:

1) In the same direction as the velocity.
2) Downward, toward the earth.
3) Away from the center of the circle.
4) Toward the center of the circle.

C-h

Unknown: t
Known: $r = 4$ ft, $g = 32$ ft/sec^2
Equation: $t = 2\pi\sqrt{\frac{r}{g}}$

Substituted equation: $t = 2 \times 3.14 \times \sqrt{\frac{4 \text{ ft}}{32 \text{ ft/sec}^2}}$

Simplifying:

1) $t = 6.28 \times \sqrt{\frac{1}{6}\frac{\text{ft}^2}{\text{sec}^2}}$
2) $t = 6.28 \times \sqrt{\frac{1}{6}\text{ sec}^2}$
3) $t = 6.28 \times \sqrt{\frac{1}{9}\text{ sec}^2}$
4) $t = 6.28 \times \sqrt{\frac{1}{8}\frac{\text{ft}^2}{\text{sec}^2}}$
5) $t = 6.28 \times \sqrt{\frac{1}{8}\text{ sec}^2}$

A-t

a) Answer: $a_c = 48$ ft/sec^2

Direction: Toward the center of the circle

b) Answer: $F_c = 6$ lb

Direction: Toward the center of the circle

C-i

Unknown: t
Known: r = 4 ft, g = 32 ft/sec^2
Equation: $t = 2\pi\sqrt{\frac{r}{g}}$
Simplified equation: $t = 6.28 \times \sqrt{\frac{1}{8}\ \text{sec}^2}$

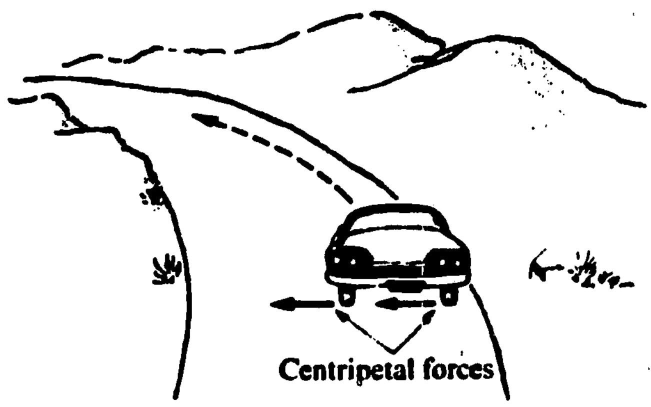
Simplifying:

1) $t = 6.28 \times 2.8$ sec
2) $t = \frac{6.28}{2.8}$ sec
3) $t = \frac{6.28}{\sqrt{2.8}}$ sec
4) $t = \frac{6.28}{8}$ sec

B

Problem:

How big would the radius of a curve have to be in order for a 3200 lb. automobile, traveling 27 mi/hr (40 ft/sec) to make the turn without slipping. The centripetal force on the car is the frictional force between tires and road. For this car that force is 800 lb.



C-1

Unknown: t

Known: $r = 4$ ft, $g = 32$ ft/sec^2

Simplified equation: $t = \frac{6.28}{2.8}$ sec

Simplifying:

1) t = 6.28 sec.
2) t = 12.8 sec.
3) t = 8.2 sec.
4) t = 2.2 sec.

C-k

Unknown: t

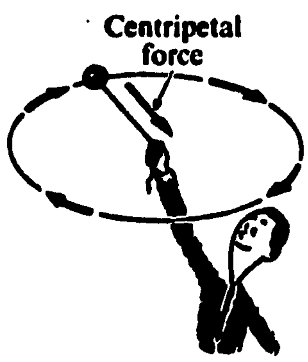
Known: r = 4 ft, g = 32 ft/sec^2

Equation: $t = 2\pi\sqrt{\frac{r}{g}}$

Substituted equation: $t = 2 \times 3.14 \times \sqrt{\frac{4\ \text{ft}}{32\ \text{ft/sec}^2}}$

Answer: t = 2.2 sec.

A. A man swings a 4 lb. ball (mass = 1/8 slug), attached to a rope, in a circle of radius 3 feet around his head. It is traveling at a constant speed of 12 ft/sec.
a) What is the centripetal acceleration of the ball?
b) What is the centripetal force on the ball?



A-c 1___, 2___, 3___, 4___, 5___, 6___.

d 1___, 2___, 3___, 4___, 5___, 6___, 7___.

e 1___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___.

i 1___, 2___, 3___, 4___.

l 1___, 2___, 3___, 4___, 5___, 6___.

m 1___, 2___, 3___, 4___, 5___, 6___.

n 1___, 2___, 3___, 4___.

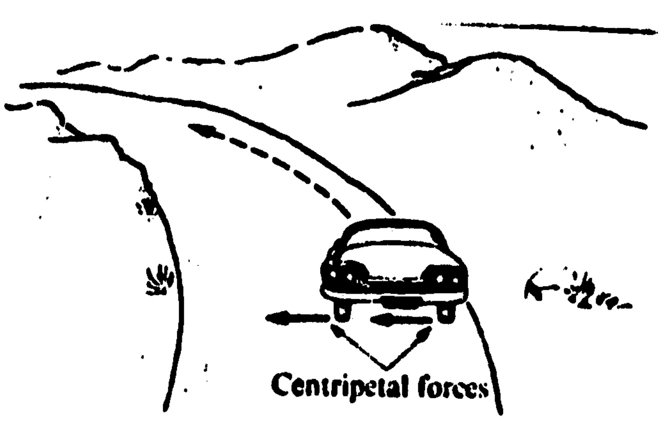
o 1___, 2___, 3___, 4___.

p 1___, 2___, 3___, 4___.

p 1___, 2___, 3___, 4___.

s 1___, 2___, 3___, 4___.

B. How big would the radius of a curve have to be in order for a 3200 lb. automobile, traveling 27 mi/hr (40 ft/sec) to make the turn without slipping. The centripetal force on the car is the frictional force between tires and road. For this car that force is 800 lb.



B-a 1___, 2___, 3___, 4___, 5___ 6___.

b 1___, 2___, 3___, 4___, 5___. 6___, 7___, 8___.

c 1___, 2___, 3___, 4___, 5___, 6___.

d 1___, 2___, 3___, 4___, 5___.

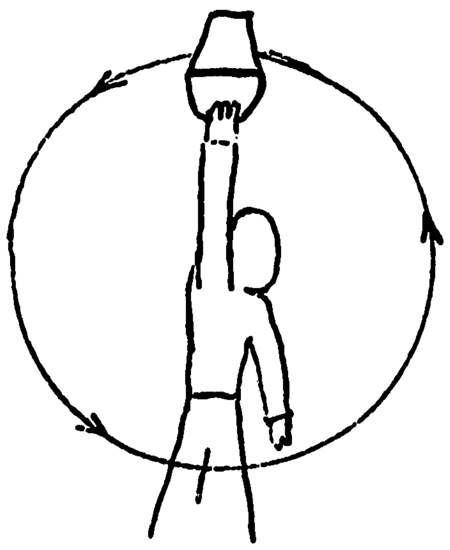
e 1 ___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___.

C. A pail of water is swung in a vertical circle of radius four feet. What is the minimum time for one revolution so that the water doesn't spill?



C-a 1___, 2___, 3___, 4___, 5___
6___.

b 1___, 2___, 3___, 4___, 5___
6___

c 1___, 2___, 3___, 4___, 5___.
6___.

d 1___, 2___, 3___, 4___.

e 1___, 2___. 3___, 4___.

f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___, 5___.

i 1___, 2___, 3___, 4___.

j 1___, 2___, 3___, 4___.

PROGRAMMED PROBLEM SOLVING LESSON

ROTATIONAL MOTION

Physics Department
Florissant Valley Community College
3400 Pershall Rd.
Ferguson, Missouri 63135

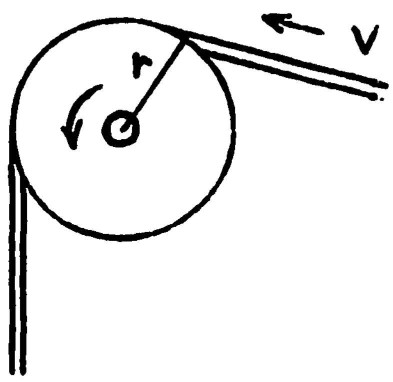
Spring, 1969

A

Problem:

A car motor is rotating at 1320 rpm and has an 8 in. diameter fan belt pulley. What is the linear speed in mi/hr of the fan belt?

Diagram:



P-1

Unknown: t

Known: ω_0 = 100 rad/sec, F_f = 10 lb,
I = 1 slug-ft^2, ω = 0 rad/sec,
r = 1 ft

Simplified equation:

$$t = 10 \frac{\text{slug-ft-rad/sec}}{\text{lb}}$$

Simplifying units:

1) t = 10 sec^2
2) t = 10 sec/rad
3) t = 10 sec
4) t = 10 rad/sec

A-a

Unknown is:

1) ω
2) t
3) α
4) d
5) v
6) a

B-1

Unknown: t

Known: ω_o = 100 rad/sec, F_f = 10 lb, I = 1 slug-ft^2, ω = 0 rad/sec, r = 1 ft

Equation: $t = \frac{I\ (\omega - \omega_o)}{-F_f r}$

Substituted equation:

$$t = \frac{1\ \text{slug-ft}^2 (0-100\ \text{rad/sec})}{-10\ \text{lb} \times 1\ \text{ft}}$$

Answer: **t = 10 sec**

Unknown: v

Known information is:

1) $v = 1320$ rpm
2) $r = 4$ in. (1/3 ft)
3) $v = 32$ ft/sec
4) $\omega = 1320$ rpm
5) $v = 8$ mi/hr
6) $g = 32$ ft/sec^2
7) $r = 8$ in. (2/3 ft)
8) 1 rpm $\cong$ .1 rad/sec

($\cong$ means approximately equal)

C

Problem:

a) What is the rotational kinetic energy of a 16 lb. bowling ball that is rolling at 10 ft/sec without slipping? b) What is its linear kinetic energy? (The moment of inertia of a solid sphere is 2/5 mr^2)

Diagram:

A-e

Unknown: v
Known: r = 4 in (1/3 ft),
ω = 1320 rpm,
1 rpm = .1 rad/sec

Equation relating unknown to knowns is:

1) $a = \frac{v^2}{r}$

2) $r = v\omega$

3) $a = \omega^2 r$

4) $v = \frac{d}{t}$

5) $v = r\omega$

C-a

Unknown in part a) is:

1) v^2
2) t
3) K.E.
4) W
5) P.E.
6) I
7) τ

A-d

Unknown: v

Known: r = 1/3 ft. ω = 1320 rpm,
1 rpm = .1 rad/sec.

Equation: $v = r\omega$

Substituting knowns into equations:

1) v = 1/3 ft x 1320 x .1 rad/sec
2) v = 3 ft x 1320 x .1 rad/sec
3) v = 1 ft x 1320 rpm
4) v = 1/3 ft x 1320 rad/sec
5) v = 1/3 ft x 1320 x 1 rad/sec

C-b

Unknown: K.E. (Rotational)

Known information is:

1) m = 16 lb
2) v = 10 ft/sec
3) g = 32 ft/sec^2
4) v = 32 ft/sec
5) w = 16 lb
6) r = 1 ft
7) I = 16 lb-ft
8) ω = 10 ft/sec

A-c

Unknown: v

Known: r = 1/3 ft, ω = 1320 rpm,
1 rpm = .1 rad/sec

Equation: $v = r\omega$

Substituted equation:
v = 1/3 ft x 1320 x .1 rad/sec

Simplifying:

1) $v = \frac{1320}{3}$ ft-rad/sec

2) $v = \frac{1320}{30}$ ft-rad/sec

3) $v = \frac{132}{3}$ ft-rad/sec

4) $v = \frac{132}{30}$ ft-rad/sec

C-c

Unknown: K.E. (Rotational)

Known: v = 10 ft/sec, g = 32 ft/sec^2
w = 16 lb.

Equations relating unknown to knowns are:

1) $w = mg$
2) $KE = mgh$
3) $v = r\omega$
4) $KE = 2/5\ mr^2$
5) $v = \frac{d}{t}$
6) $KE = 1/2\ mv^2$
7) $mv = I\omega$
8) $I = 2/5\ mr^2$
9) $\tau = I\omega$
10) $KE = 1/2\ I\omega^2$

A-f

Unknown: v

Known: $r = 1/3$ ft, $\omega = 1320$ rpm,
1 rpm = .1 rad/sec

Simplified equation: $v = \frac{132}{3}$ ft-rad/sec

Simplifying:

1) $v = 100$ ft-rad/sec
2) $v = 40$ ft-rad/sec
3) $v = 32$ ft-rad/sec
4) $v = 44$ ft-rad/sec

C-d

Unknown: K.E. (Rotational)

Known: $v = 10$ ft/sec, $g = 32$ ft/sec^2
$w = 16$ lb.

Equations: $w = mg$, $v = r\omega$, $I = \frac{2}{5} mr^2$

$$K.E. = 1/2\ I\omega^2$$

Combining equations to solve for unknown:

1) $K.E. = 1/2 \frac{w}{g} r^2 \left(\frac{v^2}{r^2}\right)$

2) $K.E. = 1/2 \left(\frac{2}{5} \frac{w}{g} r^2\right) \frac{v^2}{r^2}$

3) $K.E. = 1/2 \left(\frac{2}{5} gwr^2\right) \frac{v^2}{r^2}$

4) $K.E. = 1/2 \left(\frac{2}{5} \frac{w}{g} r^2\right) v^2 r^2$

5) $K.E. = 1/2 \left(1/2 \frac{w}{g} r^2\right) \frac{v^2}{r^2}$

A-g

Unknown: v
Known: $r = 1/3$ ft, $\omega = 1320$ rpm,
1 rpm = .1 rad/sec
Simplified equation: v = 44 ft-rad/sec

Simplifying units:

1) $v = 44$ ft/sec^2
2) $v = 44$ ft/sec
3) $v = 44$ rad/sec
4) $v = 44 \frac{\text{ft-sec}}{\text{rad}}$

C-e

Unknown: K.E. (Rotational)
Known: $v = 10$ ft/sec, $g = 32$ ft/sec^2
$w = 16$ lb.

Equation: $w = mg$, $v = r\omega$, $I = \frac{2}{5} mr^2$

$K.E. = 1/2\ I\omega^2$

Combined equation: $K.E. = 1/2 \left(\frac{2}{5} \frac{w}{g} r^2\right) \frac{v^2}{r^2}$

Simplifying:

1) $K.E. = 1/2 \frac{wv^2}{g}$
2) $K.E. = 1/5 \frac{wv^2}{gr}$
3) $K.E. = 2/5 \frac{wv^2}{g}$
4) $K.E. = 1/5 \frac{wv^2}{g}$

A-h

Unknown: v
Known: r = 1/3 ft, ω = 1320 rpm,
1 rpm = .1 rad/sec

Answer: v = 44 ft/sec

Answer in units required:

1) v = 88 mi/hr

2) v = 30 mi/hr

3) v = 60 mi/hr

4) v = 44 mi/hr

C-f

Unknown: K.E. (Rotational)
Known: v = 10 ft/sec, g = 32 ft/sec^2
w = 16 lb
Equations: w = mg, v = rω, I = 2/5 mr^2
K.E. = 1/2 Iω^2

Combined equation: K.E. = 1/5 $\frac{wv^2}{g}$

Substituting knowns into equation:

1) K.E. = 1/5 x $\frac{16 \text{ lb} \times 10^2 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2}$

2) K.E. = 1/5 x $\frac{16 \text{ lb} \times 10 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2}$

3) K.E. = 1/5 x $\frac{16 \text{ lb} \times 10 \text{ ft/sec}}{32 \text{ ft/sec}^2}$

4) K.E. = 1/5 x $\frac{15 \text{ lb} \times 10 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2}$

A-1

Unknown: v

Known: $r = 1/3$ ft, $\omega = 1320$ rpm,
1 rpm = .1 rad/sec

Equation: $v = r\omega$

Substituted equation:

$$v = 1/3 \text{ ft} \times 1320 \times .1 \text{ rad/sec}$$

Answer: $\boxed{v = 30 \text{ mi/hr}}$

C-g

Unknown: K.E. (Rotational)

Known: $v = 10$ ft/sec, $g = 32$ ft/sec^2,
$w = 16$ lb

Equation: $K.E. = 1/5 \frac{wv^2}{g}$

Substituted equation:

$$K.E. = 1/5 \times \frac{16 \text{ lb} \times 10^2 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2}$$

Simplifying:

1) $K.E. = 1/5 \times 1/2 \times 100 \frac{\text{lb-ft}^2/\text{sec}^2}{\text{ft/sec}^2}$

2) $K.E. = 1/5 \times 1/4 \times 100 \frac{\text{lb-ft/sec}^2}{\text{ft/sec}^2}$

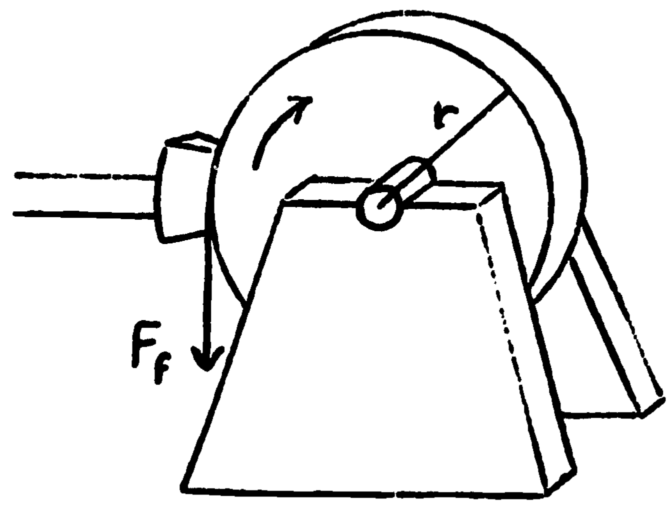
3) $K.E. = 1/5 \times 1/2 \times 10 \frac{\text{lb-ft}^2/\text{sec}^2}{\text{ft/sec}^2}$

4) $K.E. = 1/5 \times 1/4 \times 10 \frac{\text{lb-ft}^2/\text{sec}^2}{\text{ft/sec}^2}$

B

Problem:
A large flywheel with a 1 ft radius has a moment of inertia of 1 slug-ft^2 and is rotating at 100 radians per second (approximately 1000 rpm). If the maximum frictional force that a brake shoe can apply to the wheel is 10 lb, how long will it take to stop the flywheel? Note: Direction of rotation is opposite to that of frictional force.

Diagram:



C-h

Unknown: K.E. (Rotational)
Known: v = 10 ft/sec g = 32 ft/sec^2
w = 16 lb

Equation: $K.E. = \frac{1}{5} \frac{wv^2}{g}$

Simplified equation:

$$K.E. = 1/5 \times 1/2 \times 100 \frac{lb\text{-}ft^2/sec^2}{ft/sec^2}$$

Simplifying:

1) K.E. = 20 ft-lb
2) K.E. = 20 ft-lb/sec
3) K.E. = 10 ft-lb
4) K.E. = 10 ft-lb/sec

B-a

Unknown is:

1) ω
2) r
3) I
4) τ
5) v
6) t
7) F
8) d

C-1

Unknown Part a): Rotational K.E.

Known: v = 10 ft/sec. g = 32 ft/sec^2
w = 16 lb

Equation: $K.E. = 1/5 \frac{wv^2}{g}$

Substituted equation:
$K.E. = 1/5 \times \frac{16 \text{ lb} \times 10^2 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2}$

Answer to part a): **Rotational K.E. = 10 ft-lb**

8-b

Unknown: t

Known information is:

1) I = 64 lb-ft
2) ω_o = 100 rad/sec
3) F_f = 10 lb
4) I = 1 slug-ft^2
5) r = 10 ft
6) v = 100 ft/sec
7) ω = 0 rad/sec
8) r = 1 ft

9-d

Unknown in part b):

1) v^2
2) t
3) K.E.
4) W
5) P.E.
6) I
7) τ

B-c

Unknown: t

Known: ω_o = 100 rad/sec, F_f = 10 lb,
I = 1 slug-ft^2, ω = 0 rad/sec,
r = 1 ft

Equations relating unknown to knowns are:

1) $v = r\omega$
2) $\alpha = \frac{\omega - \omega_o}{t}$
3) $P = \tau\omega$
4) $\tau = -F_f r$ (- because the torque would produce counter-clockwise motion)
5) $I = mg$
6) $I = mr^2$
7) $a = r\alpha$
8) $\tau = I\alpha$

C-k

Unknown: K.E.

Known information is:

1) m = 16 lb
2) v = 10 ft/sec
3) g = 32 ft/sec^2
4) v = 32 ft/sec
5) w = 16 lb
6) I = 16 lb-ft
7) ω = 10 ft/sec

B-d

Unknown: t

Known: ω_o = 100 rad/sec, F_f = 10 lb,
I = 1 slug-ft^2, ω = 0 rad/sec,
r = 1 ft

Equation: $\alpha = \frac{\omega - \omega_0}{t}$, $\tau = -F_f r$. $\tau = I\alpha$

Combining equations for unknown:

1) $I\alpha = \frac{\omega - \omega_0}{t}$

2) $-F_f r I = \frac{\omega - \omega_0}{t}$

3) $\tau\alpha = \frac{\omega - \omega_0}{t}$

4) $\frac{-F_f r}{I} = \frac{\omega - \omega_0}{t}$

5) $\frac{-F_f I}{r} = \frac{\omega - \omega_0}{t}$

C-1

Unknown: K.E (Linear)

Known: v = 10 ft/sec, g = 32 ft/sec^2,
w - 16 lb

Equations relating unknown to knowns are:

1) w = mg
2) K.E. = mgh
3) v = rω
4) K.E. = 2/5 mr^2
5) $v = \frac{d}{t}$
6) K.E. = 1/2 mv^2
7) mv = Iω
8) I = 2/5 mr^2
9) τ = Iω
10) K.E. = 1/2 Iω^2

B-e

Unknown: t
Known: ω_o = 100 rad/sec, F_f = 10 lb,
I = 1 slug-ft^2, ω = 0 rad/sec,
r = 1 ft

Equation: $\alpha = \frac{\omega - \omega_o}{t}$, $\tau = -F_f r$, $\tau = I\alpha$

Combined equation: $\frac{-F_f r}{I} = \frac{\omega - \omega_o}{t}$

Rearranging equation to solve for unknown:

1) $t = \frac{I(\omega - \omega_o)}{-F_f r}$

2) $t = \frac{-F_f r}{I(\omega - \omega_o)}$

3) $t = \frac{-F_f r\ (\omega - \omega_o)}{I}$

4) $t = -F_f r I\ (\omega - \omega_o)$

C-m

Unknown: K.E. (Linear)
Known: v = 10 ft/sec, g = 32 ft/sec^2
w = 16 lb.
Equation: w = mg, K.E. = 1/2 mv^2

Combining equations to solve for unknown:

1) K.E. = 1/2 wv^2

2) K.E. = 1/2 $\frac{mv^2}{g}$

3) K.E. = 1/2 mgv^2

4) K.E. = 1/2 $\frac{wv^2}{g}$

5) K.E. = 1/2 wgv^2

B-f

Unknown: t

Known: ω_o = 100 rad/sec, F_f = 10 lb,
I = 1 slug-ft^2, ω = 0 rad/sec,
r = 1 ft

Rearranged equation: $t = \frac{I\ (\omega - \omega_o)}{-F_f r}$

Substituting knowns into equation:

1) $t = \frac{1 \text{ slug-ft}^2\ (100 \text{ rad/sec} - 0 \text{ rad/sec})}{-\ 10 \text{ lb} \times 1 \text{ ft}}$

2) $t = \frac{10 \text{ slug-ft}^2\ (0 - 100 \text{ rad/sec})}{-10 \text{ lb} \times 100 \text{ ft}}$

3) $t = \frac{10 \text{ slug-ft}^2\ (100 \text{ rad/sec} - 0 \text{ rad/sec})}{-\ 10 \text{ lb} \times 1 \text{ ft}}$

4) $t = \frac{1 \text{ slug-ft}^2\ (0 - 100 \text{ rad/sec})}{-10 \text{ lb} \times 1 \text{ ft}}$

C-11

Unknown: K.E. (Linear)

Known: v = 10 ft/sec, g = 32 ft/sec^2
w = 16 lb

Equation: w = mg, K.E. = 1/2 mv^2

Combined equation: K.E. = $1/2\ \frac{wv^2}{g}$

Substituting knowns into equation:

1) K.E. = $1/2 \times \frac{16 \text{ lb} \times 10 \text{ ft/sec}}{32 \text{ ft/sec}^2}$

2) K.E. = $1/2 \times \frac{16 \text{ lb} \times 100 \text{ ft}^2\text{/sec}^2}{32 \text{ ft/sec}^2}$

3) K.E. = $1/2 \times \frac{16 \text{ lb} \times 100 \text{ ft/sec}}{32 \text{ ft/sec}^2}$

4) K.E. = $1/2 \times \frac{16 \text{ lb} \times 10 \text{ ft}^2\text{/sec}^2}{32 \text{ ft/sec}^2}$

5) K.E. = $1/2 \times \frac{16 \text{ lb} \times 100 \text{ ft/sec}}{32 \text{ ft/sec}}$

B-g

Unknown: t

Known: ω_o = 100 rad/sec, F_f = 10 lb,
I = 1 slug-ft², ω = 0 rad/sec,
r = 1 ft.

Equation: $t = \frac{I(\omega - \omega_o)}{-F_f r}$

Substituted Equation: $t = \frac{1 \text{ slug-ft}^2 (0-100 \text{ rad/sec})}{-10 \text{ lb} \times 1 \text{ ft}}$

Simplifying:

1) $t = \frac{100 \text{ slug - ft}^2 \text{ rad/sec}}{-10 \text{ lb-ft}}$

2) $t = \frac{0 \text{ slug-ft}^2 \text{ rad/sec}}{-9 \text{ lb-ft}}$

3) $t = \frac{-100 \text{ slug-ft}^2 \text{ rad/sec}}{-10 \text{ lb-ft}}$

4) $t = \frac{-99 \text{ slug-ft}^2 \text{ rad/sec}}{-9 \text{ lb-ft}}$

C-o

Unknown: K. E. (Linear)

Known: v = 10 ft/sec, g = 32 ft/sec²
w = 16 lb

Equation: K. E. = $1/2 \frac{wv^2}{g}$

Substituted equation: K.E.= $1/2 \frac{16\text{lb} \times 100 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2}$

Simplifying:

1) K.E. = 25 ft-lb

2) K.E. = 50 lb/ft

3) K.E. = 100 ft-lb

4) K.E. = 50 lb/ft

B-h

Unknown: t

Known: ω_o = 100 rad/sec, F_f = 10 lb,
I = 1 slug-ft^2, ω = 0 rad/sec,
r = 1 ft

Simplified equation: $t = \frac{-100 \text{ slug-ft}^2\text{-rad/sec}}{-10 \text{ lb-ft}}$

Simplifying:

1) $t = 10 \frac{\text{slug-ft-rad/sec}}{\text{lb}}$

2) $t = -10 \frac{\text{slug-ft-rad/sec}}{\text{lb}}$

3) $t = 1/10 \frac{\text{slug-ft}^2\text{-rad/sec}}{\text{lb}}$

4) $t = 10 \frac{\text{slug-ft}^2\text{-rad/sec}}{\text{lb}}$

C-p

Unknown part b): Linear K.E.

Known: v = 10 ft/sec g = 32 ft/sec^2
w = 16 lb.

Equation: $K.E. = 1/2 \frac{wv^2}{g}$

Substituted equation:
$K.E. = 1/2 \frac{16 \text{ lb} \times 100 \text{ ft}^2/\text{sec}^2}{32 \text{ ft/sec}^2}$

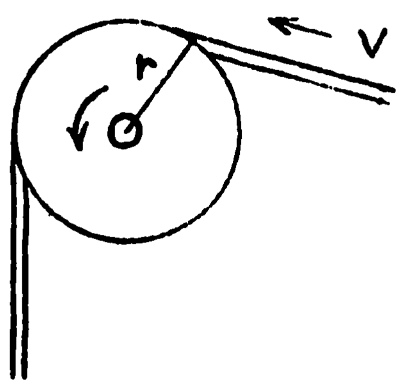
Answer to part b): **Linear K. E. = 25 ft-lb**

Answer to part a): **Rotational** K.E. = 10 ft-lb.

Answer Sheet

Name ______________________________

A. A car motor is rotating at 1320 rpm and has an 8 in diameter fan belt pulley. What is the linear speed in mi/hr of the fan belt?



A-a 1___, 2___, 3___, 4___, 5___
6___.

b 1___, 2___, 3___, 4___, 5___
6___, 7___, 8___.

c 1___, 2___, 3___, 4___, 5___.

d 1___, 2___, 3___, 4___, 5___.

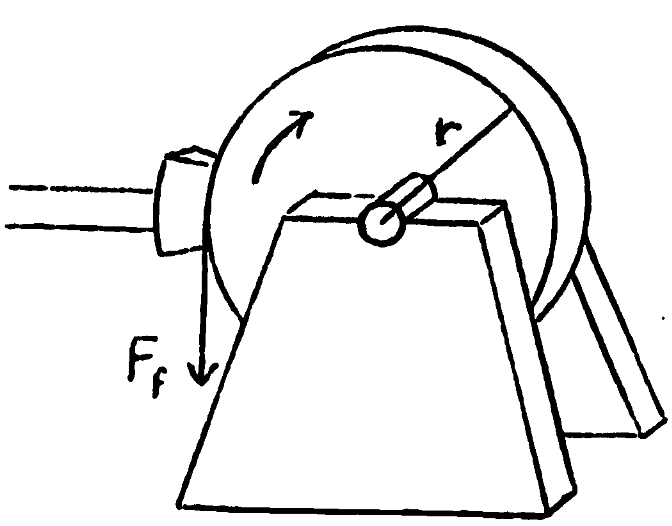
e 1___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___.

B. A large flywheel with a 1 ft radius has a moment of inertia of 1 slug-ft^2 and is rotating at 100 radians per second (approximately 1000 rpm). If the maximum frictional force that a brake shoe can apply to the wheel is 10 lb, how long will it take to stop the flywheel? Note: Direction of rotation is opposite to that of frictional force.



B-a 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___.

b 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___.

c 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___.

d 1___, 2___, 3___, 4___, 5___.

e 1___, 2___, 3___, 4___.

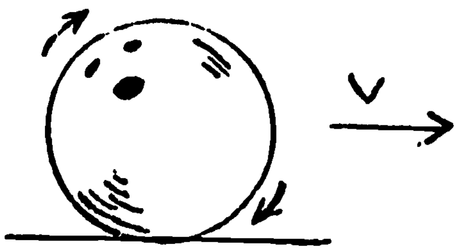
f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___.

i 1___, 2___, 3___, 4___.

C. a) What is the rotational kinetic energy of a 16 lb bowling ball that is rolling at 10 ft/sec without slipping? b) What is its linear kinetic energy? (The moment of inertia of a solid sphere is $2/5\ mr^2$.)



C-a 1___, 2___, 3___, 4___, 5___,
6___, 7___.

b 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___.

c 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___, 9___, 10___.

d 1___, 2___, 3___, 4___, 5___.

e 1___, 2___, 3___, 4___.

f 1___, 2___, 3___, 4___.

g 1___, 2___, 3___, 4___.

h 1___, 2___, 3___, 4___.

i 1___, 2___, 3___, 4___, 5___,
6___, 7___.

k 1___, 2___, 3___, 4___, 5___.
6___, 7___.

l 1___, 2___, 3___, 4___, 5___,
6___, 7___, 8___, 9___, 1___.

m 1___, 2___, 3___, 4___, 5___.

n 1___, 2___, 3___, 4___, 5___.

o 1___, 2___, 3___, 4___.

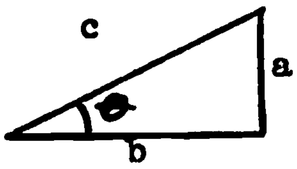
APPENDIX F

CONSTANTS:

$\pi = 3.1416$
$G = 6.67 \times 10^{-11} nm^2/kg^2$
r (earth) $= 6.3712 \times 10^6 m$
$g = 9.8 \ m/sec^2 = 32 \ ft/sec^2$
m (earth) $= 5.975 \times 10^{24}$ kg

MATH FORMULAS

Circumference of circle = 2 r
Area of a circle = r^2



$\sin \theta = a/c$
$\cos \theta = b/c$
$\tan \theta = a/b$

CONVERSION FACTORS

2.54 cm = 1 in
1 m = 3.28 ft
1 mile = 5280 ft = 1.61 km
88 ft/sec = 60 mi/hr
1 slug = 14.6 kg
1 lb = 4.45 n
1 kcal = 4.85 j
1 ft-lb = 1.36 j
1 watt = 1 j/sec = .738 ft-lb/sec
1 hp = 550 ft-lb/sec = 746 watts
1 atm = $1.013 \times 10^5 n/m^2 = 14.7 \ lb/in^2$
$^\circ F = 9/6 \ ^\circ C + 32^\circ$
$^\circ C = 5/9 \ (^\circ F - 32^\circ$

GLOSSARY

d distance
s length
L length, moment arm
h height
r radius
R range
θ angle

t time
v velocity
a acceleration
m mass
ω angular velocity
α angular acceleration
g acceleration due to gravity

w weight
F force
T tension
N normal force
μ coeff. of friction
W work
P power
τ torque

FORMULAS

Motion:

linear

$v = d/t$

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

angular

$\omega = \theta/t$

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

Free Fall:

$h = v_o t - 1/2 \ gt^2$

for constant acceleration:

$v = v_o + at$
$d = vt = v_o t + 1/2 \ at^2$
$v^2 = v_o^2 + 2ad$

$\omega = \omega_o + \alpha t$
$\theta = \omega t = \omega_o t + 1/2 \alpha t^2$
$\omega^2 = \omega_o^2 + 2 \ \theta$

Trajectory Motion:

$R = \frac{v_o^2}{g} \sin 2\theta$

Newton's first law of motion: $\Sigma F = ma$ (ΣF and a are vectors)
special form for force due to gravity: $w = mg$

Frictional force: $F_f = \mu N$

Centripetal force: $F_c = m \frac{v^2}{r}$

Power: $P = \frac{W}{t}$

Torque: $\tau = FL$

Momentum: mv
Kinetic energy: $KE = 1/2 \ mv^2$

Centripetal acceleration: $a_c = \frac{v^2}{r}$

Work: $W = Fd$ (when F is at angle θ from d: $W = Fd \cos \theta$)

Object in equilibrium: $\Sigma F = 0$
Rotational equilibrium: $\Sigma \tau = 0$
Gravitational force: $F_g = G \frac{m_1 m_2}{r^2}$

Positional potential energy: $PE = mgh$

UNITS

	British system	Metric system
Length	foot (ft)	meter (m)
Mass	slug	kilogram (kg)
Time	second (sec)	second (sec)
Acceleration	foot/second^2 (ft/sec^2)	meter/second^2 (m/sec^2)
Force	slug-ft/sec^2 = pound (lb)	kg-m/sec^2 = newton (n)

APPENDIX G

PRETEST FOR SELF-STUDY PROGRAMS

Read the problem carefully. Use only the information on the test and the accompanying page. (Some questions have more than one answer.)

1. Find the vector sum of two ten pound forces. One is to the right and at an angle of thirty degrees above the horizontal and the other is to the right and at an angle of sixty degrees above the horizontal.

    1) 19.3 lb. at 50°
    2) 3.73 lb. at 50°
    3) 19.3 lb. at 45°
    4) 3.73 lb. at 45°
    5) 37.3 lb. at 45°
    6) 1.93 lb. at 45°

2. In the problem: "A stone is dropped from the top of a one hundred foot tower. How fast is it traveling when it hits the ground?", the unknown in the problem is:

    1) time
    2) velocity
    3) acceleration
    4) acceleration due to gravity
    5) deceleration

3. The term $\frac{mv^2}{r}$ has the units of

    1) acceleration
    2) mass
    3) force
    4) weight
    5) velocity

4. In problems which involve an object dropped from a height h, $h = 1/2\ gt^2$. The object hits the ground with a final velocity $v = 2h/t$. If we combine these two equations to obtain another equation which does not involve h we get

    1) $t = \frac{2h}{gv}$
    2) $t = \frac{gt^2}{v}$
    3) $t = \frac{2v}{g}$
    4) $t = \frac{v}{g}$
    5) $t = \frac{g}{2v}$

5. "A stone is thrown upward with an initial velocity of sixty-four feet per second. How high will the stone go?"

Which of the following information is given or implied in the problem?

1) $v = 64$ ft/sec
2) $g = 32$ ft/sec^2
3) $v_o = 0$
4) $v = 0$
5) $h = 64$ ft
6) $v_o = 64$ ft/sec

6. The definition of a newton is:

1 newton = 1 $\frac{\text{kilogram-meter}}{\text{second}^2}$. Then

$\frac{\text{newtons}}{\text{kilograms}}$ has units of

1) force
2) weight
3) mass
4) acceleration
5) velocity
6) time

7. The two equations, w - mg and $\Sigma F = ma$, are often combined in problems involving force and motion. Combining these two equations into a single equation for (a) that does not involve m, we get

1) $a = \frac{\Sigma F}{wg}$

2) $a = \frac{\Sigma F}{w}$

3) $a = \frac{\Sigma Fw}{g}$

4) $a = \frac{\Sigma Fg}{w}$

8. "What force is necessary to increase the velocity of a four-thousand pound automobile from fifty-five miles per hour to sixty-five miles per hour in three seconds?"

Which of the following information, either given or implied in the problem, is necessary to obtain the answer?

1) $m = 4000$ lb
2) $g = 32$ ft/sec^2
3) $w = 4000$ lb.
4) $t = 3$ seconds
5) $v_o = 55$ mi/hr
6) $v = 65$ mi/hr
7) $a = 10$ mi/hr/sec
8) $F = 4000$ lb.

9. "A 64 lb. object is pulled across a table at a constant speed of 1/2 ft/sec by a force of 16 lb. The coefficient of friction between the object and the table is .250. What is the mass of the object?"

Which of the following items from the problem and accompanying page are necessary to obtain the answer?

1) $\mu = .250$
2) $m = 64$ lb.
3) $F = 16$ lb.
4) $w = 16$ lb.
5) $v = 1/2$ ft/sec
6) $g = 32$ ft/sec
7) $w = 64$ lb.
8) $a = 1/2$ ft/sec
9) $m = 16$ lb.
10) $F_f = 16$ lb.

10. The maximum force that the brakes can apply to a 3200 lb. car is 1000 lb. How far will it travel in coming to a stop from 60 mi/hr. Assume it does not slide. The answer is

1) 115 ft.
2) 121 ft.
3) 180 ft.
4) 246 ft.
5) 386 ft.

POST TEST FOR SELF-STUDY PROGRAMS

Read the problem carefully. Use only the information on the test and the accompanying page. (Some questions have more than one answer.)

1. Find the vector sum of two five pound forces. One is to the right and at an angle of thirty degrees above the horizontal and the other is to the right and at an angle of sixty degrees above the horizontal.

   1) 9.66 lb. at 50°
   2) 3.73 lb. at 50°
   3) 3.73 lb. at 45°
   4) 9.66 lb. at 45°
   5) 1.93 lb. at 45°

2. In the problem: "The shaft of a motor rotates at the constant angular velocity of 3000 rpm. How many revolutions will it have turned through in 1/2 min?", the unknown is:

   1) time
   2) angular velocity
   3) angle
   4) acceleration
   5) radius

3. The quantity $1/4\ m\ r^2\omega^2$ has the units of

   1) energy
   2) force
   3) acceleration
   4) inertia
   5) velocity

4. In problems which involve a spherical object accelerating down an inclined plane, the frictional force between the sphere and plane produces a torque which in turn results in the rotational motion of the sphere. The equation for rotational motion is then, $\tau = I\alpha$. Using the relations $\tau = F_f r$, $a = r\alpha$ and $I = 2/5\ mr^2$ the relationship between frictional force, F_f and the acceleration down the plane is

   1) $F_f = ma$
   2) $F_f = 2/5\ mr^2a$
   3) $F_f = 1/2\ mr^2a$
   4) $F_f = 2/5\ ma$
   5) $F_f = 2/5\ m\alpha$

5. "A 2 ton truck (4000 lb) is brought to a stop from 60 mph in 6 seconds. What force is necessary to produce this deceleration?"

Which of the following information is given or implied in the problem?

1) $t = 6$ sec
2) $v = 0$
3) $F = 4000$ lb
4) $m = 2$ tons
5) $w = 4000$ lb
6) $g = 32$ ft/sec^2
7) $v_o = 0$
8) $v = 60$ mph
9) $v_o = 60$ mph
10) $a = 10$ ft/sec^2

6. The definition of a watt is:

$$1 \text{ watt} = 1 \frac{\text{newton-meter}}{\text{second}}. \quad \text{Then}$$

$\frac{\text{watt-second}}{\text{meter}}$ has units of

1) force
2) mass
3) acceleration
4) velocity
5) time

7. The two equations, $F = ma$ and $Fd = 1/2\ mv^2$, are often combined in problems involving work and energy. Combining these two equations into a single equation for v that does not involve F, we get

1) $v = 2dm^2a$

2) $v = m\sqrt{2da}$

3) $v = \sqrt{2dma}$

4) $v = \sqrt{2da}$

5) $v = 2da$

8. "A 3200 lb automobile traveling at 30 mph is brought to a stop by a telephone pole in one half second. What average force did the pole exert on the automobile?"

Which of the following information, either given or implied in the problem, is necessary to obtain the answer?

1) m = 3200 lb
2) v = 30 mph
3) $g = 32\ ft/sec^2$
4) a = 15 mph/sec
5) w = 3200 lb
6) 30 mph = 44 ft/sec
7) v_o = 30 mph
8) v = 0
9) t = 1/2 sec
10) F = 3200 lb

9. "What is the increase in potential energy of a 100 lb object that is lifted slowly to a height of 100 ft?"

Which of the following information from the problem is necessary to obtain the answer?

1) m = 100 lb.
2) h = 100 ft
3) $g = 32\ ft/sec^2$
4) w = 100 lb
5) F = 100 lb

10. A flywheel rotating at 1000 rpm stops in 10 revolutions. What is the angular acceleration of the flywheel in radians per second squared? The answer is

1) $\alpha = 500\ rad/sec^2$
2) $\alpha = -80\ rad/sec^2$
3) $\alpha = 5\ rad/sec^2$
4) $\alpha = -500\ rad/sec^2$
5) $\alpha = 80\ rad/sec^2$
6) $\alpha = -5\ rad/sec^2$

A P P E N D I X H

QUESTIONNAIRE

	Strongly Agree	Mildly Agree	Not Sure	Mildly Disagree	Strongly Disagree
Do you feel that the programs were a help to you in problem solving?	☐	☐	☐	☐	☐
Did the problems have too much detail?	☐	☐	☐	☐	☐
Were the problems generally too difficult?	☐	☐	☐	☐	☐
Were the programs too long?	☐	☐	☐	☐	☐
Did you like the colored slides better than the black and white slides?	☐	☐	☐	☐	☐

	A-V	Written
Which form of the programs did you use?	☐	☐

Please make any comments you care to make about the programs.

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