



RANKING TASK EXERCISES IN PHYSICS

edited by

Thomas L. O'Kuma

Lee College
Baytown, Texas

David P. Maloney

Indiana University-Purdue University Fort Wayne
Fort Wayne, Indiana

Curtis J. Hieggelke

Joliet Junior College
Joliet, Illinois

Library of Congress Cataloging-in-Publication Data

Ranking task exercises in physics / edited by Thomas L. O'Kuma, David P. Maloney, Curtis J. Hieggelke.

p. cm. -- (Prentice Hall series in educational innovation)

Includes bibliographical references

ISBN 0-13-022355-7

1. Physics Problems, exercises, etc. I. O'Kuma, Thomas L. II. Maloney, David P. III. Hieggelke, Curtis J. IV. Series.

QC32 .R28 1999

530' 076 dc21

99-32915

CIP

Executive Editor: Alison Reeves

Editor-in-Chief: Paul F. Corey

Assistant Vice President of Production and Manufacturing: David W. Riccardi

Executive Managing Editor: Kathleen Schiaparelli

Assistant Managing Editor: Lisa Kinne

Production Editor: Linda DeLorenzo

Marketing Manager: Steven Sartori

Editorial Assistant: Gillian Buonanno

Manufacturing Manager: Trudy Piscioti

Art Director: Jayne Conte

Cover Designer: Bruce Kenselaar

©2000 by Prentice-Hall, Inc.

Upper Saddle River, New Jersey 07458

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-022355-7

Prentice-Hall International (UK) Limited, London

Prentice-Hall of Australia Pty. Limited, Sydney

Prentice-Hall Canada, Inc., Toronto

Prentice-Hall Hispanoamericana, S.A., Mexico

Prentice-Hall of India Private Limited, New Delhi

Prentice-Hall of Japan, Inc., Tokyo

Prentice-Hall (Singapore) Pte Ltd.

Editora Prentice-Hall do Brasil, Ltda., Rio De Janeiro

Contents

Foreward	viii
Preface.....	ix
Acknowledgments.....	x
Contributors and Institutions.....	xi
Background, Insights, and Uses	xii
Ranking Task Sample I.....	xvii
Ranking Task Sample II.....	xviii
Practice Ranking Task.....	xix
Kinematics Ranking Tasks.....	1
Ball Motion Diagrams—Velocity I	2
Ball Motion Diagrams—Acceleration I	3
Ball Motion Diagrams—Velocity II	4
Ball Motion Diagrams—Acceleration II	5
Objects in Different Situations—Accelerations	6
Vertical Model Rockets—Maximum Height	7
Vertical Arrows—Maximum Height	8
Position Time Graphs—Displacement	9
Cars—Change of Velocity	10
Position Time Graphs—Average Speed	11
Motion Diagrams—Displacement	12
Motion Diagrams—Average Velocity	13
People on Trains—Speed Relative to Ground	14
Force Ranking Tasks	15
Carts Moving Along Horizontal Surface—String Tension	16
Carts Moving Along Horizontal Surface—Acceleration	17
Carts Moving Along Horizontal Surface—Slowing Down	18
Two-Dimensional Forces on a Treasure Chest—Final Speed	19
Two-Dimensional Forces on a Treasure Chest—Acceleration	20
Arrows—Acceleration	21
Rocks Thrown Upward—Net Force	22
Model Rockets Moving Upward—Net Force	23
Blocks Attached to Fixed Objects—Rope Tension	24
Ball Motion Diagram—Net Force	25
Force Acceleration Graphs—Mass	26
Two Different Blocks and a Pulley—Tension	27
Ropes Pulling Boxes—Acceleration	28
Ropes Pulling Boxes—Rope Tension	29
Two Different Blocks and a Pulley—Net Force	30
Moving Car and Boat Trailer—Force Difference	31
Accelerating Car and Boat Trailer—Force Difference	32
Car and Boat Trailer on an Incline—Force Difference	33
Forces on Objects on Smooth Surfaces—Velocity Change	34

Forces on Objects on Smooth Surfaces—Speed Change	35
Forces on Objects on Rough Surfaces—Velocity Change	36
Forces on Objects on Rough Surfaces—Speed Change	37
Person in an Elevator Moving Upward—Scale Weight	38
Person in an Elevator Moving Downward—Scale Weight	39
Two Blocks at Rest—Force Difference	40
Two Moving Blocks—Force Difference	41
Two Accelerating Blocks—Force Difference	42
Horizontal Arrows at Different Distances—Force	43
Horizontal Arrows at Different Times—Force	44
Horizontal Arrows at Different Distances and Times—Force	45
Projectile and Other Two-Dimensional Motion Ranking Tasks.....	46
Water Over a Waterfall—Time to Reach Ground	47
Horizontal Arrows—Time to Hit Ground	48
Rifle Shots—Time to Hit Ground	49
Toy Trucks Rolling Off Tables—Time in Air	50
Spheres Thrown Horizontally Off Cliffs—Time to Hit Ground	51
Arrows—Maximum Heights	52
Rock Throw—Maximum Heights	53
Model Rockets Fired at an Angle—Horizontal Speed at Top	54
Cannon Shots—Acceleration at the Top	55
Carts on Incline—Height After Leaving Incline	56
Projectile—Horizontal Distance	57
Projectile—Time in Air	58
Work—Energy Ranking Tasks	59
Boxcars and Ropes—Stopping Force in Same Distance	60
Cars and Barriers—Stopping Force in Same Distance I	61
Cars and Barriers—Stopping Distance with the Same Force.....	62
Cars—Work Done in Change of Velocity	63
Bouncing Cart—Change in Kinetic Energy	64
Bouncing Cart—Work Done by the Barrier	65
Bouncing Cart—Work Done on the Barrier	66
Model Rockets—Kinetic Energy	67
Sliding Masses on Incline—Kinetic Energy	68
Sliding Masses on Incline—Change in Potential Energy	69
Cars—Change in Kinetic Energy During a Change of Velocity	70
Ball Motion Diagram—Kinetic Energy	71
Equal Forces on Boxes—Work Done on Box	72
Equal Force on Boxes—Work Done on Hand	73
Velocity Time Graph—Work Done on Box	74
Pendulums—Maximum Speed of the Bob.....	75
Force Pushing Box—Change in Kinetic Energy	76
Pushing Box with Friction—Change in Kinetic Energy	77
Impulse—Momentum Ranking Tasks	78
Carts and Springs—Spring Compression Time	79
Cars and Barriers—Stopping Time with the Same Force.....	80
Exploding Shells—Final Location of Center of Mass	81
Bouncing Cart—Change in Momentum I.....	82
Bouncing Cart—Change in Momentum II	83

Bouncing Cart—Change in Momentum III	84
Force Pushing Box—Change in Momentum.....	85
Force Pushing Box—Final Momentum.....	86
Cars—Impulse During a Change of Velocity	87
Cars—Change in Momentum During a Change of Velocity	88
Rotation Ranking Tasks.....	89
Four L's Rotating About an Axis (side view)—Moment of Inertia.....	90
Five T's Rotating About an Axis (top view)—Moment of Inertia	91
Four T's Rotating About an Axis (side view)—Moment of Inertia	92
Five T's Rotating About an Axis (top view)—Net Gravitational Torque.....	93
Five T's Rotating About an Axis (top view)—Angular Acceleration	94
Blocks on Rotating Turntables—Horizontal Force.....	95
Hanging Weights and Fixed Disks—Torque.....	96
Horizontal Uniform Rods—Angular Acceleration	97
Horizontal Uniform Rods—Change in Angular Momentum	98
Rotating Systems of Point Masses—Difficult to Rotate	99
Rotating Systems of Point Masses—Center of Mass	100
Statics—Difficult to Hold I	101
Statics—Difficult to Hold I I.....	102
Properties of Matter Ranking Tasks.....	103
Springs and Masses—Period of Oscillating Mass	104
Blocks Suspended in Liquids—Buoyant Force	105
Blocks Suspended in Liquids—Volume of Liquid Displaced	106
Blocks Suspended in Liquids—Mass of Liquid Displaced	107
Blocks Suspended in Liquids at Different Depths—Buoyant Force	108
Floating Blocks with Different Loads—Buoyant Force	109
Blocks Suspended in Water—String Tension	110
Blocks Suspended in Liquids—Buoyant Force II	111
Blocks Floating in Liquids—Buoyant Force	112
Blocks at the Bottom of Liquids—Buoyant Force	113
Cylinders of Water—Pressure on the Plug I	114
Cylinders of Liquids—Pressure on the Plug II	115
Heat and Thermodynamics Ranking Tasks.....	116
Copper and Water in Styrofoam Cups—Maximum Temperature	117
Various Thermodynamic Processes—Work Done by Gas	118
Gas Cylinders—Pressure	119
Pressure vs. Volume Graph—Temperature at Different Points I	120
Pressure vs. Volume Graph—Temperature at Different Points II	121
Pressure, Temperature, and Molecules—Internal Energy	122
Pressure, Volume, and Molecules—Temperature	123
Internal Energy, Volume, and Molecules—Temperature	124
Internal Energy, Volume, and Molecules—Pressure	125
Temperature, Pressure, and Molecules—Internal Energy	126
Wave Ranking Tasks	127
Wave Forms with Same Frequency—Wave Speed	128
Wave Pulses—Leading Edge Time to Travel	129
Standing Waves—Frequency.....	130
Standing Waves—Wavelength	131
Standing Waves Systems—Wave Speed.....	132

Wave Forms with Same Wavelength—Wave Speed	133
Pairs of Transverse Waves—Superposition	134
Wave Forms with Same Wavelength—Wave Energy	135
Electrostatics Ranking Tasks.....	136
Two Electric Charges—Electric Force	137
Three Linear Electric Charges—Electric Force	138
Two Nonlinear Electric Charges—Electric Force.....	139
Charged Conducting Spheres—Electric Field at the Center	140
Charged Conducting Spheres—Electric Potential at the Center	141
Charged Conducting Spheres—Electric Field at Various points	142
Charged Conducting Spheres—Electric Potential at Various Points.....	143
Charges Outside a Conducting Sphere—Force on Enclosed Charge	144
Point Charges Outside Conducting Spheres—Electric Field Within	145
Induced Charges—Positive and Negative	146
Induced Charges—Near a Charged Rod	147
Pairs of Charges—Attractive and Repulsive Force	148
Suspended Charges—Angle.....	149
Uniform Electric Field—Electric Force on Charge at Rest I	150
Uniform Electric Field—Electric Force on Charge at Rest II	151
Uniform Electric Field/Potential Lines—Electric Force on Charge at Rest III.....	152
Uniform Electric Field—Electric Force on Various Charges at Rest	153
Two Electric Charges—Electric Field Along Line	154
Electron Within a Charged Capacitor—Force on the Electron	155
Transfer of Charge in Conductors—Left Conductor	156
Transfer of Charge in Conductors—Right Conductor	157
Non-Uniform Electric Field—Electric Potential	158
Non-Uniform Electric Field—Electric Field Strength	159
Uniform Electric Field—Potential Difference	160
Uniform Electric Field—Strength of the Electric Field I	161
Uniform Electric Field—Strength of the Electric Field II.....	162
Uniform Electric Field/Potential Lines—Strength of the Electric Field	163
Uniform Electric Field—Electric Potential at Different Points II	164
Uniform Electric Field—Potential Energy of a Positive Charge.....	165
Uniform Electric Field—Potential Energy of a Negative Charge	166
Uniform Electric Field—Change in Potential Energy of a Positive Charge.....	167
Uniform Electric Field—Change in Potential Energy of a Negative Charge	168
Electron Within a Charged Capacitor—Electric Potential Energy	169
DC Circuit Ranking Tasks.....	170
Basic Circuits with Identical Capacitors—Charge on a Capacitor	171
Circuits with Identical Capacitors—Charge on a Capacitor	172
Simple Capacitor Circuits—Charge on a Capacitor	173
Basic Circuits with Identical Capacitors—Voltage Across a Capacitor.....	174
Circuits with Resistors and Capacitors—Current	175
Current Carrying Wires with Different Lengths—Net Charge	176
Batteries and Bulbs—Bulb Brightness.....	177
Simple Resistor Circuits—Current	178
Current Carrying Wires with Different Resistances—Net Charge	179
Simple Series Circuit—Voltage Across Bulb X	180
Simple Resistor Circuits—Voltage Drop	181

Parallel Circuits—Voltmeter Readings Across Open Switches I	182
Parallel Circuits—Voltmeter Readings Across Open Switches II	183
Circuit with Two Open and Closed Switches—Ammeter Readings	184
Circuit with Two Open and Closed Switches—Voltmeter Readings	185
Circuit with Three Open and Closed Switches—Voltmeter Readings I	186
Circuit with Three Open and Closed Switches—Voltmeter Readings II	187
Circuit with Three Open and Closed Switches—Ammeter Readings	188
Simple Series Circuit with Various Resistors—Current I	189
Simple Series Circuit with Various Resistors—Voltmeter	190
Resistive Circuit Concepts Diagnostic Test.....	191
Resistive Circuit Concepts Diagnostic Test—Instructions	192
Resistive Circuit Concepts Diagnostic Test	193
Resistive Circuit Concepts Diagnostic Test— Fill-In Answer Sheet.....	198
Resistive Circuit Concepts Diagnostic Test— Multiple Choice Answer Sheet	202
Resistive Circuit Concepts Diagnostic Test—Answer Key and Wrong Conception Code Key	203
Resistive Circuit Concepts Diagnostic Test—Wrong Conception Code	204
Magnetism and Electromagnetism Ranking Tasks	205
Moving Charges in Uniform Magnetic Field—Acceleration	206
Moving Charges in Uniform Magnetic Field—Change in Kinetic Energy	207
Charges Near Magnets—Magnetic Force	208
Pairs of Long Current Carrying Wires—Magnetic Field	209
Pairs of Equal Current Electromagnets—Force.....	210
Pairs of Equal Current Electromagnets— Magnetic Field Between.....	211
Unequal Current Electromagnets— Magnetic Field at Ends.....	212
Electromagnets with Unequal Currents—Magnetic Field Between	213
Graph of Current vs. Time—Induced Current	214
Answer Key	215

Foreword

Thirty years of careful study by physicists and others interested in education reveals that students enter our introductory courses with conceptual beliefs that differ considerably from the accepted concepts of physics. Unfortunately, a good fraction of these same students leave our courses with their alternative beliefs unchanged. Because of these studies, there is now more interest in helping students build a better conceptual foundation for their studies in physics.

Building this foundation is aided by uncovering students' alternative beliefs, a task well-suited for Ranking Tasks. A ranking task provides a question with several contextually similar situations. The situations differ in the value of one or more physical quantities (number of parallel or series bulbs, speed and mass of a swinging object, and so forth). The student ranks the situations according to some other physical quantity (electric current, rope tension and so forth). The student also provides reasons for their ranking. The ranking order and the explanation provide a window into the student's mind and helps a teacher or professor identify different models for what students are thinking.

Ranking tasks are also very useful for helping students modify their conceptual beliefs. Students are given a ranking task. The student completes the task working alone. The student then compares their thinking with that of another student and tries to reconcile any differences in thinking. The ranking task serves as the focus for a small group or classroom discussion. The tasks can also be given as homework problems and on quizzes and exams.

The present set of materials was developed during a series of workshops for two-year college physics professors which was supported by the National Science Foundation and organized and facilitated by Curt Hieggelke and Tom O'Kuma. David Maloney, the inventor of Ranking Tasks, was a co-leader for one series of these workshops. David taught participants how to use ranking tasks and then asked them to develop one or more tasks. Participants found the use and development of these tasks a valuable and enjoyable part of these intensive three-day workshops.

Do they make a difference? The gains of workshop participants' students on the Force Concept Inventory conceptual test and on the Mechanics Baseline problem-solving test have been excellent (see for example, TO-C and M-PD95b-C in Figure 4 on page 68 of Hake¹). Curt Hieggelke's students, who use ranking tasks extensively, have some of the highest scores on the recently developed Conceptual Survey of Electricity and Magnetism. Perhaps more important is the ease with which faculty can learn to use and develop ranking tasks.

The authors (O'Kuma, Maloney and Hieggelke and the many talented two-year college professors who contributed to this book) have provided us with a rich resource of learning activities. Give them a try—you'll like them.

Alan Van Heuvelen

¹ R.R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.* **66**, 64-74 (1998).

Preface

On November 21–23, 1991, a workshop for two-year college physics teachers on Conceptual Exercises and Overview Case Studies was held at Joliet Junior College, Joliet, IL. This workshop was the first of many such workshops conducted as part of the Two-Year College (TYC) Physics Workshop Project, which was sponsored by Joliet Junior College, Lee College (Baytown, TX), and a series of grants from the Division of Undergraduate Education of the National Science Foundation. At one of the sessions in this workshop, the participants, working together in groups of three or four, constructed ranking tasks and then presented them to the larger group for feedback and response. (A ranking task is a conceptual exercise created by David P. Maloney as one of the many ways to ascertain a student's understanding of concepts.)

During the 1991–98 period, the TYC Physics Workshop Project continued to hold workshops during which a variety of ranking tasks for introductory physics were developed at or as part of the follow-up activities after the workshop by the participants. During the academic year 1993–94, the ranking tasks that had been developed as part of the TYC Physics Workshops were categorized and put into electronic form at Lee College. These were called *A Collection of Physics Ranking Tasks* and were distributed to previous workshop participants in May 1994. During the academic year 1994–95, a subset of these ranking tasks and newly developed ones were further refined and widely distributed by Joliet Junior College as *A Selection of Physics Ranking Tasks*. This book is a revision and expansion of that book.

Although these materials are copyrighted by Prentice Hall, professors have the right to use the materials for noncommercial educational purposes and can copy or have copied the materials in the book for the students in their classes. However, these materials, whether in their original or in an altered form, may not otherwise be distributed, transmitted, or included in other documents without express written permission from the publisher. We have included a CD with this book that has a pdf version of each ranking task exercise in 8 1/2 x 11 format to further facilitate professors' use of these materials in their own classes, workshops, or for any noncommercial use. If you do not already have Adobe Acrobat Reader, please contact Adobe's web site (<http://www.adobe.com>), where it can be downloaded for free. This software will allow you to print and/or modify these ranking tasks.

In the first section, we have included some background material, including sample and practice ranking tasks, which give students an understanding of this type of instrument, and examples of how to complete a ranking task. The main body of ranking tasks is divided into broad topical areas, with mechanics in the first section. The second section includes properties of matter, heat and thermodynamics, and waves. The third section covers electricity and magnetism. And finally, we have included an answer key for this edition.

You are invited to visit our web site for corrections, updates, and additional ranking tasks (<http://www.tycphysics.org>). If you have any questions about these ranking tasks, please contact us.

Tom O'Kuma
Dave Maloney
Curtis Hieggelke

tokuma@lee.edu
maloney@ipfw.edu
curth@jic.cc.il.us

Acknowledgments

First, we want to acknowledge and thank all the participants who attended our workshops and were willing to share their ideas and work. Also, special thanks to all the workshop and conference leaders who made this project so successful.

Next, we want to give special thanks to the National Science Foundation for their support of the Two-Year College Physics Workshop Projects. We thank the many program directors at NSF that have supported this project, especially Duncan McBride, William Rauckhorst, William Kelly, Ken Krane, Ruth Howes, J. D. Garcia, Jack Hehn, and Karen Johnston.

At Joliet Junior College we particularly thank and acknowledge the support of this project by Michael Lee, Chairman of the Natural Science Department; Vice Presidents James Lepanto, Denis Wright, and J. D. Ross; and Presidents Raymond Pietak, Thomas Gamble, and J. D. Ross.

In addition, at Lee College we want to give special thanks to Wayne Miller and Carolyn Foster, Division Chairs of the Math, Science, and Engineering Division; Dean Donnetta Suchon; and Presidents Vivian Blevins and Jackson Sasser.

We want to thank Karen Dailey, who spent considerable time converting hard copy ranking tasks into electronic form at Lee College. We are also grateful for the assistance in various areas of this book by David Pequeno, Reggie Delgado, Regina Barrera, Sherry Green, Greg Gober, and Kathy O'Kuma.

At Joliet Junior College, we want to thank Craig Sumner, who reworked many diagrams, bringing them into final form. We also appreciate the help at different stages in this book by Jan Coleman, Judy Bond, Aaron Stone, Matt Kelly, Steve Clark, Eric Manuel, Geoff White, and Gale Ruggiero. Also, special thanks to physics professors Joe Krivicich (Joliet Junior College), William Hogan (Joliet Junior College), and Duane Desbain (Highland Community College, Highland, KS), who reviewed many of these ranking tasks.

We also want to thank our students, who tried out these ranking tasks and provided us with valuable feedback.

This material is based upon work supported by the Division of Undergraduate Education of the National Science Foundation under grant numbers USE 9150334, USE 9154271, DUE9255466, DUE 9353998, and DUE 9554683. Any opinions, findings, and conclusions or recommendations are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Finally, we thank Alison M. Reeves at Prentice Hall, who supported this project and the publication of this book.

Contributors and Institutions

Albers, Dennis	Columbia College	Sonora	CA
Bennie-George, Toni	Green River Community College	Auburn	WA
Bryant, Light	South Mountain Community College	Phoenix	AZ
Cole, Jonathan	Mira Costa Community College	Oceanside	CA
D'Alessandris, Paul	Monroe Community College	Rochester	NY
Davies, Chad	Cloud County Community College	Concordia	KS
Dickison, Alex	Seminole Community College	Sanford	FL
Diesslin, Butch	Vermilion community College	Ely	MN
Eckard, Eldon	Bainbridge College	Bainbridge	GA
Emerson, Bruce	Central Oregon Community College	Bend	OR
Ezrailson, Cathy	Montgomery College	Conroe	TX
Fang, Chuen Chuen	Shelton State Community College	Tuscaloosa	AL
Fazzari, Greg	Walla Walla Community College	Walla Walla	WA
Golden, Peter	Isothermal Community College	Spindale	NC
Gundlach, Jim	John A. Logan College	Carterville	IL
Heath, Sally	Santa Rosa Community College	Santa Rosa	CA
Hehn, Jack	Tarrant County Junior College/AAPT	Hurst	TX
Hieggelke, Curtis	Joliet Junior College	Joliet	IL
Hill, Charlotte	Tarrant County Junior College	Hurst	TX
Johnson, Robert	Del Mar College	Corpus Christi	TX
Kaasa, Bruce	Iowa Central Community College	Fort Dodge	IA
Karmon, Oshri	Diablo Valley College	Pleasant Hill	CA
Keramati, Beta	Holmes Community College	Goodman	MS
Krupp, Robert	Wilber Wright College	Chicago	IL
Lam, Clement	North Harris College	Houston	TX
Loucks, Stuart	Solano Community College	Suisun	CA
Maloney, David	Indiana University–Purdue University Fort Wayne	Fort Wayne	IN
Mann, Myron	Los Angeles Valley College	Van Nuys	CA
Marquard, Paul	Casper College	Casper	WY
Nelson, Marvin	Green River Community College	Auburn	WA
Nicholson, Nick	Central Alabama Community College	Alexander City	AL
O'Kuma, Tom	Lee College	Baytown	TX
Pandey, Umesh	Albuquerque Technical–Vocational Institute	Albuquerque	NM
Plumb, Marie	Jamestown Community College	Jamestown	NY
Popp, John	Moraine Valley Community College	Palos Hills	IL
Saavrda, Sherry	Lake Sumter Community College	Leesburg	FL
Schramme, Dave	Rogers State College	Claremore	OK
Selgrad, Ot	Moraine Park Technical College	Fond du Lac	WI
Shepherd, Gordon	Guilford Technical Community College	Jamestown	NC
Speers, Bob	Fireland College – Bowling Green St. Univ.	Huron	OH
Splett, John	Erie Community College – City Campus	Buffalo	NY
Szalai, Imre	Delaware County Community College	Media	PA
Takahashi, Leo	Penn State – Beaver Campus	Monaca	PA
Taylor, Jack	Baltimore City Community College	Baltimore	MD
Thompson, Winston	Montgomery College	Takoma Park	MD
Ting, Cheng (David)	Southeast College–Houston Community College	Houston	TX
Van Heuvelen, Alan	The Ohio State University	Columbus	OH
Weiner, Adam	Green River Community College	Auburn	WA
West, Myra	Kent State University	Kent	OH
Wetz, Karen	Manatee Community College	Venice	FL
Willis, Bob	New Mexico Military Institute	Roswell	NM

Background, Insights, and Uses

This book is intended as a resource for physics instructors who are looking for tools to incorporate more conceptual analysis in their courses. In putting together this collection of ranking tasks (RTs), we have been guided by two major goals.

First, we wanted to provide instructors with a set of immediately useful RTs from as many topic domains in physics as possible. Although the number of RTs on different topics is not uniform, this collection does contain RTs from all topics of classical physics except for optics. (Optics has proven to be a topic for which it is difficult to design good conceptual ranking tasks.) The RTs in this manual can be copied directly from the manual and used immediately in the classroom. Or an instructor can quickly modify one of the items in the book to fit his or her style and context.

Second, we wanted to illustrate a wide variety of RTs so that instructors could get an idea of the flexibility of the format and ideas about how to generate RTs for themselves. Generation or examination of a ranking task will often suggest an easily produced variation or variations. Student responses to a ranking task are another good source of ideas for other RTs. We hope that seeing a range of variations for a variety of RTs will enable instructors to develop sufficient familiarity with RTs so that they will be able to develop their own. Constructing good ranking tasks is not easy, but interested instructors should be able to generate viable ones with some practice.

Nature and Structure

The idea of ranking tasks arose from research into students' conceptions using a technique called rule assessment, developed by Robert S. Siegler (1976). The rule-assessment technique involved having subjects make a comparative judgment about a large variety of arrangements of a specific situation. The ranking tasks were conceived as a shorter format for eliciting such comparative judgments.

A ranking task is a paper-and-pencil exercise that presents students with a set of variations on a particular physical situation. The students are supposed to rank the variations on a specified basis. After explicitly writing out their ranking sequence or choosing the option that all of the variations are equivalent, the students are asked to write out an explanation of their reasoning. Finally, students are given an opportunity to identify how sure they were of the reasoning they used in the task.

As explained in the original ranking tasks article (Maloney, 1987) the basic structure of RT has four elements: the description of the situation, including the constraints and the basis for ranking the arrangements; a set of figures showing the different arrangements to be compared; a place to identify the response sequence chosen or to indicate that all of the arrangements have the same value for the ranking basis; and a place to explain the reasoning for the answer produced. Many of the RTs in this book have an additional element—a scale at the bottom of the page for the students to indicate how sure they were about their answers. This can be useful in at least two ways. First, it can tell an instructor how strongly the students are consciously committed to their ideas. Second, many students often feel that they are “just guessing” when they answer the RT, and that is what they want to write for their explanation of the reasoning. Having the scale at the bottom of the page provides an outlet for the students

to express these feelings so they can use the explanation section to describe what they actually did when working the task.

Ranking tasks contain few clues about how they should be worked. In addition, they require students to think about the situations in an unusual manner. Usually students deal with such situations in physics by calculating a specific numerical value given a limited number of other numerical values, all of which are normally needed in the calculation. In a ranking task students are confronted with a set of variations that usually differ in the specific values for two variables, and they have to decide how these variables affect the behavior of interest of the system.

Although most of the ranking tasks in this manual contain numerical values for two variables, we think of RTs as conceptual exercises. One might wonder how this works. The reason for our contention is that experience has shown that students often use the numerical values in inappropriate ways. Such use reveals one of several problems. One common problem is that the students do not understand the relations they are using, but rather just know to plug whatever numerical values are available into whatever relation is available. A second common problem is for students to apply the wrong relation to the situation. An example of this difficulty is students' strong tendency to use the product of mass and speed when they actually need to use the kinetic energy. So having the students use the numerical values in inappropriate ways can provide insight into their concepts and strategies.

The RTs in this manual vary widely in a number of ways. One way in which they vary is in how much computation is required to do a task. There are several reasons for this variation. One case is the "Two Different Blocks and a Pulley–Net Force" task on page 30, where students need to set up Newton's second law for the two masses and solve the equations simultaneously. Students seldom approach this task in this manner, but they also lack an equation they can quickly apply, so presenting them with such a situation makes them generate a procedure. It is often useful to see what students do with such a task. Sometimes we do want the students to learn how to do certain calculations, e.g., "Five T's Rotating About an Axis (top view)–Angular Acceleration" on page 94. And in some cases students need to do the calculations to understand that a priori ideas (e.g., symmetry considerations) don't always work out.

Reasons for Using Ranking Tasks

A fairly obvious question at this point is why an instructor would want to use ranking tasks. One strong reason for using them is the fact that they frequently elicit students' natural ideas about the behavior of physical systems rather than a memorized response. This ability of the ranking tasks to elicit students' natural ideas provides instructors with a way to gain important insights into students' thinking. With the help of those insights the instructor can help the students adapt to the scientifically accepted ideas.

Research in physics education (Clement, 1982; Peters, 1982; Halloun and Hestenes 1985; McDermott, 1991) has demonstrated that it is often difficult to get students to change their natural ideas about the physical world. A productive part of any effort to change students' ideas can be getting them to consider the same idea in a variety of ways. In a sense we want to be able to ask the same question in a variety of ways. Ranking tasks are a useful tool in such an effort, since they provide a way to frame questions in a manner that is novel for almost all students. Subsequently showing the students that they have responded in a different way to

the same question asked in different ways can be useful for getting them to think about why they responded as they did in each case. That, in turn, can lead them to think about which, if either, response they believe in more strongly and why.

Another important reason for using RTs is that they can be used to reframe a question asked in a traditional problem, or a multiple choice item, or an essay, but in a different way. So RTs can be used to determine how robust a student's concept is. Students get used to responding to multiple choice items, and they often develop coping mechanisms that allow them to respond to such items without really thinking the situation through. Couching the same question in a different format, which requires a different way of evaluating the situation, makes the students think about the concepts, principles, and relations in another way.

We have found that certain RTs are excellent for helping students develop legitimate understanding of some concepts. For example, there are a number of ranking tasks in this book involving uniform electric fields. It has been our experience that if students are not asked about uniform electric fields, they have definite misconceptions about them. However, after some work with ranking tasks, such as those in this book, most students develop a robust understanding of this issue. We believe that there are a number of ideas for which well-designed ranking tasks are an especially effective way to help students learn.

Uses

Ranking tasks are useful in a variety of ways. They make good homework assignments and good test questions. Ranking tasks are a good “size” and form as homework assignments because they are simple and easy for the students to understand but require careful and thorough analysis for correct completion. But RTs can be made challenging enough that they can even be assigned as homework where the students are allowed (encouraged) to work together. An example of such an item is “Circuit with Three Open and Closed Switches–Voltmeter Readings I” on page 186.

As test items RTs provide two parts—the ranking sequence and the explanation—that can be scored separately; for example, 2 points of 5 for the correct ranking sequence and 3 of 5 for a correct explanation. RTs are usually challenging test items for students. When using RTs as test items it is often best to have only four or five variations so that the students do not spend too much time, and/or make silly errors, with the calculations.

Ranking tasks are also very useful if an instructor wants to generate class discussions or have students engage in peer instruction or group work. A productive way to generate a class discussion is to give the class a ranking task, allow them about 5 minutes to work it, have them talk to each other about their solutions, and then ask selected individuals to present their answers. The instructor can then either have these students defend their ideas, assuming conflicting ideas have been presented, or can talk about the ideas and how to reason to the correct response. Giving ranking tasks to the students, who have been assigned to small groups, and telling each group that they have to come to a consensus about the answer is another good way to use RTs.

Sets of related tasks are also good for class discussions. Tasks can be related by having different objects exhibiting the same physical behavior, e.g., an arrow, a stream of water, and a rock undergoing projectile motion, by changing the variables for the situation, e.g., mass and speed, mass and height, or speed and height for a ball thrown off a building, or by a number

of other modifications of a situation. After the students work individual RTs from the related set, the students can be grouped by the particular version of the task they worked to discuss their answers. (This assumes the class is small enough for them to move around the room.)

Ranking tasks can be used to pre- and posttest students to check on the extent to which their ideas have been changed by instruction. Since RTs often bypass students' memorized physics ideas, they are especially useful in determining the extent to which instructors have been successful in changing students' natural (common sense) beliefs about physical situations.

The first time students are presented with ranking tasks, we suggest first giving them one of the sample ranking task pages. Give them an opportunity to read through the page carefully and check to see if they have any questions about how to work these tasks. Then we suggest passing out the practice RT and having them work it. Go over the answer, emphasizing explicitly showing how ties in the answer sequence are indicated and writing a complete explanation.

There is one very important point about using RTs in situations where students will earn credit for doing them. Since RTs are unfamiliar to students, it is critical for the students to have an opportunity to practice with the format in a noncredit context first. This is important to assure that students explicitly show ties and that they write complete explanations.

Related Ranking Tasks

If an instructor decides that they want to generate their own ranking tasks, a good way to start is to generate a variation on an existing task. There are several ways to vary existing tasks to produce new tasks.

One way is to have students rank the same situation on a different basis. An example of this technique is found in the “Cars and Barriers—Stopping Distance/Time with the Same Force” tasks on pages 62 and 80. In a similar way it is often possible to ask the same question in different ways. An example of this is “Carts Moving Along Horizontal Surface” on pages 17 and 18. This approach is especially useful when one version of the question uses the technical language of physics while the other employs natural, everyday language. Another related technique is to ask the same question but have different variables for the students to work with.

A different approach is to have the same variables and question but vary the physical situation. An example of this is shown in “Horizontal Arrows,” “Rifle Shots,” “Toy Trucks,” and “Spheres Thrown Horizontally Off Cliffs” tasks on pages 48 – 51. All of these are the same projectile motion situation, however, students often think that different physical systems will behave differently. Getting students to see past these noncritical surface features to the physical principle that applies is an important aspect of learning to do physics.

Another very important aspect that can be varied is the representation used for presenting the information. An example of this is shown in “Uniform Electric Field—Electric Force on Charge at Rest” tasks on pages 150–152. Students often learn information in one representation, i.e., they will know what to do if given a kinematic equation, but will be lost if the same situation and information is presented in graphical form. Ability to handle tasks represented in various ways is a good indicator of solid understanding.

It will be easier to construct variations for some situations, concepts, or principles than for others. And for some situations, concepts, or principles students may need to work through a wider variety of those variations in order to develop a solid understanding. Our experience indicates that the topic of sinking, floating, and buoyancy is one topic where a wider variety of tasks is useful. Consequently, both to present ideas about generating related RTs and to give a specific example of how to approach such a topic, there is what will probably seem to many a large number of RTs on sinking, floating, and buoyancy.

A unique contribution to this book is the Resistive Circuits Concepts Diagnostic Test developed by Dennis Albers. This test is a sequence of ranking tasks on basic electric circuit concepts. In a way this test takes the idea of using related ranking tasks to the extreme, but having this set of interrelated ranking tasks enables an instructor to get a clear understanding of students' ideas about simple electric circuits. Similar tests could obviously be developed for other physics topics.

Finally some other ideas for different types of RTs, such as using comparative values for variables rather than specific numerical values and other ways to develop tasks that involve three variables, can be found in Maloney and Friedel (1996).

In writing RTs we believe there are several issues that should be carefully considered. First, we believe instructors should take account of known, or suspected, student alternative conceptions when developing an RT. Because RTs frequently elicit students' natural ideas, using those ideas in writing the RT can make it a better conceptual exercise. A second issue is the language—natural, i.e., everyday, versus technical—used in the RT. If one wants to elicit students' common-sense ideas, then natural language is usually more effective. But having students respond to the same task written in natural and technical language can be a useful exercise. A third issue is how many variations to present in the RT. In some situations this can be fixed by the situation, which may have a fixed number of variations. In most other cases the number of variations to include is usually tied to how the RT is to be used. As a homework assignment, eight variations might be chosen to provide practice in calculating and evaluating alternatives. For a test item, between four and six variations are more reasonable.

The editors would appreciate feedback about the items in this book. We are especially interested in learning about other variations and uses of ranking tasks and about new RTs. We would also like to hear about any errors that may have crept in despite our best efforts to ensure that everything is correct.

Clement, J. (1982) Students' Preconceptions in Introductory Mechanics, *American Journal of Physics* **50**: 66-71.

Halloun, I. A. and Hestenes, D. (1985) The Initial Knowledge State of College Physics Students, *American Journal of Physics* **53**: 1043-1055

McDermott, L. C. (1991) Millikan Lecture 1990: What we Teach and What is Learned—Closing the Gap, *American Journal of Physics* **59**: 301-315.

Maloney, D. P. (1987) Ranking Tasks; A New Type of Test Item, *Journal of College Science Teaching* **16**(6): 510.

Maloney, D. P. and Friedel, A.W. (1996) Ranking Tasks Revisited, *Journal of College Science Teaching* **25**: 205-210.

Peters, P. C. (1982) Even Honors Students Have Conceptual Difficulties with Physics, *American Journal of Physics* **50**: 501-508.

Siegler, R. S. (1976) Three Aspects of Cognitive Development, *Cognitive Psychology* **8**: 481-520.

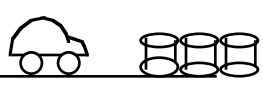
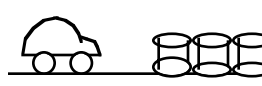
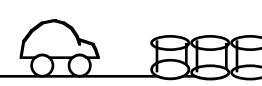
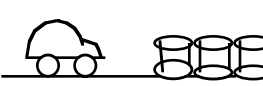
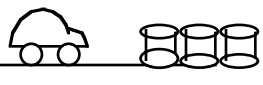
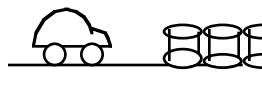
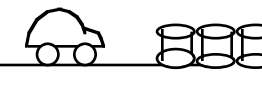
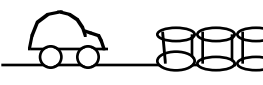
Ranking Task Sample I

For a ranking task, each item will have a number of situations as illustrated. Your task will be to rank the items in a specific order. After ranking them you will be asked to identify the basis you used for the ranking and the reasoning behind your choice. It is extremely important that you are careful to write out the proper ranking once you have determined what basis you are going to use, i.e., make sure all of the situations are ranked in the proper order according to your basis. The sample below shows how to rank items and what your explanation should be like. **NOTE: Although the procedure for working the item is correct, the particular answer, which was chosen at random from actual student responses, may not be correct.**

Example:

Shown below are eight cars that are moving along horizontal roads at specified speeds. Also given are the masses of the cars. All of the cars are the same size and shape, but they are carrying loads with different masses. All of these cars are going to be stopped by plowing into barrel barriers. All of the cars are going to be stopped in the same distance.

Rank these situations from greatest to least on the basis of the strength of the forces that will be needed to stop the cars in the same distance. That is, put first the car on which the strongest force will have to be applied to stop it in x meters, and put last the car on which the weakest force will be applied to stop the car in the same distance.

<p>12 m/s →</p>  <p>A</p> <p>1200 kg</p>	<p>16 m/s →</p>  <p>B</p> <p>1000 kg</p>	<p>8 m/s →</p>  <p>C</p> <p>1600 kg</p>	<p>5 m/s →</p>  <p>D</p> <p>1500 kg</p>
<p>9 m/s →</p>  <p>E</p> <p>1200 kg</p>	<p>12 m/s →</p>  <p>F</p> <p>1600 kg</p>	<p>5 m/s →</p>  <p>G</p> <p>1500 kg</p>	<p>10 m/s →</p>  <p>H</p> <p>1100 kg</p>

Greatest

1. B 2. A F 3. 4. H 5. E 6. C 7. D G 8. Least

Or, all cars require the same force. _____

Please carefully explain your reasoning

Since acceleration is the change in velocity divided by the change in time and all the changes in times are the same, then I used the change in velocity.

How sure were you of your ranking? (circle one)

Basically Guessed

Sure

Very Sure

1 2 3 4 5 6 7 8 9 10

Notice in this example that two situations produced the same result for the ranking and that these were listed in the same answer blank. Such a possibility exists for all items. In the same way, it is possible that all of the situations will give the same result. If that occurs, and only if that occurs, the option of all equal, or all the same, should be chosen.

Ranking tasks (Redish 2003a, O'Kuma et al., 2000) are considered efficient both for improving students' conceptual understanding and for evaluation purposes. This kind of problem asks students to rank physical situations, systems or quantities according to different criteria and to explain their reasoning. ... Ranking of information problems are scarcely offered in physics textbooks, but there exist research-based collections of them. Ranking problems [39] [40], UW tutorials [6], UM tutorials [32], and comparison tasks [8] contain such problems. Example Rank these cases from the highest to the lowest acceleration based on the drawings shown in Fig. This student text contains 218 Ranking Task Exercises that cover all classical physics topics. Ranking Tasks are an innovative type of conceptual exercise that asks students to make comparative judgments about a set of variations on a particular physical situation. These exercises were developed by participants in the Two-Year College (TYC) Physics Workshop Project sponsored by Joliet Junior College, Lee College, and a series of grants from the Division of Undergraduate Education of the National Science Foundation, and were edited by Thomas L. O'Kuma (Lee College), David P. Maloney (Indiana This is a resource book for physics educators containing approximately 200 Ranking Task Exercises (conceptual exercises that ask students to make comparative judgments about a set of variations on a particular physics situation) which cover all classical physics topics. Series Name: Educational Innovation- Physics Pages 140. <http://vig.prenhall.com/catalog/academic/product/0,1144,013144851X> Subjects. physics terminology edition two publishing speedy. piaggio maintenance manual. pioneer cx 3250 service manual. 218 Ranking Task Exercises, covering all of Classical Physicsâ€”Gives students ample opportunity to work these unique exercises. Unique Ranking Task structureâ€”Designed for clarity, the exercises consist of four elements: 1) a description of the physical situation, including any constraints and the basis for ranking different arrangements; 2) a set of figures showing the different arrangements of the situation to be compared; 3) a place to record the ranking of each variation; 4) a place to explain the reason for each ranking choice. Table of Contents. Kinematics Ranking Tasks. Force Ranking Task...