

Westfield Studios

PHYSICS 101

Guidebook and Quizzes

A companion guide to the Physics 101 DVD set

Wes Olson

PHYSICS 101

Guidebook and Quizzes

Special thanks to
Michael Bost and Cody Bost
for their great efforts in proof-reading this text.
Thanks also to Ruth Leach.
Any grammatical and punctuation errors remaining
in the text are due to my oversight.

Copyright © 2015, 2017 by Westfield Studios. All rights reserved.
You and your print shop have permission to make copies of this guidebook and accreditation booklet
for your family and/or co-op class.
For all other purposes, no part of this guidebook may be reproduced in any manner whatsoever without
written permission, except for brief quotations in articles and reviews.

Revision: 06-17-17

www.the101series.com

A Guide to the Guidebook

Side Bar Trivia
The text on the left side of the page contains interesting facts on a whole host of physics-related subjects.

Physics Trivia.
These side boxes have information that did not necessarily make it into the film but may be interesting enough for the Guidebook. For example, if an atom were expanded to the size of a stadium, then the electrons would be the size of honey bees flying somewhere inside.

Lorem ipsum

This paragraph is a variation on what publishers call “filler text,” the most common of which is lorem ipsum which looks like this: *Lorem ipsum dolor sit amet, consectetur adipiscing*, etc. Lorem ipsum has been around for nearly 500 years, used by the printing industry as a text placeholder. You probably were unaware that lorem ipsum even existed but I’ll bet you will see lorem ipsum somewhere in a few days just because I brought your attention to it. You’re welcome.

1. Introduction

1. The question here is almost always: “How many people ever read sections like this?” Very few and only a small handful of people ever write in and say, “I read it! I read that quirky section that no one reads!” If you read this, send me that email.
2. The number “2” is unique. Without it, you could never move to “3.” Any number divisible by two is called an even number. Two is the atomic number of helium. *Two* rhymes with *glue*.
3. Three is the minimum number used when people want to synchronize something like, “*On the count of three, everybody pull!*” The predicted timing of “three” is based on the rate of the “one” and “two” that came before it. Timing is everything—just ask any chef, comedian, or tennis player.

Air and Water. Air is so common we hardly think about it at all...unless you are missing it, then you can’t stop thinking about it. The weight of our entire atmosphere is estimated at over 5 quadrillion tons—that’s a 5 followed by 14 zeros. The first ten feet of the oceans hold as much heat as the *entire* Earth’s atmosphere! Water absorbs heat *much* better than air. In other words, water is a better conductor than air.

1. Dr. Bob Schwartz, *Physics Jokes*, P. 133. Dr. Schwartz recognizes that you can never really trust an atom because they make up everything. The book is full of bad puns like this.

Footnotes

Video Information
This area with black text is information from the film...usually.

Stories & Commentary
The text in a box usually contains interesting biographies and observations.

I. TABLE OF CONTENTS

I. TABLE OF CONTENTS.....	ii
SEGMENT 1	1
INTRODUCTION TO PHYSICS.....	1
SEGMENT 2	3
THE PHYSICS OF LIGHT “LIGHT AND COLOR”	3
I. SOME LIGHT BASICS.....	3
II. “WHY IS THE SKY BLUE?”.....	3
III. “WHAT MAKES RAINBOWS?”.....	4
IV. “WHAT’S THE DIFFERENCE BETWEEN LIGHT AND PIGMENT COLOR?”.....	4
SEGMENT 3	7
THE PHYSICS OF LIGHT “MIRRORS AND LENSES”	7
I. “WHY IS MY FACE UPSIDE DOWN IN A SPOON?”.....	7
II. MIRRORS	7
III. LENSES	8
SEGMENT 4	10
PHYSICS OF LIGHT “INVISIBILITY & THE SPEED OF LIGHT”	10
I. “WHAT WOULD IT BE LIKE TO BE THE INVISIBLE MAN?”.....	10
II. “HOW CAN YOU MEASURE THE SPEED OF LIGHT?”.....	12
SEGMENT 5	14
THE PHYSICS OF SOUND “INTRODUCTION TO SOUND”	14
I. “WHY DO YOU SEE LIGHTNING FIRST THEN HEAR IT LATER?”.....	14
II. “HOW DO WE KNOW THAT SOUND IS A WAVE?”.....	14
III. “WHAT ARE HERTZ?”.....	15
SEGMENT 6	17
THE PHYSICS OF SOUND “ACOUSTICS: THE SOUND OF MUSIC”	17
I. “WHY DO I SOUND SO GOOD WHEN I SING IN THE SHOWER?”.....	17
II. “WHY DOES A WINE GLASS SING WHEN I RUB IT?”.....	18
III. “WHY DOES MY VOICE SOUND DIFFERENT WHEN I HEAR IT IN A RECORDING?”.....	18
SEGMENT 7	20
THE PHYSICS OF HEAT “WHAT IS FIRE?”.....	20
I. THE PHYSICS OF HEAT.....	20
SEGMENT 8	23
THE PHYSICS OF HEAT “LAWS OF THERMODYNAMICS”	23
I. 1 ST LAW OF THERMODYNAMICS: CONSERVATION OF ENERGY.....	23
II. 2 ND LAW OF THERMODYNAMICS: ENTROPY	25
III. 3 RD LAW OF THERMODYNAMICS: ABSOLUTE ZERO	26

SEGMENT 9	28
THE PHYSICS OF HEAT “REFRIGERATION: HOT & COLD”	28
I. COLD ISN’T A THING	28
II. THE THREE WAYS HEAT MOVES	30
III. SEVEN COMMON HEAT QUESTIONS	30
IV. THREE DIFFERENT TEMPERATURE SCALES	32
SEGMENT 10	34
THE PHYSICS OF ELECTRICITY AND MAGNETISM “WHAT IS ELECTRICITY?”	34
I. HISTORY OF ELECTRICITY	34
II. THE FOUNDATIONS OF THE UNIVERSE	35
III. MATTER IS MADE OF CHARGE.....	35
IV. MOVING CHARGE	36
V. THE GREAT INVISIBLE FORCE FIELD.....	37
VI. ELECTRICITY IS TWO THINGS	38
SEGMENT 11	40
THE PHYSICS OF ELECTRICITY AND MAGNETISM “OUTLETS AND CIRCUITS”	40
I. OUTLETS AROUND THE WORLD	40
SEGMENT 12	46
THE PHYSICS OF ELECTRICITY AND MAGNETISM	46
“BATTERIES AND THE ELECTROMAGNETIC SPECTRUM”	46
I. BATTERIES ARE ANOTHER CHARGE PUMP	46
II. “WHAT IS A MAGNET?”	47
III. “WHAT IS THE ELECTROMAGNETIC SPECTRUM?”	48
SEGMENT 13	50
THE PHYSICS OF MOTION “THE LIFE OF ISAAC NEWTON”	50
I. EARLY LIFE.....	50
II. MIDDLE YEARS	51
III. NEWTON’S BLACK YEAR	52
IV. LATER YEARS.....	52
V. NEWTON’S RELIGION.....	52
SEGMENT 14	54
THE PHYSICS OF MOTION “NEWTON’S UNIVERSAL LAW OF GRAVITY”	54
I. GALILEO HITS THE GROUND AT THE SAME TIME	54
II. THE UNIVERSAL LAW OF GRAVITY	54
III. THE MOUSE AND THE ELEPHANT	55
IV. 9.8 METERS PER SECOND PER SECOND.....	55
V. BALLOONS DON’T DEFEAT GRAVITY	55
VI. WE STILL DON’T UNDERSTAND GRAVITY.....	56

SEGMENT 15	58
THE PHYSICS OF MOTION “NEWTON’S FIRST LAW OF MOTION”	58
I. FORCE	59
II. INERTIA: THE FIRST LAW OF MOTION	59
III. VELOCITY	59
IV. CENTRIFUGAL “FEELING”	60
V. CENTRIPETAL “FORCE”	60
VI. FRICTION.....	61
VII. WEIGHTLESSNESS	61
SEGMENT 16	63
THE PHYSICS OF MOTION: “THE 2ND AND 3RD LAWS OF MOTION”	63
I. ACCELERATION	63
II. THE SECOND LAW OF MOTION.....	63
III. THE THIRD LAW OF MOTION.....	64
SEGMENT 17	68
THE PHYSICS OF THE WEIRD “THE LIFE OF ALBERT EINSTEIN”	68
I. EARLY LIFE.....	68
II. MIDDLE YEARS	69
III. LATER YEARS.....	71
IV. EINSTEIN AND HIS FAMILY	71
V. EINSTEIN AND GOD	72
SEGMENT 18	74
THE PHYSICS OF THE WEIRD “RELATIVITY”	74
I. SPECIAL RELATIVITY.....	74
II. GENERAL RELATIVITY	76
SEGMENT 19	79
THE PHYSICS OF THE WEIRD “QUANTUM MECHANICS”	79
I. QUANTUM MECHANICS	79
II. ATOM MECHANICS	80
III. QUANTUM PHILOSOPHY.....	81
IV. DIFFERENT WAYS TO INTERPRET THE NEW ATOM MECHANICS.....	82
V. WORLDVIEWS AFFECT ALL SCIENCE	82
VI. PRACTICAL INVENTIONS FROM QUANTUM MECHANICS	83
VII. SUMMARY OF PHYSICS OF THE WEIRD	84
SEGMENT 20	86
THE FUTURE OF PHYSICS	86
I. PHYSICS TOMORROW	86
II. PHYSICS IN YOUR LIFETIME	89
III. PHYSICS IN THE FAR FUTURE	89

ANSWERS TO THE QUIZZES.....	91
SEGMENT 1.....	91
SEGMENT 2.....	91
SEGMENT 3.....	91
SEGMENT 4.....	91
SEGMENT 5.....	91
SEGMENT 6.....	91
SEGMENT 7.....	91
SEGMENT 8.....	91
SEGMENT 9.....	92
SEGMENT 10.....	92
SEGMENT 11.....	92
SEGMENT 12.....	92
SEGMENT 13.....	92
SEGMENT 14.....	92
SEGMENT 15.....	92
SEGMENT 16.....	92
SEGMENT 17.....	92
SEGMENT 18.....	92
SEGMENT 19.....	92
SEGMENT 20.....	92





SEGMENT 1

Introduction to Physics

Nature. That's what the word "physics" literally means in Greek. It's the branch of science that studies the make-up of nature; what matter is and how matter interacts with itself. It used to be called "natural philosophy" or "the philosophy of nature."

1. People naturally have things that come to mind when we say "biology" or "chemistry." But generally nothing normally comes to our minds when we say the word, "physics." Perhaps because physics is such an all-encompassing, broad subject.
2. The physicist looks behind the periodic table to determine how the universe functions: light, sound, heat, motion and the particles that make up all matter.
3. The chemist wants everything to be different and is surprised when everything is the same. The physicist wants everything to be the same and is surprised when everything is different.
4. Science is limited by design. It is limited to the measurable and testable. But some of the most important aspects of life are outside this realm:
 - Morality
 - Art and aesthetics
 - Supernatural, also known as *metaphysics*

Discussion Questions

Science is limited and has no jurisdiction in the arenas of good and evil. If no people existed, would there still be such a thing as good and evil? Why or why not?

What did Ernest Rutherford mean when he said, "*All science is either physics or stamp collecting?*"

Segment 1 Quiz - "Introduction to Physics"

1. Physics means
 - a) *Science* in Greek
 - b) Matter and motion
 - c) Nature
2. There is an absolute and clear distinction between chemistry and physics
 - a) True
 - b) False
3. Which of these is generally considered the realm of physics?
 - a) The Periodic Table of Elements
 - b) Gold atoms
 - c) Sound
 - d) Making a new glue
4. Which is not a repeatable area of science?
 - a) Math
 - b) The temperature of the sun
 - c) The speed of light
 - d) The origin of the universe

Answers are on page 91

LIGHT

SEGMENT 2

The Physics of Light “*Light and Color*”

Light was one of the first things God created after making the heavens and the Earth. In some way, light represents an important background for everything that was to follow in the creation week. In modern physics, light forms the timing for everything in the universe. This means dimensions and time modify themselves to ensure light is always at a constant speed, an idea we will explore more closely in the segments on Einstein and in the Physics of the Weird.

I. Some Light Basics

Newton and Roy
It was Isaac Newton who came up with the seventh color, indigo. He said there was:

1. **Red**
2. **Orange**
3. **Yellow**
4. **Green**
5. **Blue**
6. **Indigo**
7. **Violet**

This is where the name Roy G. Biv comes from, as a way to memorize the spectral colors.

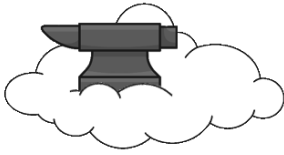
- A. Light is energy. Modern quantum physics says when electrons move down an energy level in the atom, they lose energy, and that energy is what we see as visible light.
- B. Light often acts as though it is a wave, but sometimes acts as though it is a particle.
- C. As a wave, different colors of light are determined by the length of the light wave. Our eyes perceive longer waves of visible light as red, and the shortest waves our eyes perceive as the color violet.
- D. Light waves are very small...50 times smaller than the width of your hair. The only reason you can see objects is because light reflects off of them, into your eye. Light has to physically enter your eye. The light stimulates nerves that send impulses to the back of your brain...and that's actually where you “see” objects.

II. “Why is the Sky Blue?”

Lord Rayleigh
Lord Rayleigh is the man who discovered “blue light scattering” and the effect was named after him: Rayleigh Scattering.

His real name was John Strutt, but Lord Rayleigh sounds more authoritative.

- A. The atmosphere is full of dust particles and tiny molecules of oxygen, nitrogen, and other gases. Gas molecules are smaller than any light wave.
- B. Light waves pass by most these gas particles, except the blue light waves. Because of their smaller size, they tend to interact with and scatter off many of these particles, and that scattering of blue light gives us a blue sky.
- C. The sky is red in evening as there is much more atmosphere for the light to have to travel through when it is at the evening angle. Thus, much more light gets scattered and lost and only the longer reds and oranges get through.



Heavy Clouds

An average cloud all by itself, puffy up in the sky, contains tons of water. If it's a mile long, it has about 500 tons of water in it!

III. "What Makes Rainbows?"

- A. Prisms are transparent or translucent objects with an angle that refracts light. Drops of water act together, as millions of tiny prisms, to fracture white light into the separated colors.
- B. Any time light travels between two different mediums, such as air to water, it slows the speed of light down, slightly bending it. When it bends out of its normal path, it causes the wavelengths to spread out and you can see the individual colors—a rainbow.
- C. Each color reflects at a precise angle. Red, for example, reflects off at 42° in a complete circle in front of you. If the land was not there, you would see the complete rainbow circle; since the land is in the way, it looks like a half-circle, or bow.
- D. Halo: white circle around the moon or sun caused by ice crystals in the sky.
Sundogs: bright spots on the sides of halos.
Glory: a rainbow-like effect that surrounds a person's shadow or an airplane shadow when seen from above
- E. Thin-film interference is white light separating into a rainbow when you look, for example, at oil in water on the ground.
- F. Crepuscular rays are the amazing rays streaming from clouds in the evening.

Pigment is Latin for *paint*.

IV. "What's the Difference between Light and Pigment Color?"

- A. Light has three primary colors: Red, Green, Blue.
Pigment has three primary colors: Magenta, Yellow, and Cyan.
- B. Color Addition. This is for objects that produce their own light (for example, monitors and flashlights). Add the three primary light colors and you get white light.
- C. Color Subtraction. This is for objects that have pigments inside them and the pigments reflect light back into your eye. All three primary colors (white light) will hit a red apple. The pigments in the apple subtract green and blue, but reflect the red.



Traffic Light Reminder
Remember that a traffic light reminds you of one of the subtractive colors. Remove blue (the sky) from red and green (top and bottom lights) and you get yellow (middle light).

The other two colors are magenta and cyan.

- D. The three primary pigment colors are white light minus one primary light color. For example, remove red and you get a color called *cyan*, which is close to blue...but not exactly blue.
- E. Light isn't *absorbed* like a sponge but the light waves resonate with the pigments, causing them to vibrate and turning the visible light into physical heat.



Discussion Questions



- Do you think children's paint sets should have the true primary colors of magenta and cyan in them or should they continue to use red and blue instead?
- If there is a fire nearby, or if there is a lot of pollution in the air, why do you suppose the sun looks particularly red?

Segment 2 Quiz – “Light and Color”

1. On what day did God create light?
 - a) 1st
 - b) 2nd
 - c) 3rd
 - d) 4th
2. Modern physics says light is created by the movement of
 - a) Protons
 - b) Electrons
 - c) Heat
 - d) Dilithium crystals
3. Which is the longest wave?
 - a) Red
 - b) Orange
 - c) Yellow
 - d) Green
 - e) Blue
 - f) Violet
4. *Pigment* literally means
 - a) Paint
 - b) Color
 - c) Light
 - d) Pig
5. The sky is blue because
 - a) It reflects the ocean
 - b) Sunlight is mostly blue
 - c) Blue light gets scattered in the air
 - d) Nobody knows
6. The word for light scattering is called
 - a) Strutt scattering
 - b) Ray light scattering
 - c) Rayleigh scattering
 - d) None of the above
7. Sunsets are mostly red and orange because
 - a) Sunlight is mostly red and orange
 - b) It reflects the colors of the desert
 - c) Long red light waves make it through the thick evening atmosphere
 - d) Our eyes are tired by evening and long red waves are easiest to perceive
8. A rainbow is caused by
 - a) Raindrops acting as little prisms
 - b) Dust particles refracting white light
 - c) Electrons jumping to a higher energy level
9. The three primary pigment colors are
 - a) Red, Yellow, Blue
 - b) Red, Green, Blue
 - c) Magenta, Blue, Red
 - d) Magenta, Yellow, Cyan
10. Color addition is used when objects
 - a) Generate their own light
 - b) Reflect their own light
 - c) We never use color addition
11. What happens to *absorbed* light?
 - a) It just goes away
 - b) It turns to heat
 - c) It remains as light
 - d) It reflects as invisible light
12. White light is the combination of all three primary colors
 - a) True
 - b) False

Answers are on page 91