Problems on Brian Greene's "The Fabric of the Cosmos"

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Introduction

Problems on Brian Greene's "The Fabric of the Cosmos" (PGF) is a supplementary source book for a modern physics course. The book is available in electronic form to instructors by request to the author. It is free courseware and can be freely used and distributed, but not used for commercial purposes.

The problems are grouped by topics in chapters: see Contents below. The chapters correspond to the chapters of Brian Greene's *The Fabric of the Cosmos*. There are only multiple-choice problems. All the problems have will have complete suggested answers eventually. The answers may be the greatest benefit of PGF. The questions and answers can be posted on the web in pdf format.

At the end of the book is an appendix of answer tables for multiple choice questions.

PGF is currently under construction and whether it will grow to adequate size depends on whether I have any chance to teach the modern physics course again.

Everything is written in plain TeX in my own idiosyncratic style. The problems all have codes and keywords for easy selection electronically or by hand. The keywords will be on the problem code line with additional ones on the extra keyword line which may also have a reference for the problem A fortran program for selecting the problems and outputting them in quiz, assignment, and test formats is also available. Note the quiz, etc. creation procedure is a bit clonky, but it works. User instructors could easily construct their own programs for problem selection.

I would like to thank the Department of Physics the University of Idaho for its support for this work. Thanks also to the students who helped flight-test the problems.

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Chapt. 1 Roads to Reality

Multiple-Choice Problems

001 qmult 00070 1 4 5 easy deducto-memory: seven samurai

Extra keywords: not a serious question

1. “Let’s play *Jeopardy*! For $100, the answer is: In Akira Kurosawa’s film *The Seven Samurai* in the misremembering of popular memory, what the samurai leader said when one of the seven asked why they were going to defend this miserable village from a horde of marauding bandits.”

   What is “____________,” Alex?

   a) For honor. b) It is the way of the samurai. c) It is the Tao. d) For a few dollars more. e) For the fun of it.

001 qmult 00080 1 4 3 easy deducto-memory: Arabian Nights

Extra keywords: mathematical physics

2. “Let’s play *Jeopardy*! For $100, the answer is: It is a story very much like a course in physics.”

   What is ____________, Alex?

   a) the *Theogony* by Hesiod (circa 700 BCE)
   b) *The Odyssey* by Homer (circa 700 BCE?)
   c) *A Thousand Nights and a Night* by Anonymous (circa 800–900)
   d) *War and Peace* by Lev Tolstoy (1828–1910)
   e) *Ulysses* by James Joyce (1882–1941)

001 qmult 00090 1 1 3 easy memory: Greene’s fabric

3. Brian Greene probably titled his popular book on modern physics *The Fabric of the Cosmos* mostly maybe because:

   a) he’s a proponent of superstring theory.
   b) he’s **NOT** a proponent of superstring theory.
   c) in imitation of Stephen Toulmin and June Goodfield’s *The Fabric of the Heavens*.
   d) in the modern age every book has to have a farfetched metaphorical title like *The God Particle* or *The Snail’s Ear*: a title like *A Popular Account of Modern Particle Physics and Cosmology* just doesn’t cut it.
   e) of random processes.

001 qmult 00095 1 4 5 easy memory: Brian Greene’s ocean

Extra keywords: Gre-580

4. On the back cover of Brian Greene’s *The Fabric of the Cosmos* (pocket-size paperback), Brian Greene (one supposes) is in front of an ocean. Which ocean and why?

   a) Greene lives in New York state, and so it’s probably the Atlantic Ocean.
   b) It’s not an ocean. One can descry Port Colborne, Ontario on the horizon. He’s in front of Lake Erie on the New York State side. In fact, he’s probably at Angola-on-the-Lake—which is not in Africa whatever you may think.

c) Well . . .

> . . . like stout Cortez when with eagle eyes
> He star'd at the Pacific—and all his men
> Look'd at each other with a wild surmise—
> Silent, upon a peak in Darien.

d) Quoting Newton:

> I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

That's the one.

e) I've no idea.

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001 qmult 06030 1 4 5 easy deducto-memory: superstring theory defn.
Extra keywords: Gre-17–18

5. "Let's play *Jeopardy*! For \$100, the answer is: In this physical theory (circa 2004 at least), the basic element of matter is a string/filament/little-thingy which vibrates in different ways to make the fundamental particles (e.g., electron, neutrino, quark). The theory requires 9 or 10 space dimensions plus 1 time dimension and thus 10 or 11 spacetime dimensions. The higher numbers are for the version called M-theory."

What is ____________, Alex?

a) Aristotelian physics b) Newtonian physics c) Einsteinian relativistic physics
d) quantum mechancis e) superstring theory

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001 qmult 06040 2 3 3 moderate math: Planck units
Extra keywords: Gre-17

6. The Planck units are quantities constructed by dimensional analysis from 5 fundamental constants:

$$\begin{cases} c = 2.99792458\times10^{8}\,\mathrm{m/s} \approx 3\times10^{8}\,\mathrm{m/s} & \text{the vacuum light speed;} \\ G = 6.67428(67)\times10^{-11}\,\mathrm{J\,m/kg^2} \approx 7\times10^{-11}\,\mathrm{J\,m/kg^2} & \text{the gravitational constant which can also be given the units } \mathrm{m^5/(J\,s^4)}; \\ \hbar = 1.054571628(53)\times10^{-34}\,\mathrm{J\,s} \approx 1\times10^{-34}\,\mathrm{J\,s} & \text{which is h-bar or Dirac's constant or Planck's constant divided by } 2\pi; \\ k_{\mathrm{C}} = \dfrac{1}{4\pi\epsilon_0} = 8.987551787\times10^{9}\,\mathrm{J\,m/C^2} \approx 9\times10^{9}\,\mathrm{J\,m/C^2} & \text{the Coulomb force constant where } \epsilon_0 = 8.854187817\times10^{12}\,\mathrm{F/m} \text{ is the vacuum permittivity;} \\ k = 1.3806504(24)\times10^{-23}\,\mathrm{J/K} \approx 1.4\times10^{-23}\,\mathrm{J/K} & \text{which is Boltzmann's constant,} \end{cases}$$

where the values have been taken from Wikipedia (2007oct21). The Planck units (originally proposed by Max Planck) are based only on general universal physics and not arbitrary human choices. They should have some fundamental significance and are often ingredients in advanced theory. Its helpful in constructing Planck units to note that G/c^4 has units of m/J and G/c^5 has units of s/J (which incidentally makes it the inverse of the Planck power).

Brian Greene (Gre-17), in the customary arcane jargon of grand high theorists, refers to a length "some hundred billion billion times smaller than a single atomic nucleus." Atomic nuclei have a size scale of order 10^{-15} m. Evidently, he is referring to the Planck length. Construct the Planck length from the above constants and evaluate it approximately.

a) $\sqrt{\hbar c^5/G} \approx 1.8 \times 10^9\,\mathrm{m}$
b) $\sqrt{\hbar G/c^5} \approx 5 \times 10^{-44}\,\mathrm{m}$
c) $\sqrt{\hbar G/c^3} \approx 1.6 \times 10^{-35}\,\mathrm{m}$
d) $\sqrt{\hbar c/G} \approx 2 \times 10^{-8}\,\mathrm{m}$
e) $\sqrt{c^5/(\hbar G)} \approx 2 \times 10^{43}\,\mathrm{m}$

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001 qmult 08010 1 1 1 easy thinking: coming of age

7. Nowadays takeoffs on cultural detritus of all kinds frequently occur without any acknowledgement. The section title *Coming of Age in Space and Time* of Greene's chapter 1, section 8 is probably a takeoff on:

a) both of (b) and (c) maybe.
b) *Coming of Age in the Milky Way* (1989) by Timothy Ferris (1944–).
c) *Coming of Age in Somoa* (1928) by Margaret Mead (1901–1978).
d) *The Waning of the Middle Ages* (1924) by Johan Huizinga (1872–1945).
e) *Coming of Nonage in Fermullan* by Thomas Caskey, Sr. (1883–1964 or so).

Full-Answer Problems

Chapt. 2 The Universe and the Bucket

Multiple-Choice Problems

002 qmult 03010 1 4 1 easy deducto-memory: Newton bucket
Extra keywords: mathematical physics

1. "Let's play *Jeopardy*! For \$100, the answer is: A thought experiment (which can actually be done) that has been used for arguing for absolute space as a physically active thing."

   What is ____________, Alex?

   a) Newton's bucket experiment
   b) Maxwell's demon experiment
   c) Einstein's elevator experiment
   d) Bohr's microscope experiment
   e) Schrödinger's cat experiment

002 qmult 05030 1 4 1 easy deducto-memory: Ernst Mach glory
Extra keywords: Gre-33

2. Ersnt Mach (1838–1916), a Czech-Austrian physicist, is noted for Mach's principle (first so called by Einstein). This principle, which is really vague hypothesis, is that inertia is determined somehow by the universal distribution of mass. How it does so and what formulae apply have never adequately established. Mach is also famous:

   a) for Mach number. This is the speed of an object relative to a fluid medium in units of the sound speed in that medium.
   b) in ornithology. He is the eponym of the Machingbird.
   c) for work in pyrology. You've heard of machsticks.
   d) the invention of the mach: a kind of cooking pan.
   e) for his forceful character whence "macho", "machismo", and "Sado-Machocism".

002 qmult 06010 1 4 3 easy deducto-memory: Mach principle
Extra keywords: mathematical physics

3. "Let's play *Jeopardy*! For \$100, the answer is: It is the vague hypothesis that the bulk distribution of matter in the universe determines the inertial mass of bodies."

   What is ____________, Alex?

   a) Zeno's paradox
   b) Fermat's last theorem
   c) Mach's principle
   d) Poincaré's conjecture
   e) the Merton thesis

Full-Answer Problems

Chapt. 3 Relativity and the Absolute

Multiple-Choice Problems

003 qmult 10030 1 1 2 easy memory: GR accelerated motion
Extra keywords: Gre-67

1. In general relativity, free-fall with no other forces acting is at least in Gre-67's interpretation (and this interpretation is different from one used in most physics contexts):

   a) accelerated motion. b) unaccelerated motion. c) simple harmonic oscillation. d) anharmonic oscillation. e) static equilibrium.

003 qmult 11010 1 4 3 easy deducto-memory: general relativity 1
Extra keywords: Gre-498

2. "Let's play *Jeopardy*! For $100, the answer is: It is a theory in which mass-energy determines the geometry of spacetime and in which the geometry of spacetime (which is the cause of gravity) plus other forces determine the motion of mass-energy."

   What is ____________, Alex?

   a) quantum mechanics b) special relativity c) general relativity d) Newtonian physics e) Maxwellian electromagnetism

003 qmult 13030 1 1 4 easy memory: dynamic spacetime
Extra keywords: Gre-75

3. Because spacetime responds to mass-energy in general relativity, one can say that in general relativity spacetime is:

   a) static. b) ellipsoidal. c) hyperbolical. d) dynamic. e) flat.

Full-Answer Problems

Chapt. 4 Entangling Space

Multiple-Choice Problems

Full-Answer Problems

Appendix 5 Multiple-Choice Problem Answer Tables

Note: For those who find scantrons frequently inaccurate and prefer to have their own table and marking template, the following are provided. I got the template trick from Neil Huffacker at University of Oklahoma. One just punches out the right answer places on an answer table and overlays it on student answer tables and quickly identifies and marks the wrong answers

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	6.	O	O	O	O	O
2.	O	O	O	O	O	7.	O	O	O	O	O
3.	O	O	O	O	O	8.	O	O	O	O	O
4.	O	O	O	O	O	9.	O	O	O	O	O
5.	O	O	O	O	O	10.	O	O	O	O	O

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	11.	O	O	O	O	O
2.	O	O	O	O	O	12.	O	O	O	O	O
3.	O	O	O	O	O	13.	O	O	O	O	O
4.	O	O	O	O	O	14.	O	O	O	O	O
5.	O	O	O	O	O	15.	O	O	O	O	O
6.	O	O	O	O	O	16.	O	O	O	O	O
7.	O	O	O	O	O	17.	O	O	O	O	O
8.	O	O	O	O	O	18.	O	O	O	O	O
9.	O	O	O	O	O	19.	O	O	O	O	O
10.	O	O	O	O	O	20.	O	O	O	O	O

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	16.	O	O	O	O	O
2.	O	O	O	O	O	17.	O	O	O	O	O
3.	O	O	O	O	O	18.	O	O	O	O	O
4.	O	O	O	O	O	19.	O	O	O	O	O
5.	O	O	O	O	O	20.	O	O	O	O	O
6.	O	O	O	O	O	21.	O	O	O	O	O
7.	O	O	O	O	O	22.	O	O	O	O	O
8.	O	O	O	O	O	23.	O	O	O	O	O
9.	O	O	O	O	O	24.	O	O	O	O	O
10.	O	O	O	O	O	25.	O	O	O	O	O
11.	O	O	O	O	O	26.	O	O	O	O	O
12.	O	O	O	O	O	27.	O	O	O	O	O
13.	O	O	O	O	O	28.	O	O	O	O	O
14.	O	O	O	O	O	29.	O	O	O	O	O
15.	O	O	O	O	O	30.	O	O	O	O	O

NAME:

Answer Table for the Multiple-Choice Questions

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	26.	O	O	O	O	O
2.	O	O	O	O	O	27.	O	O	O	O	O
3.	O	O	O	O	O	28.	O	O	O	O	O
4.	O	O	O	O	O	29.	O	O	O	O	O
5.	O	O	O	O	O	30.	O	O	O	O	O
6.	O	O	O	O	O	31.	O	O	O	O	O
7.	O	O	O	O	O	32.	O	O	O	O	O
8.	O	O	O	O	O	33.	O	O	O	O	O
9.	O	O	O	O	O	34.	O	O	O	O	O
10.	O	O	O	O	O	35.	O	O	O	O	O
11.	O	O	O	O	O	36.	O	O	O	O	O
12.	O	O	O	O	O	37.	O	O	O	O	O
13.	O	O	O	O	O	38.	O	O	O	O	O
14.	O	O	O	O	O	39.	O	O	O	O	O
15.	O	O	O	O	O	40.	O	O	O	O	O
16.	O	O	O	O	O	41.	O	O	O	O	O
17.	O	O	O	O	O	42.	O	O	O	O	O
18.	O	O	O	O	O	43.	O	O	O	O	O
19.	O	O	O	O	O	44.	O	O	O	O	O
20.	O	O	O	O	O	45.	O	O	O	O	O
21.	O	O	O	O	O	46.	O	O	O	O	O
22.	O	O	O	O	O	47.	O	O	O	O	O
23.	O	O	O	O	O	48.	O	O	O	O	O
24.	O	O	O	O	O	49.	O	O	O	O	O
25.	O	O	O	O	O	50.	O	O	O	O	O

Answer Table

Name:

	a	b	c	d	e
1.	O	O	O	O	O
2.	O	O	O	O	O
3.	O	O	O	O	O
4.	O	O	O	O	O
5.	O	O	O	O	O
6.	O	O	O	O	O
7.	O	O	O	O	O
8.	O	O	O	O	O
9.	O	O	O	O	O
10.	O	O	O	O	O
11.	O	O	O	O	O
12.	O	O	O	O	O
13.	O	O	O	O	O
14.	O	O	O	O	O
15.	O	O	O	O	O
16.	O	O	O	O	O
17.	O	O	O	O	O
18.	O	O	O	O	O
19.	O	O	O	O	O
20.	O	O	O	O	O
21.	O	O	O	O	O
22.	O	O	O	O	O
23.	O	O	O	O	O
24.	O	O	O	O	O
25.	O	O	O	O	O
26.	O	O	O	O	O
27.	O	O	O	O	O
28.	O	O	O	O	O
29.	O	O	O	O	O
30.	O	O	O	O	O

	a	b	c	d	e
31.	O	O	O	O	O
32.	O	O	O	O	O
33.	O	O	O	O	O
34.	O	O	O	O	O
35.	O	O	O	O	O
36.	O	O	O	O	O
37.	O	O	O	O	O
38.	O	O	O	O	O
39.	O	O	O	O	O
40.	O	O	O	O	O
41.	O	O	O	O	O
42.	O	O	O	O	O
43.	O	O	O	O	O
44.	O	O	O	O	O
45.	O	O	O	O	O
46.	O	O	O	O	O
47.	O	O	O	O	O
48.	O	O	O	O	O
49.	O	O	O	O	O
50.	O	O	O	O	O
51.	O	O	O	O	O
52.	O	O	O	O	O
53.	O	O	O	O	O
54.	O	O	O	O	O
55.	O	O	O	O	O
56.	O	O	O	O	O
57.	O	O	O	O	O
58.	O	O	O	O	O
59.	O	O	O	O	O
60.	O	O	O	O	O