Conceptual Physics **NAME:**

Homework 0: What is this Thing Science?: Homeworks are due usually a day after the corresponding textbook part/lecture is completed. Due dates will be announced in class. Multiple-choice problems will all be marked. **USE** the answer table for these problems. The rest of the homeworks will be marked for apparent completeness and some full-answer problems will/may be marked in detail. Make the full-answer solutions sufficiently detailed that the grader can follow your reasoning. Solutions will be posted eventually after the due dates. The solutions are intended to be (but not necessarily are) super-perfect and often go beyond full answers. For an argument or discussion problem, there really is no single right answer. The instructor's answer reflects his long experience in physics, but there could be objections to his arguments, assumptions, nuances, style, facts, etc.

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

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001 qmult 00300 1 4 5 easy deducto-memory: Eratosthenes circumference

1. "Let's play *Jeopardy*! For $100, the answer is: He was the first person to measure the circumference of the Earth."

   Who is ____________, Alex?

   a) Parmenides (early 5th century BCE) b) Democritus (ca. 460–ca. 370 BCE)
   c) Aristotle (384–322 BCE) d) Aristarchus of Samos (c. 310–c. 230 BCE)
   e) Eratosthenes (c. 276–c. 195 BCE)

   SUGGESTED ANSWER: (e)

   Wrong answers:
   a) Perhaps, the inventor of the round Earth theory. On the other hand, it could have been Pythagoras or one of his followers.
   b) A flat-Earther. The Earth was a residue at the bottom of the cosmos membrane.

   Redaction: Jeffery, 2012jan01

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001 qmult 00410 1 4 1 easy deducto-memory: heliocentrism deduction

2. "Let's play *Jeopardy*! For $100, the answer is: The theory that allowed the relative positions of the planets to be deduced."

   What is the ____________ solar system theory, Alex?

   a) heliocentric b) geocentric c) marsocentric d) lunacentric e) plutocentric

   SUGGESTED ANSWER: (a)

   Wrong answers:
   c) Oh, c'mon.

   Redaction: Jeffery, 2012jan01

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001 qfull 00100 1 3 0 easy math: science defined

3. Define science in one sentence. Now define science in a paragraph of a few sentences. Use your own words in both cases.

   SUGGESTED ANSWER:

   There are no unique right answers. One just does the best one can.

   The one-sentence old-college try is as follows.

   Science is the study of objective reality in which knowledge of reality ideally consists of theories which are tested by detailed observation or experiment.

   The one-paragraph try is as follows.

   Science is the study of objective reality in which knowledge of reality ideally consists of theories which are tested by detailed observation or experiment. The theories consist of axioms from which all behavior in the realm of the theory can be derived usually introducing micro-axioms along the way. Theories are usually not perfect. They are not as general or as exact as one would like. The theories are tested and improved by a cycle of theorizing and experimentation and/or detailed observation. This cycle is called the scientific method. Science can be progressive since reality itself is a gold standard that continually be used to check the adequacy of theories by experimentation and/or detailed observation.

   Redaction: Jeffery, 2008jan01

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001 qfull 00120 1 3 0 easy math: is the scientific method scientific?

4. Is the scientific method a scientific theory? Discuss.

   SUGGESTED ANSWER:

   The scientific method is a prescription for doing science: i.e., improving theory and observation/experimentation by making them more exact and general. It can be vaguely described as a cycle of improving theory and observation. One oscillates between theorization and observation with each guiding and correcting the other. “One” may be an individual or a group or a community or all of humanity throughout history.

Is the scientific method a scientific theory? Well it does not match a one ideal of a scientific theory. It is not expressible a mathematical formula. One can write down axioms for it, but there is no unique set of axioms. Every writer can come up with different set. The sets almost certainly differ in details, emphasis, nuance, and some philosophical basis. Also one can specify axioms that are often left implicit. For example, the scientific method relies on human nature and the human context in the universe (the human condition). For another example, objective reality has to be such as to allow its exactly and approximately true theories to be discovered.

But most sets of axioms for the scientific method are in vague agreement, and so most people would agree that there is well defined scientific method—though not perfectly well defined. The vague set of axioms is not a complete prescription of course for doing science. A multipicitly of other rules, rules of thumb, and procedures must be invoked in doing science. Scientists seldom try to specify these all exactly—and fail if they did. But this is not unusual for a scientific theory. Most scientific theories outside of pure math need a host of micro-axioms to supplement the basic set. For example, special relativity is often said to be derived frome two axioms: the vacuum speed of light axiom and the relativity axiom. But if you actually start deriving the theory, you find all kinds of reasonable assumptions (which I call micro-axioms) have to be introduced along the way. For human comprehension of special relativity, the introduction of micro-axioms along the way is far better than trying to invent a myriad of axioms right at the start. Humans can swim in an ocean of concepts without holding them all in mind at any one instant.

So the scientific method is certainly not an ideal scientific theory. But neither are most scientific theories.

Is the scientific method a theory about objective reality and is it falsifiable. Well it is about objective reality since we say that it improves scientific knowledge which part of objective reality.

What about falsifiability? Well the scientific method is supposed to improve science: make it more general and exact. Historically, the scientific method certainly has done that. Of course, this is an overall or average conclusion, not one applying to every limited spacetime region of scientific activity. So one can argue that the scientific method predicts improvement on average over the course of human activity. If this prediction fails (which it never has), then the scientific method would be falsified. The fact that it has never failed gives us reasonable, but not perfect, confidence that it is true theory like, for example, Newtonian physics viewed as an emergent theory. I admit that saying it has never failed on average actually requires a detailed argument, but I’m pretty confident that the conclusion of no failure would be reached.

To conclude, I think that the scientific method is a scientific theory and a true one. Others might disagree or give different and probably better arguemtns for agreeing.

A whole other realm of argument can be based on whether the scientific method can be automated. Well in certain limited contexts in can using genetic programming. In genetic programming, there are precise, if lengthy, rules for automating the scientific method. The automated scientific method has indeed led to discoveries and rediscoveries. There have been lots of failures too, but it seems likely that those are due to inadequate implementations of the automation. It is conceivable that the scientific method may one day be proven by exhaustive experimentation by artificial intelligence.

Redaction: Jeffery, 2012jan01

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001 qfull 00220 1 3 0 easy math: SI base units

5. Briefly discuss the need for units and how units are set.

SUGGESTED ANSWER:

All measurement of quantities requires a standard amount of the quantity to be the unit of that quantity. The quantity is then measured to be so many units. For example in SI (which is the conventional unit system for science and almost all countries), the unit of length is the meter.

Since we want measurements to be as exactly comparable as possible over all of spacetime, it is, among other things, required that units be defined to be as exact and invariant is possible. How is this to be done?

Historically, base units (those which need to be set independently) of other units were based on natural properties or artifacts that are variable. For example, astronomical time periods (especially the day, lunar month, and year) were all used as units of time. But eventually it became clear that these periods vary. They vary relative to each other both periodically and secularly. Also Newtonian physics showed that they should in theory vary, and therefore are not in principle ideal definitions of time units.

Length and mass/weight units were in much poorer shape in pre-modern times. Nature has given us no obviously invariant natural objects of human size scale to use for length or mass/weight units. The human body, however, is approximately invariant and is everywhere people are, and so could and did provide unit definitions. For example, foot can be used for many purposes length measurement. But foot length obviously varies from person to person and there is no theoretical guarantee that the average foot length is invariant over all spacetime. A standard foot length can defined by an artifact: e.g., a bar. But bars change length with temperature and can slowly gain or lose material no matter how carefully they are kept. Also in reproduction there must always be some variation.

Artifacts for both length and mass/weight were certainly adequate for pre-modern civilizations for long periods of time. But variations in reproduction and the fall of the authorities that supported the artifact usage certainly resulted in variations in units over history.

In the modern age, the program is to define base units by natural properties that are known theoretically to be invariant. The theories guaranteeing invariance (essentially quantum mechanics and relativistic physics) are extremely well verified—much of modern technology would simply not work if those theories were not very nearly exactly true and there is no reason to believe they must be inexact. The units defined by invariant natural properties are the ideal. Currently, of all the base units needed for the physical sciences only the mass unit is not yet based on an invariant natural property, but it probably will be soon. At present, the mass unit is defined to be the mass of the prototype kilogram kept—well in Paris—it's a nice place.

Seven base units are needed: the most obvious ones are for time, length, and mass. All other units in the physical sciences can be derived from these units and are called derived units. The quantities needing derived units are related to the quantities having base units by theoretically exact physical formulas and those formulas give the derived units. For example, $\vec{F}_{\rm net} = m\vec{a}$ is Newton's 2nd law for one dimensional motion. It relates net force $\vec{F}_{\rm net}$ on a object to its mass m and acceleration $\vec{a}$. The unit of mass is the kilogram and of acceleration is the meter per second squared. So the precisely defined derived unit of force is the kilogram meter per second squared which has the special name newton.

Of course, most measurements to not make direct use of the exactly defined procedures for the base and derived units. They use measuring devices calibrated from those procedures usually at some great remove.

Redaction: Jeffery, 2012jan01

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001 qfull 00520 1 3 0 easy math: pinhole projection of the Sun

6. Use pinhole projection to observe the Sun. You will need the Sun in a clear sky region. About how big an image can create? Can you see sunspots? Incidentally, can you see narrow dark and bright fringes just near the edges of shadows (e.g., of a pencil)? You need to look really closely. A magnifying glass might help.

SUGGESTED ANSWER:

OK, I did this on 2011aug23. The sky was mostly overcast, but a for few seconds I could see the Sun's pinhole image. I could only make the image only two or three millimeters in size. Pulling the pinhole screen back farther from the image screen made the image too faint to see.

There was no chance of seeing sunspots. In any case, the web suggests that seeing sunspots with simple pinhole projection is only marginally possible.

No, I didn't see any fringes. The Sun was not bright enough. It is claimed that you see diffraction fringes if the Sun is really bright. These fringes are not predicted by geometrical optics. They are a wave phenomenon.

Redaction: Jeffery, 2012jan01