Exam 1 (October 14, 2009)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work where requested in order to be considered for partial credit. In problems where you are requested to show your work, no credit will be given unless your work is shown.

Problem 1 (5 pts, no need to show work):

A satellite orbits the earth at a constant speed of 18,000 miles per hour. This satellite

a) is accelerating
b) has a changing velocity.
c) experiences both (a) and (b).
d) experiences none of the above.

Problem 2 (5 pts, no need to show work):

Jack rides a bicycle northward at 12 miles per hour. Jill rides southward on the same road at 12 miles per hour. As Jack and Jill pass each other

a) their speeds are identical and their velocities are identical.
b) their speeds are different and their velocities are different.
c) their speeds are different but their velocities are identical.
d) their speeds are identical but their velocities are different.
e) none of the above.
f) theoretical physics predicts, surprisingly enough, that they will turn into giant frogs.

Problem 3 (5 pts, no need to show work):

A scientific theory could best be described as

a) as idea that has been proven by observations of the natural world.
b) an observed fact or collection of facts about the natural world.
c) any mental picture, or idea, about the way that the natural world operates.
d) an idea that explains a large collection of observations of the natural world.
e) A tentative guess about the way the natural world operates.

Problem 4 (5 pts, no need to show work):

You push your 2 kg physics book along a tabletop, pushing it with 10 newtons of force. If the book is greased so that friction is negligible, the book's acceleration is

a) 0.2 m/s^2.
b) 5 m/s^2.
c) 20 m/s^2.
d) too large to measure.
e) zero.

$$F = Ma$$

$$10 N = (2 kg)a$$

$$a = 5 M/s^2$$

Problem 5 (5 pts, no need to show work):

$c = v\lambda$

The frequency of a television signal (electromagnetic wave) is 150 x 10^6 hertz (or s⁻¹). The wavelength of this electromagnetic wave is

5 —
   a) 1.0 meters.
   b) 1.5 meters.
   c) 2.0 meters.
   d) 0.02 meters.
2 —
   e) 0.5 meters.

$$3 \times 10^8 = (150 \times 10^6)\lambda$$

$$\lambda = \frac{3 \times 10^8 \, M/s}{150 \times 10^6 \, 1/s} =$$

Problem 6 (5 pts, no need to show work):

For light waves, different frequencies mean different

   a) brightness.
   b) colors.
   c) amplitudes.
2 —
   d) speeds.
   e) none of the above

Wow!

Problem 7 (10 pts, no need to show work):

Biff and Buffy pass each other in rocket ships at a relative velocity of half of lightspeed. Buffy has an ice cream cone that melts in five minutes if not refrigerated. She removes her cone from the refrigerator and allows it to melt. According to Biff, how long does it take for Buffy's cone to melt?

   a) More than five minutes.
   b) Less than five minutes.
   c) Five minutes.
   d) It could be more or less than five minutes depending on whether it is Buffy or Biff who is at rest.
   e) It is impossible to know because insufficient information is given in the problem.

10   4

According to Buffy, how long does it take for her cone to melt?

   a) More than five minutes.
   b) Less than five minutes.
   c) Five minutes.
   d) It could be more or less than five minutes depending on whether it is Buffy or Biff who is at rest.
   e) It is impossible to know because insufficient information is given in the problem.
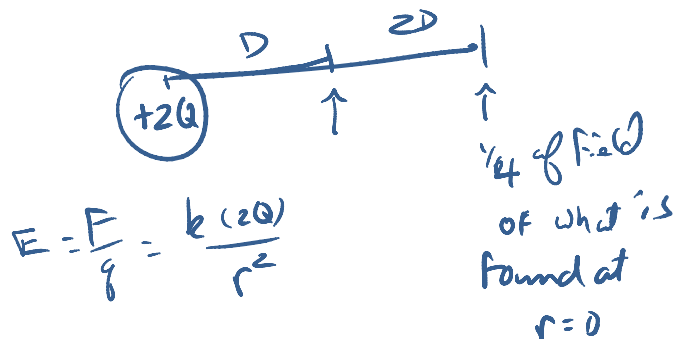
Problem 8 (5 pts, no need to show work):

A charge of +2Q sits out in space. How does the strength of the electric field a distance D away from the charge compare to the electric field a distance 2D away from the charge (along the same radial line)?

   a) The field at D is the same as the field at 2D.
   b) The field at D is ½ the size of the field at 2D.
2 —   c) The field at D is twice the size of the field at 2D.
   d) The field at D is ¼ the size of the field at 2D.
5 —   e) The field at D is four times the field at 2D.

D   2D

+2Q

$$E = \frac{F}{q} = \frac{k(2Q)}{r^2}$$

¼ of field
of what is
found at
r = 0

Problem 9 (11 pts, no need to show work):

A positive 'test' charge is placed at the point p in each of seven different situations below as shown in the seven boxes labeled A-G below. Other positive and negative charges are arranged in each box as shown.

In which situation (or situations) does the test charge at point p feel the least force due to the other charges in the box? **A, G   Force is zero at P** (in both cases forces from two charges cancel)

In which situation (or situations) does the test charge at point p feel the largest force due to the other charges in the box?

E, F   Force is greatest
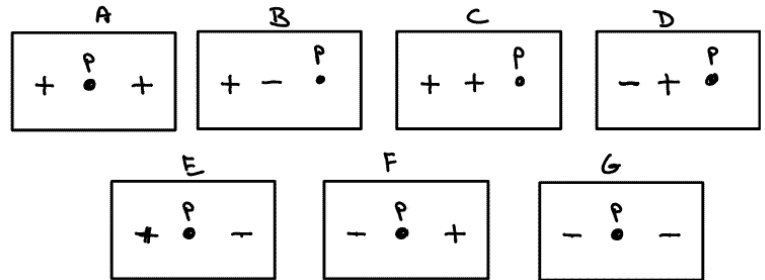
+ •p ⟶ −   both charges close by forces add

A
+ •p +

B
+ − •p

C
+ + •p

D
− + •p

E
+ •p −

F
− •p +

G
− •p −

Problem 10 (11 pts, show work):

Suppose earth collapsed down to one-tenth of its present radius while retaining all of its present mass. How would your weight before the collapse compare to your weight after the collapse (assuming you survived the trauma of the geological catastrophe)?

$$\text{Weight} = mg$$

$$g \sim \frac{M_E \, G}{R_E^2}$$

if R_E is reduced by a factor of 10 "g" increases by a factor of 100 So your weight would increase by a factor of 100.

Problem 11 (11 pts, ~~no need to~~ show work):

Suppose that over Thanksgiving break upon hearing that you are taking a course called Visions of the Multiverse you grandma says to you, "You know, Munchkin, I always wanted to know what people mean when they talk about the computational multiverse, which is sometimes called the simulated multiverse. Can you tell me about that?" Briefly write below what you would tell your grandma.

Grandma, the size of the universe is vast. In addition our universe may be only one of innumerable other universes in a multiverse reality. Given this, it is very reasonable to believe intelligent life has evolved elsewhere in the great multiverse a great many times and places. One could imagine that in some of those instances life has arisen that reached a level of technological advancement greater than our own. It is reasonable to imagine that they may have learned to simulate different possible universes — perhaps even simulating conscious beings simulating different universes. This creates something of a slippery slope since once this state is achieved the "fake" universes will proliferate and greatly outnumber the real universes. Wierd, huh, Grandma?

Problem 12 (11 pts, ~~no need to show work~~):

Is the concept of an afterlife a scientific concept? Briefly defend your answer.

To date there is no scientific observation that supports any concept of the afterlife. Belief in the afterlife is a matter of faith, not science.

Problem 11 (13 pts, ~~no need to show work~~):

Powerful rockets that send payloads into orbit are typically designed in multiple "stages". That is to say the rocket is generally two or three distinct rockets in a stack. When the rocket is launched initially, the lowest stage – or rocket – is ignited. When the lowest stage runs out of fuel, it is disconnected from the rising rocket and falls to earth while the second stage – second to lowest in the stack of rockets – ignites and pushes the rocket. If there is a third stage to the rocket, the process continues. Briefly explain the advantage this multiple stage rocket design has over the design of a single large rocket (single stage design).

By dropping the shell of each successive stage when it runs out of fuel the mass of the rocket is reduced. With the reduced mass the force applied by the next rocket accelerates the rocket more than it would with the larger mass.

$$F = ma$$

↑ force applied by rocket   ↑ mass of rocket

If the rocket is designed as a single stage the entire mass of the rocket must be lifted and accelerated during the entire trip. The reduction of mass during flight that is enabled by the staged design increases the acceleration for a given rocket force at the later stages of the flight ... This allows the rocket to have a longer range / larger payload than it would otherwise.

Some potentially useful formulas

$F = \dfrac{G m_1 m_2}{r^2}$ $\left(\begin{array}{c} m_1 \text{ and } m_2 \text{ in kg} \\ r \text{ in meters} \end{array} \right) \rightarrow G = 6.7 \times 10^{-11}$

$F = \dfrac{k q_1 q_2}{r^2}$ $\left(\begin{array}{c} q_1, q_2 \text{ in Coulombs} \\ r \text{ in meters} \end{array} \right) \rightarrow k = 9 \times 10^{9}$

in both cases force comes out in Newtons

$F = ma$

$(\text{distance}) = (\text{Speed})(\text{time})$

$v = \dfrac{\Delta x}{\Delta t}$

$a = \dfrac{\Delta v}{\Delta t}$

Work = force × distance

Momentum = $p = mv$

$\Delta x' = \gamma \Delta x$, Δx longest in Proper frame

$\Delta t' = \gamma \Delta t$, Δt shortest in proper frame

$\gamma = \dfrac{1}{\sqrt{1 - \left(\frac{v}{c} \right)^2}}$

$1 \text{ Joule} = 1.6 \times 10^{-19} \text{ eV}$

Speed of Sound $= 330 \text{ M/s}$

$c = 3 \times 10^{8} \text{ M/s}$

$v = \lambda \nu$

$\nu = \dfrac{1}{T}$ $(T = \text{period})$

gravitational force at Earth's surface

$F = mg$ where

$g = \dfrac{G M_E}{R_E^2} = 9.8 \text{ M/s}^2$