P100 University of Rochester NAME Soln key - SLM
S. Manly Spring 2007

Exam 1 (February 21, 2007)

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 (6 pts, no need to show work):

Quotes that might have been … next to each of the fictitious quotes, put the letter of the person we have studied who would most likely have said it based on your knowledge of what that person is known to have done.

Example

___A__ "Steroids? Isn't that when you have *two* hemorrhoids?"

__N__ "Electricity and magnetism are not separate beasts. They are different faces on one thing, the electromagnetic force."

__B__ "Just tell your teacher that time is relative and that you aren't really late for class."

__D__ "It seems that no matter how stable the table on which I place my microscope, the dust in the drop I am examining wiggles."

__G__ "When you push on a wall, the wall pushes back on you."

__E__ "Cool! Check this out. If I double the distance between these charged spheres, the force between them drops by a factor of four."

__I__ "If you rip apart this toga into smaller and smaller bits, eventually you will encounter the smallest, indestructible part which I call an atom."

A.	**Barry Bonds**
B.	**Albert Einstein**
C.	**Mao Tse-Tung**
D.	**Robert Brown**
E.	**Charles Coulomb**
F.	**Frederick Douglass**
G.	**Isaac Newton**
H.	**James Joule**
I.	**Democritis**
J.	**Plato**
K.	**Madonna**
L.	**Caligula**
M.	**Johannes Kepler**
N.	**James Maxwell**

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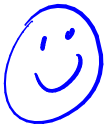
Scores
1. 6/6
2. 6/6
3. 8/8
4. 6/6
5. 6/6
6. 6/6
7. 9/9
8. 6/6
9. 11/11
10. 6/6
11. 6/6
12. 8/8
13. 8/8
14. 8/8

Total 100/100

Great job!



Problem 2 (6 pts, no need to show work):

If work is done on a body, that body must

W = force · Dist

a. accelerate. ← half credit Answer
b. be in equilibrium.
c. not exert a force on any other object.
d. have no friction force exerted on it.
e. [✓ move.] ← full credit Answer

Problem 3 (8 pts, show your work):

A particle accelerates uniformly from a speed of 30 m/s to 40 m/s in a period of 5 seconds and thereafter moves at a constant speed of 40 m/s for an additional 3 seconds. What is the average speed of the particle over this 8 second period?

Ave speed in 1st 5 seconds is 35 m/s

dist. Travelled will be (5)(35) = 175 m

In last 3 seconds, dist Travelled is (40 m/s)(3 s) = 120 m

Total distance Travelled = Dist in 1st 8 sec + Dist in last 3 sec

= 175 + 120 = 295 m

Ave speed in 8 sec

$= \frac{295\ m}{8\ s} = 37\ m/s$

Problem 4 (6 pts, no need to show work):

You hold a scale in your hand over the edge of a building. A rock sits at rest on the scale. The scale reads 10 pounds. Now you drop the scale/rock. Looking over the edge of the building you see the scale read ______ as it falls. … (neglect air resistance)

a. 10 pounds
b. [✓ 0 pounds]
c. 10*g pounds
d. Approximately 13 pounds
e. Approximately 7 pounds

Both in free fall – Normal force of scale on rock and rock on scale are zero.

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

Two point charges of unknown magnitude and sign are a distance d apart. If the electric field strength is zero at a point between them on the line joining them, you can conclude that

a. the charges are equal in magnitude but opposite in sign.
b. the charges are equal in magnitude and have the same sign. ← half credit Answer
c. the charges are not necessarily equal in magnitude but have opposite sign.
d. [✓ the charges are not necessarily equal in magnitude but have the same sign.] ← Full credit Answer
e. there is not enough information to say anything specific about the charges.

Field strength → 0 means no force on test particle

pull
must push in opposite directions

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

half credit

An electron moves horizontally due north and enters a region of an electric field that is pointed due east. The force on the electron due to the electric field is in what direction?

→ a. east
→ [✓ b. west]
c. north
d. Upward because it must counteract the force due to gravity.
e. There is no force on the electron due to the electric field.

full credit

⊕ Particles experience a force in the direction of the electric field

⊖ particles (such as electrons) experience a force in the opposite direction.

Problem 7 (9 pts, show work):

Estimate how many times the human heart beats during one lifetime. State your assumptions and logic clearly. Assign a rough error to your estimate. Motivate your reasoning for the error you assign to your estimate.

Assume heart beats 1 time per second

Assume lifetime is 70 years = $70\,yr \times 365 \frac{days}{yr} \times 24 \frac{hr}{day} \times 3600 \frac{s}{hr} = 2.2\times10^9\,s$

So heart beats 2.2 billion times in one lifetime

heartbeat time probably good to 20%

Assume high heartrate times offset by low heartrate times

lifetime probably good to 15 years out of 70 or ~20 %

So my estimate is probably good to ~20 to 40% depending on how you combine the errors in heartrate and lifetime assumptions. Lets go with 30%

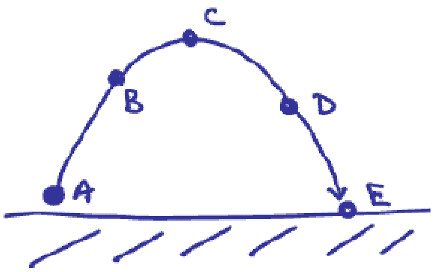
heartbeats = 2.2 ± .6 billion heartbeats

Problem 8 (6 pts, no need to show work):

A ball is thrown up in the air as shown in the sketch. Which of the following statements best describes the motion of the ball?

a. **The velocity of the ball is the same at points A, B, C, D and E.**
b. **The acceleration of the ball is 9.8 m/s^2 at points A, B, D and E and zero at point C.**
c. **The acceleration of the ball is -9.8 m/s^2 at points A, B, D and E and zero at point C.**
d. **The velocity of the ball is constant at all points.**
e. [✓ **The velocity of the ball changes continuously during its flight.**]

a is CONSTANT
↳ v is always changing



Problem 9 (11 pts):

A football running back accelerates from rest to a full run during a game. Briefly describe this process in terms of Newton's three laws of motion.

As per Newton's 1st law,
The running back starts at rest and will remain at rest unless acted on by a force. As the running back pushes on the ground horizontally the ground pushes on him according to Newton's 3rd law. Because of the unbalanced force of the ground pushing on him, the running back accelerates according to Newton's 2ND law F=ma.

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Problem 10 (6 pts, no need to show work):

If you apply the same force to objects with masses M and 4M, the acceleration of the mass M is

- **a. the same as for the mass 4M.**
- **b. [✓ four times the acceleration of the mass 4M.]**
- **c. one-fourth the acceleration of the mass 4M.**
- **d. twice the acceleration of the mass 4M.**
- **e. one-half the acceleration of the mass 4M.**

Problem 11 (6 pts, show your work and/or defend your answer):

Two stars are a distance d apart out in space. One star has a mass M. The other star has a mass 4M. How does the gravitational attraction of the small star for the big star compare to the attraction of the big star for the small star?

The attraction of M for 4M is the same as that of 4M for M due to the forces being an action-reaction pair.

Problem 12 (8 pts, show your work):

A pion (an unstable subatomic particle) lives on average 2.6x10^{-8}s (measured in its own frame of reference) before decaying.

a) If such a particle is moving with respect to the laboratory with a speed of 0.978c, what (average) lifetime is measured in the laboratory?

$\tau' = \gamma \tau$

$\gamma = \frac{1}{\sqrt{1-(.978)^2}} = 4.8$

Time dilation
time shortest in properframe

$\tau' = \tau_{lab} = \gamma \tau_{particle}$

$\tau_{lab} = (4.8)2.6\times10^{-8}s$

Properframe is particle's frame

$\tau_{lab} = 1.2\times10^{-7}s$

b) How far will the pion travel (on average) in the laboratory?

distance travelled $= (\tau_{lab})(0.978c)$

$= (1.2\times10^{-7}s)(.978)(3\times10^{8}\,m/s) = 35$ meters

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Problem 13 (8 pts, show your work):

Alfred the Klingon zips past you in a spaceship. He holds a meter stick so that it is oriented parallel to the direction of his motion. You measure the stick to be 0.9 m in length. How fast is Alfred's ship moving relative to you?

$1\,m = (0.9\,m)\gamma$

$\gamma = 1.1$

length cont.

length longest in proper frame

$$1.1 = \frac{1}{\sqrt{1-(\frac{v}{c})^2}}$$

$v \cong 0.41c$

Problem 14 (8 pts):

Briefly explain why you think Newtonian mechanics preceded the development of relativistic mechanics (relativity) by many years?

I had 3 thoughts - Not all necessary for full credit though

All of our everyday experiences can be explained using Newtonian mechanics. It seems likely that it arose first out of necessity. Relativistic mechanics simplifies to Newtonian Mechanics in the limit of small speeds (compared to that of light) which is what we typically experience.

Also, relativity requires the infrastructure of basic mechanics as a framework. It would be natural to develop ideas about forces and Motion in the Newtonian worldview before encountering the subtleties leading to relativity.

Some might argue that the puzzling results of the Michelson-Morley experiment (constancy of speed of light) were needed for acceptance of relativity.

Some potentially useful formulas

$$F = \frac{G m_1 m_2}{r^2}$$

$$F = \frac{k q_1 q_2}{r^2}$$

$F = ma$

(distance) = (speed)(time)

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

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

work = force x distance

Momentum = $p = mv$

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

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

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