

Name: \_\_\_\_\_



**Cornell University**  
Prison Education Program

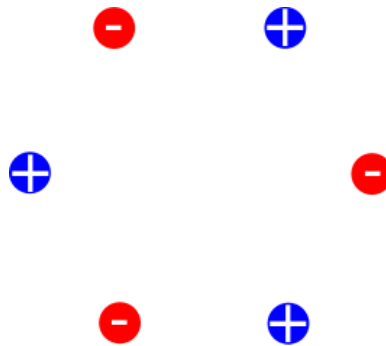
Conceptual Physics  
Second Partial Test  
**INDIVIDUAL**  
May 18, 2018

You are free to use all notes on your two-sided cheat sheet. There are extra blank sheets at the end, which can be used for calculations, and if you require more please ask and be sure to include them when you hand back the test. Please be sure to include all your work and calculations.

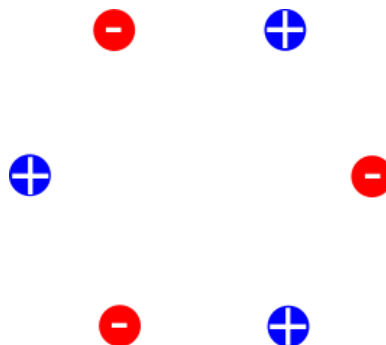
There are 6 problems for a total of 32 points. (One of the questions is a bonus though.)

1. **Drawing Field Lines:** Six particles are arranged on a hexagon. They all have identical masses. Some are positively charged, and some are negatively charged. They all have charge of  $\pm 1$  (so the size of all charges are the same).

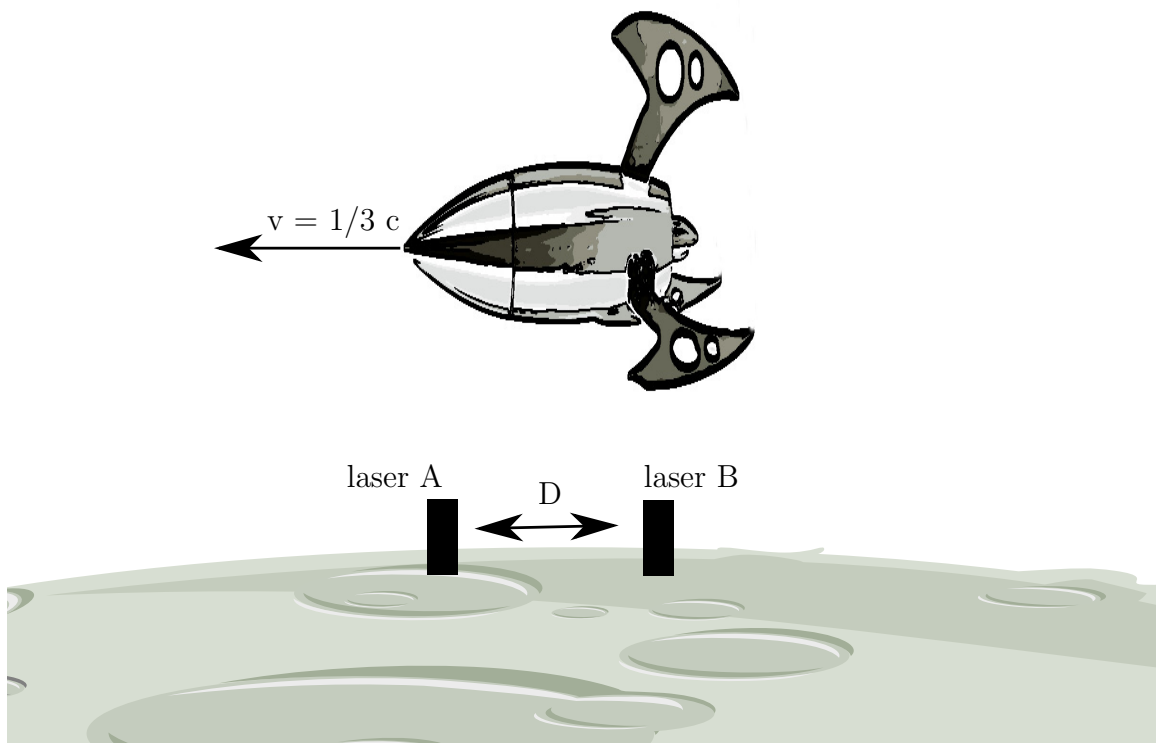
(a) (2 points) Draw the **electric field** lines around the particles. If there is a point with **zero** electric field, indicated it on the diagram.



(b) (2 points) Draw the **gravitational field** lines around the particles. If there is a point with **zero** gravitational field, indicated it on the diagram.



2. **Alien Planet:** On a distant planet, aliens have set up a monitoring post with two lasers that are distance  $D$  apart. They see a spaceship traveling at  $1/3$  the speed of light, passing over their lasers and decide to fire at the ship, creating scorch marks on the ship's hull. **The image below shows this setup from the perspective of an alien on the planet.**

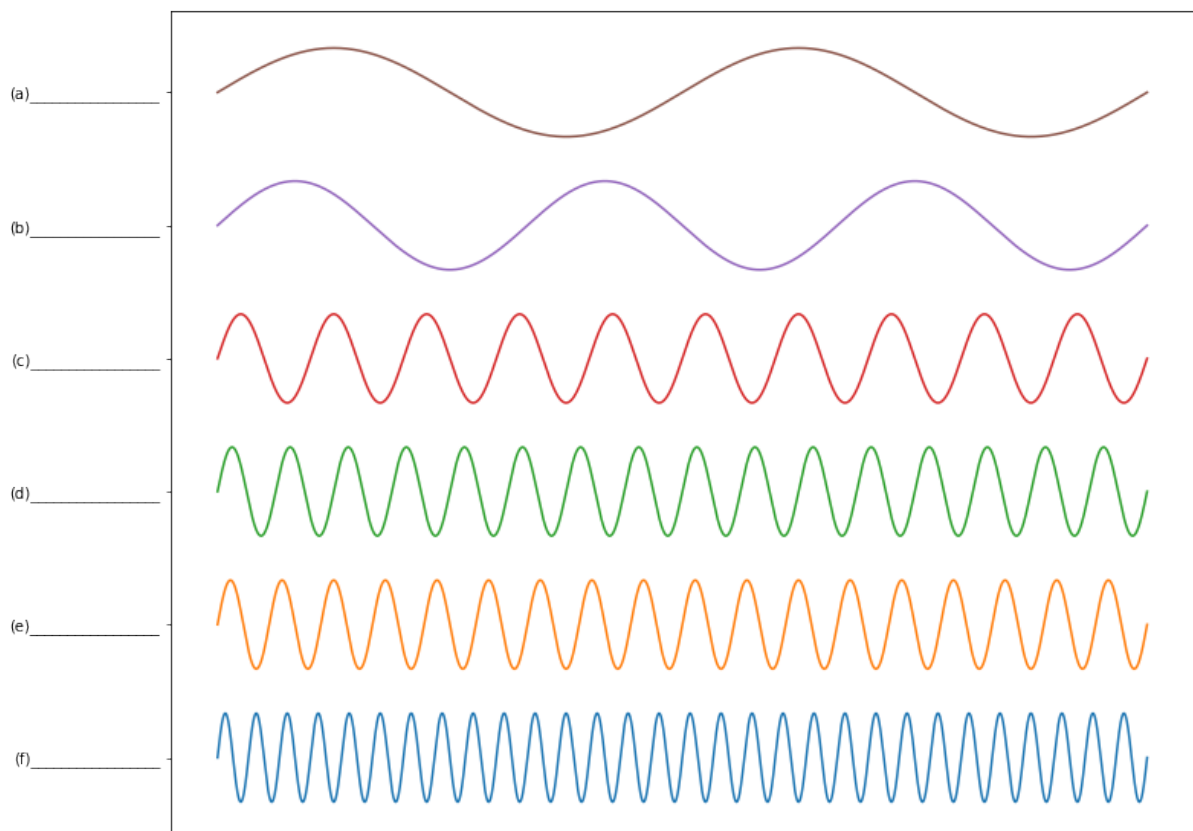


- (a) (2 points) The aliens on the planet fire the lasers at the same time. How far apart would they say the scorch marks on the ship are?
- A. Exactly a distance  $D$  apart.
  - B. A distance greater than  $D$  apart.
  - C. A distance less than  $D$  apart.
- (b) (2 points) From the perspective of an alien *on the ship*, how far apart are the scorch marks on the ship?
- A. Exactly a distance  $D$  apart.
  - B. A distance greater than  $D$  apart.
  - C. A distance less than  $D$  apart.
- (c) (2 points) From the perspective of an alien *on the ship*, how far apart are the laser cannons on the planet?
- A. Exactly a distance  $D$  apart.
  - B. A distance greater than  $D$  apart.
  - C. A distance less than  $D$  apart.
- (d) (2 points) An alien on the planet says that the laser beams strike the ship simultaneously. Would an alien on the ship agree?
- A. Yes, the lasers were fired at the same time and so they would agree.
  - B. No, they would say the beam from laser A struck first.
  - C. No, they would say the beam from laser B struck first.

3. **Quark Energies:** Quarks are elementary particles (meaning that, to our knowledge, they cannot be broken down). Three quarks can come together to make up a proton or a neutron, and because there are different kinds of quarks the different combinations can yield different particles. There are 6 different quarks, each with a different mass:

up quark	$4.30 \times 10^{-30}$ kg
down quark	$8.59 \times 10^{-30}$ kg
charm quark	$2.28 \times 10^{-27}$ kg
strange quark	$1.70 \times 10^{-28}$ kg
top quark	$3.09 \times 10^{-25}$ kg
bottom quark	$7.48 \times 10^{-27}$ kg

- (a) (2 points) Considering Einstein's equation which relates mass to energy,  $E = mc^2$ , which quark has the **most** mass-energy?
- (b) (2 points) Considering Einstein's equation which relates mass to energy,  $E = mc^2$ , which quark has the **least** mass-energy?
- (c) (2 points) By the principle of wave-particle duality, we know that these different quarks also have different wavelengths. Below are six different waves (shown with decreasing wavelength), which represent the wavelengths of these different quarks (assuming their velocities are negligible). Label them.



1  
IA  
1A

2  
IIA  
2A

13  
IIIA  
3A

14  
IVA  
4A

15  
VA  
5A

16  
VIA  
6A

17  
VIIA  
7A

18  
VIIIA  
8A

1  
H  
Hydrogen  
1.008

3  
Li  
Lithium  
6.941

11  
Na  
Sodium  
22.990

19  
K  
Potassium  
39.098

37  
Rb  
Rubidium  
84.468

55  
Cs  
Cesium  
132.905

87  
Fr  
Francium  
223.020

4  
Be  
Beryllium  
9.012

12  
Mg  
Magnesium  
24.305

20  
Ca  
Calcium  
40.078

38  
Sr  
Strontium  
87.62

56  
Ba  
Barium  
137.327

88  
Ra  
Radium  
226.025

5  
B  
Boron  
10.811

13  
Al  
Aluminum  
26.982

31  
Ga  
Gallium  
69.723

49  
In  
Indium  
114.818

81  
Tl  
Thallium  
204.383

113  
Uut  
Ununtrium  
unknown

6  
C  
Carbon  
12.011

14  
Si  
Silicon  
28.086

32  
Ge  
Germanium  
72.61

50  
Sn  
Tin  
118.71

82  
Pb  
Lead  
207.2

114  
Fl  
Flerovium  
[289]

7  
N  
Nitrogen  
14.007

15  
P  
Phosphorus  
30.974

33  
As  
Arsenic  
74.922

51  
Sb  
Antimony  
121.760

83  
Bi  
Bismuth  
208.980

115  
Uup  
Ununpentium  
unknown

8  
O  
Oxygen  
15.999

16  
S  
Sulfur  
32.066

34  
Se  
Selenium  
78.09

52  
Te  
Tellurium  
127.6

84  
Po  
Polonium  
[209]

116  
Lv  
Livermorium  
[293]

9  
F  
Fluorine  
18.998

17  
Cl  
Chlorine  
35.453

35  
Br  
Bromine  
79.904

53  
I  
Iodine  
126.904

85  
At  
Astatine  
[210]

117  
Uus  
Ununseptium  
unknown

10  
Ne  
Neon  
20.180

18  
Ar  
Argon  
39.948

36  
Kr  
Krypton  
84.80

54  
Xe  
Xenon  
131.29

86  
Rn  
Radon  
222.018

118  
Uuo  
Ununoctium  
unknown

2  
He  
Helium  
4.003

10  
Ne  
Neon  
20.180

18  
Ar  
Argon  
39.948

36  
Kr  
Krypton  
84.80

54  
Xe  
Xenon  
131.29

86  
Rn  
Radon  
222.018

118  
Uuo  
Ununoctium  
unknown

Atomic Number

Symbol

Name

Atomic Mass

8

VIII

10

57

La

Lanthanum

138.906

58

Ce

Cerium

140.115

59

Pr

Praseodymium

140.908

60

Nd

Neodymium

144.24

61

Pm

Promethium

144.913

62

Sm

Samarium

150.36

63

Eu

Europium

151.965

64

Gd

Gadolinium

157.25

65

Tb

Terbium

158.925

66

Dy

Dysprosium

162.50

67

Ho

Holmium

164.930

68

Er

Erbium

167.26

69

Tm

Thulium

168.934

70

Yb

Ytterbium

173.04

71

Lu

Lutetium

174.967

89

Ac

Actinium

227.028

90

Th

Thorium

232.038

91

Pa

Protactinium

231.036

92

U

Uranium

238.029

93

Np

Neptunium

237.048

94

Pu

Plutonium

244.064

95

Am

Americium

243.061

96

Cm

Curium

247.070

97

Bk

Berkelium

247.070

98

Cf

Californium

251.080

99

Es

Einsteinium

[254]

100

Fm

Fermium

257.095

101

Md

Mendelevium

258.1

102

No

Nobelium

259.101

103

Lr

Lawrencium

[262]

Alkali Metal

Alkaline Earth

Transition Metal

Basic Metal

Semimetal

Nonmetal

Halogen

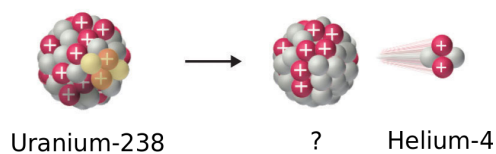
Noble Gas

Lanthanide

Actinide

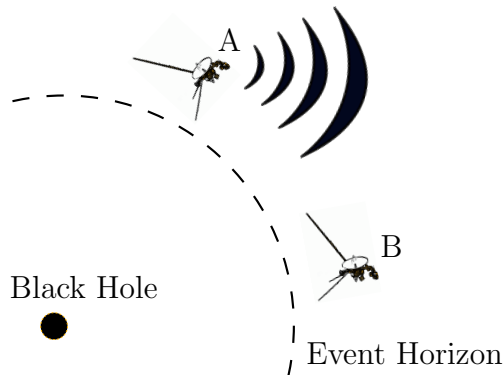
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4. **Uranium Decays:** Uranium-238 decays via alpha decay (where it emits a Helium-4 nucleus).



- (a) (2 points) What element does uranium-238 decay to?
- (b) (2 points) How many protons and neutrons does this decay product have?
- (c) (2 points) The half-life of uranium-238 is about 5 billion years. After 15 billion years, what fraction of a block of uranium-238 will **remain**?
- (d) (2 points) The half-life of uranium-238 is about 5 billion years. After 20 billion years, what fraction of a block of uranium-238 will have **decayed**?

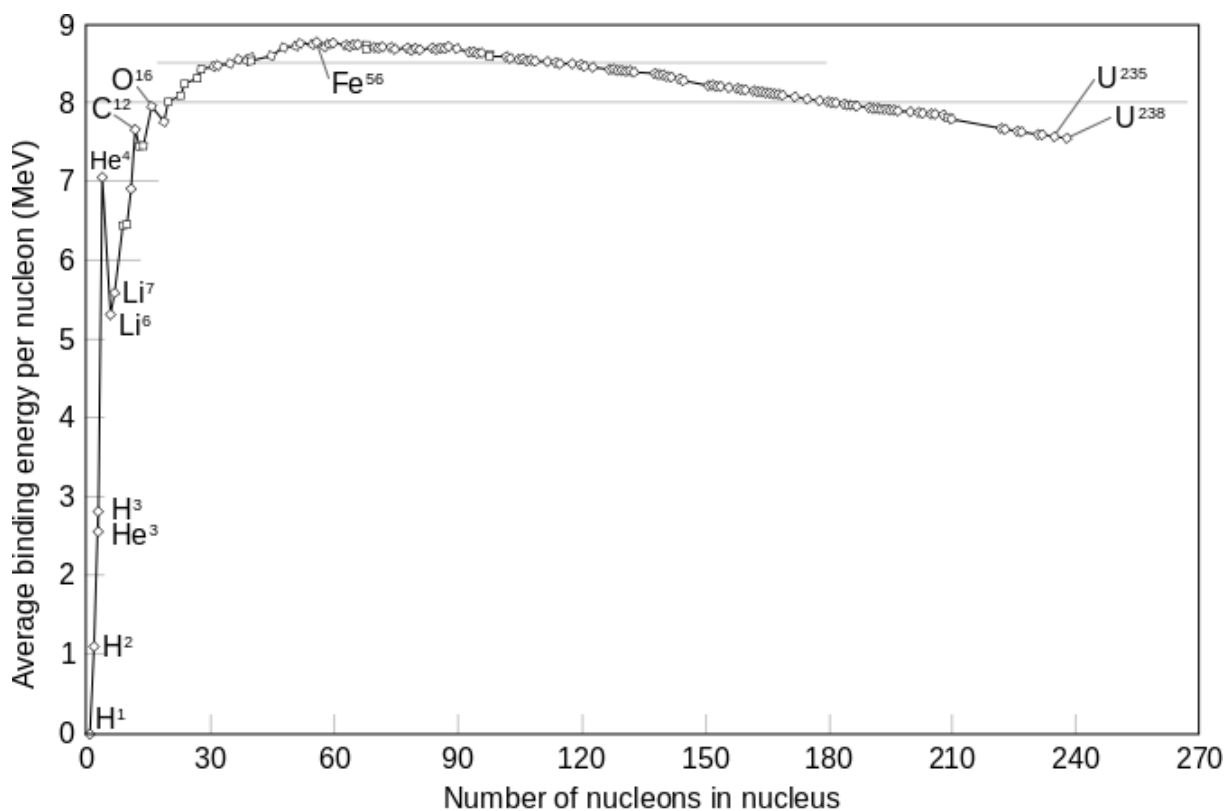
5. **Black Holes:** Suppose scientists on Earth decide to launch two satellites at a black hole. Both satellites are identical, and transmit information via radio waves, which observers on Earth can detect. Both satellites are in an identical orbit around the black hole (so *they are stationary with respect to each other*), just outside the event horizon.



- (a) (1 point) Satellite *A* emits two radio pulses, 5 seconds apart. To an observer on Earth, who is watching the satellite and detecting the pulses,
- A. The timing between pulses is also 5 seconds.
  - B. The timing between pulses is greater than 5 seconds.
  - C. The timing between pulses is less than 5 seconds.
- (b) (1 point) Satellite *A* emits two radio pulses, 5 seconds apart. To an observer on satellite *B*, who is able to observe satellite *A*,
- A. The timing between pulses is also 5 seconds.
  - B. The timing between pulses is greater than 5 seconds.
  - C. The timing between pulses is less than 5 seconds.
- (c) (1 point) The frequency of radio waves emitted by satellite *A* is 5 MHz. To an observer on Earth, who is watching the satellite and detecting the light,
- A. The frequency of the radio waves is also 5 MHz.
  - B. The frequency of the radio waves is greater than 5 MHz.
  - C. The frequency of the radio waves is less than 5 MHz.
- (d) (1 point) The frequency of radio waves emitted by satellite *A* is 5 MHz. To an observer on satellite *B*, who is able to detect the light from satellite *A*,
- A. The frequency of the radio waves is also 5 MHz.
  - B. The frequency of the radio waves is greater than 5 MHz.
  - C. The frequency of the radio waves is less than 5 MHz.

- (e) (1 point) The frequency of radio waves emitted by satellite *A* is 5 MHz. To an observer on Earth, who is watching the satellite and detecting the light,
- The radio waves coming from satellite *A* are traveling at the speed of light.
  - The radio waves coming from satellite *A* are traveling slower than the speed of light.
  - The radio waves coming from satellite *A* are traveling faster than the speed of light.
- (f) (1 point) The frequency of radio waves emitted by satellite *A* is 5 MHz. To an observer on satellite *B*, who is watching the satellite and detecting the light,
- The radio waves coming from satellite *A* are traveling at the speed of light.
  - The radio waves coming from satellite *A* are traveling slower than the speed of light.
  - The radio waves coming from satellite *A* are traveling faster than the speed of light.

6. (2 points (bonus)) **Creating Elements:** A nuclear physicist in a lab wishes to create lithium. The graph below shows the binding energies for different elements and isotopes:



- (a) She combines  ${}^3He$  to create  ${}^6Li$ . Overall, would this release or require energy?
- (b) She breaks apart  ${}^{238}U$  to create  ${}^6Li$ . Overall, would this release or require energy?

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