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Cornell University

Prison Education Program

Conceptual Physics

Second Partial Test

GROUP

May 18, 2018

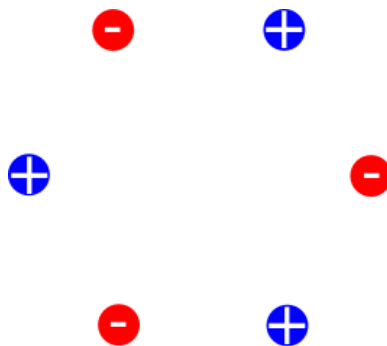
You are free to use all notes on your two-sided cheat sheet. There are extra blank sheets at the end, which can be used for calculations, and if you require more please ask and be sure to include them when you hand back the test. Please be sure to include all your work and calculations.

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

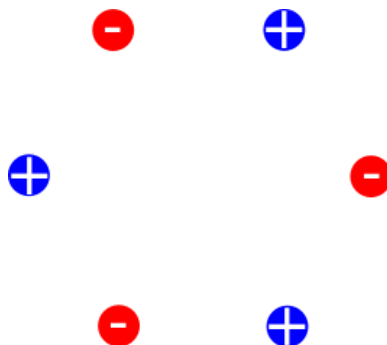
I will randomly pick 1 test per group, and the entire group will receive that grade: It is therefore vital that everyone in the group be involved.

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 ± 1 (so the size of all charges are the same).

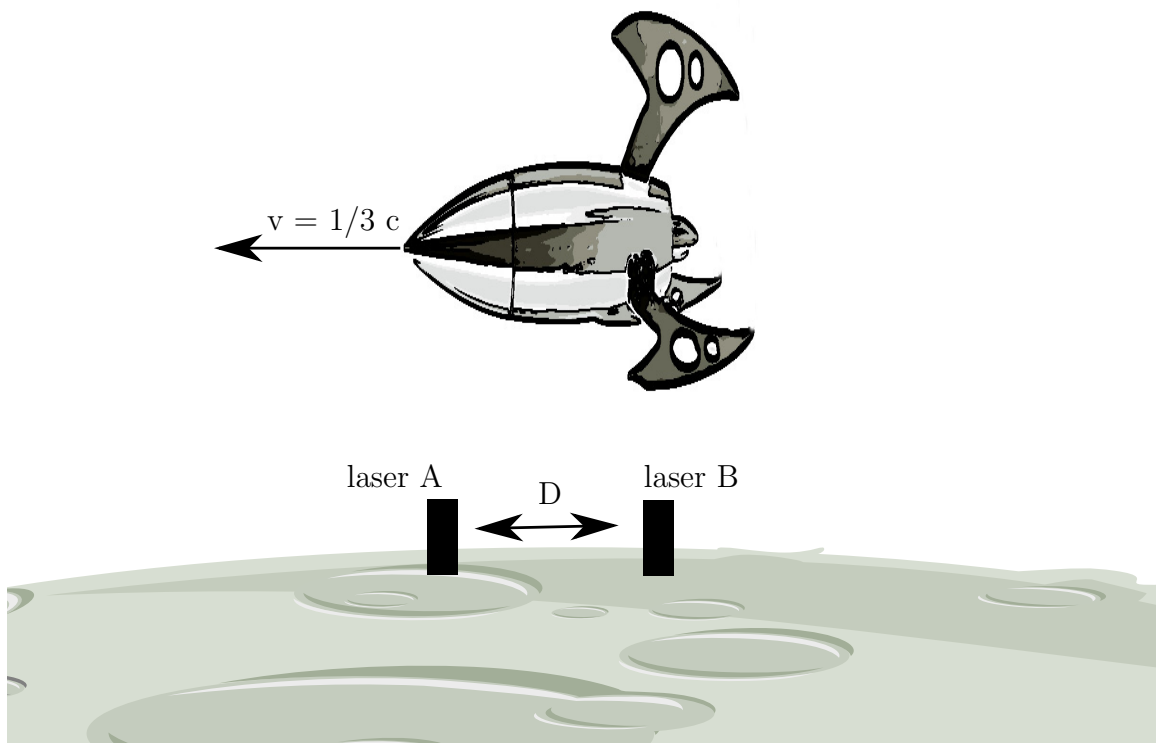
(a) (2 points) Draw the **electric field** lines around the particles. If there is a point with **zero** electric field, indicated it on the diagram.



(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.**

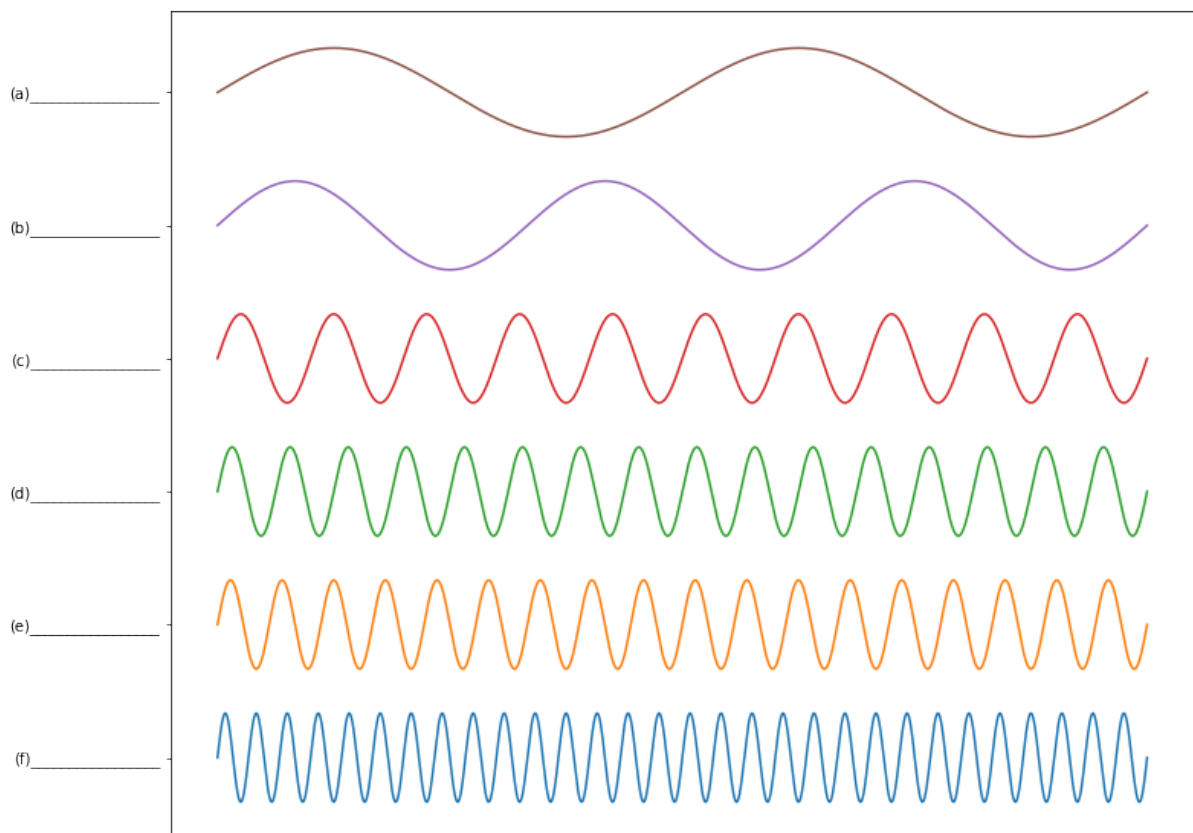


- (a) (2 points) The aliens on the planet fire the lasers at the same time. How far apart would they say the scorch marks on the ship are?
- A. Exactly a distance D apart.
 - B. A distance greater than D apart.
 - C. A distance less than D apart.
- (b) (2 points) From the perspective of an alien *on 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	4.30×10^{-30} kg
down quark	8.59×10^{-30} kg
charm quark	2.28×10^{-27} kg
strange quark	1.70×10^{-28} kg
top quark	3.09×10^{-25} kg
bottom quark	7.48×10^{-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.



Periodic Table of the Elements

<div style="display: flex; justify-content: space-between;"> 1 IA 1A 2 IIA 2A 13 IIIA 3A 14 IVA 4A 15 VA 5A 16 VIA 6A 17 VIIA 7A 18 VIIIA 8A </div>																	
<div style="display: flex; justify-content: space-around;"> <div> Atomic Number Symbol Name Atomic Mass </div> </div>																	
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 Al Aluminum 26.982	4 Si Silicon 28.086	5 P Phosphorus 30.974	6 S Sulfur 32.066	7 Cl Chlorine 35.453	8 Ar Argon 39.948										
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [271]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Nh Nihonium [284]	114 Fl Flerovium [289]	115 Mc Moscovium [288]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]
<div style="display: flex; justify-content: space-around; align-items: center;"> <div> <div>57 La Lanthanum 138.906</div> <div>89 Ac Actinium 227.028</div> </div> <div> <div>58 Ce Cerium 140.115</div> <div>90 Th Thorium 232.038</div> </div> <div> <div>59 Pr Praseodymium 140.908</div> <div>91 Pa Protactinium 231.036</div> </div> <div> <div>60 Nd Neodymium 144.24</div> <div>92 U Uranium 238.029</div> </div> <div> <div>61 Pm Promethium 144.913</div> <div>93 Np Neptunium 237.048</div> </div> <div> <div>62 Sm Samarium 150.36</div> <div>94 Pu Plutonium 244.064</div> </div> <div> <div>63 Eu Europium 151.965</div> <div>95 Am Americium 243.061</div> </div> <div> <div>64 Gd Gadolinium 157.25</div> <div>96 Cm Curium 247.070</div> </div> <div> <div>65 Tb Terbium 158.925</div> <div>97 Bk Berkelium 247.070</div> </div> <div> <div>66 Dy Dysprosium 162.50</div> <div>98 Cf Californium 251.080</div> </div> <div> <div>67 Ho Holmium 164.930</div> <div>99 Es Einsteinium [254]</div> </div> <div> <div>68 Er Erbium 167.26</div> <div>100 Fm Fermium 257.095</div> </div> <div> <div>69 Tm Thulium 168.934</div> <div>101 Md Mendelevium 258.1</div> </div> <div> <div>70 Yb Ytterbium 173.04</div> <div>102 No Nobelium 259.101</div> </div> <div> <div>71 Lu Lutetium 174.967</div> <div>103 Lr Lawrencium [262]</div> </div> </div>																	

Alkali Metal

Alkaline Earth

Transition Metal

Basic Metal

Semimetal

Nonmetal

Halogen

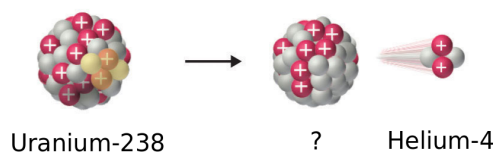
Noble Gas

Lanthanide

Actinide

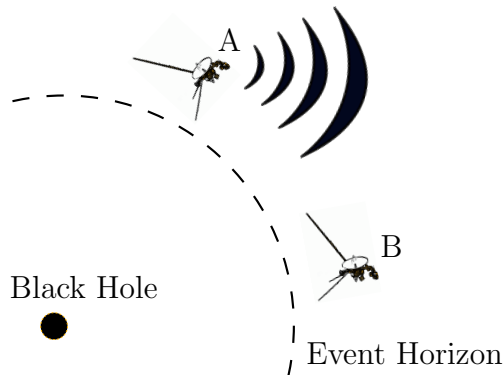
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4. **Uranium Decays:** Uranium-238 decays via alpha decay (where it emits a Helium-4 nucleus).



- (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**?

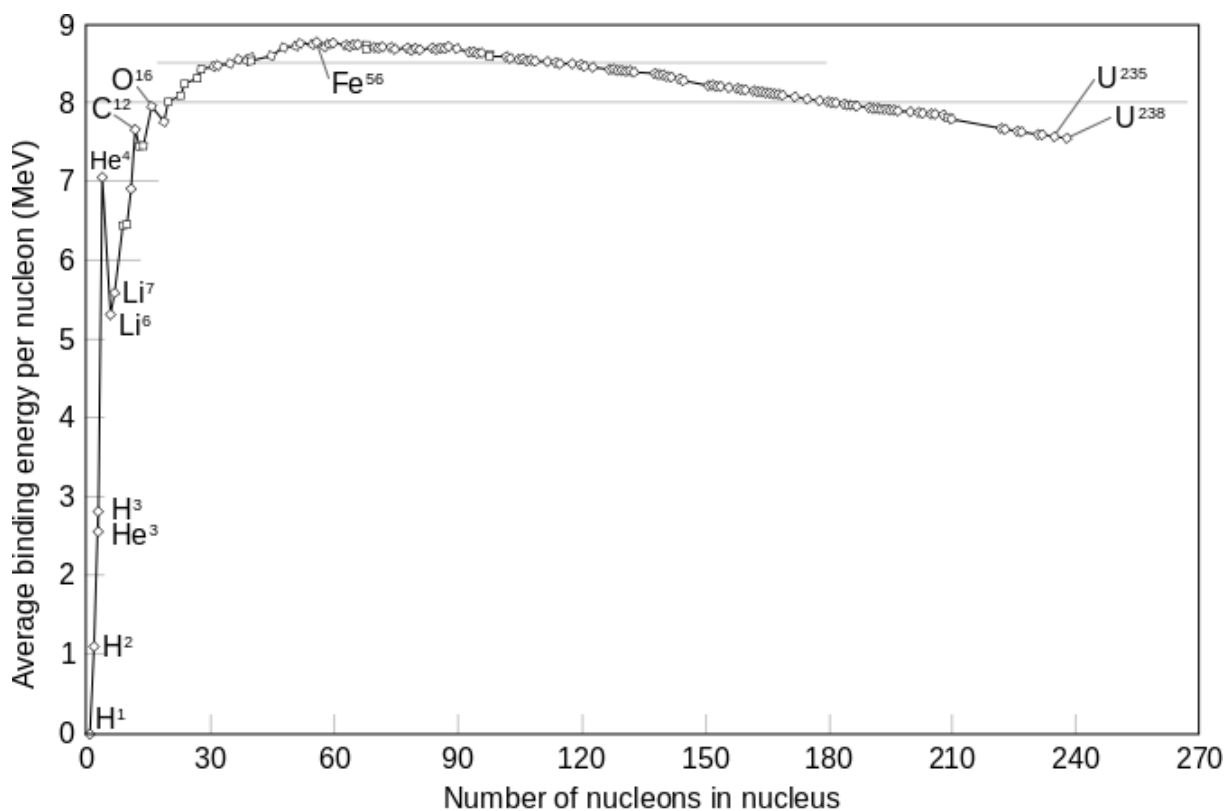
5. **Black Holes:** Suppose scientists on Earth decide to launch two satellites at a black hole. Both satellites are identical, and transmit information via radio waves, which observers on Earth can detect. Both satellites are in an identical orbit around the black hole (so *they are stationary with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