Name: _____

Cornell University
Prison Education Program

# Conceptual Physics
# First Partial Test
# March 30, 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.

Some useful geometric quantities for this test may include:

$$\text{Area of a Circle} = \pi \times (\text{radius})^2$$
$$\text{Area of a Triangle} = \frac{1}{2}\text{base} \times \text{height}$$
$$\text{Area of a Rectangle} = \texttt{base} \times \text{height}$$

There are 5 problems for a total of 24 points. (One of the questions is a bonus though.)

1. **Jupiter's Moons:** Jupiter is the largest planet in our solar system, and has 53 named moons (although NASA scientists think it has a total of 69 moons). The largest one is called *Ganymede*. Most orbits are not perfectly circular, and are in fact shaped like ellipses. In the diagram below, images (I), (II), (III) and (IV) show snapshots in time of Jupiter and its largest moon in orbit around it. Use these images to answer the following questions. **For each question, please also *explain your answer.***
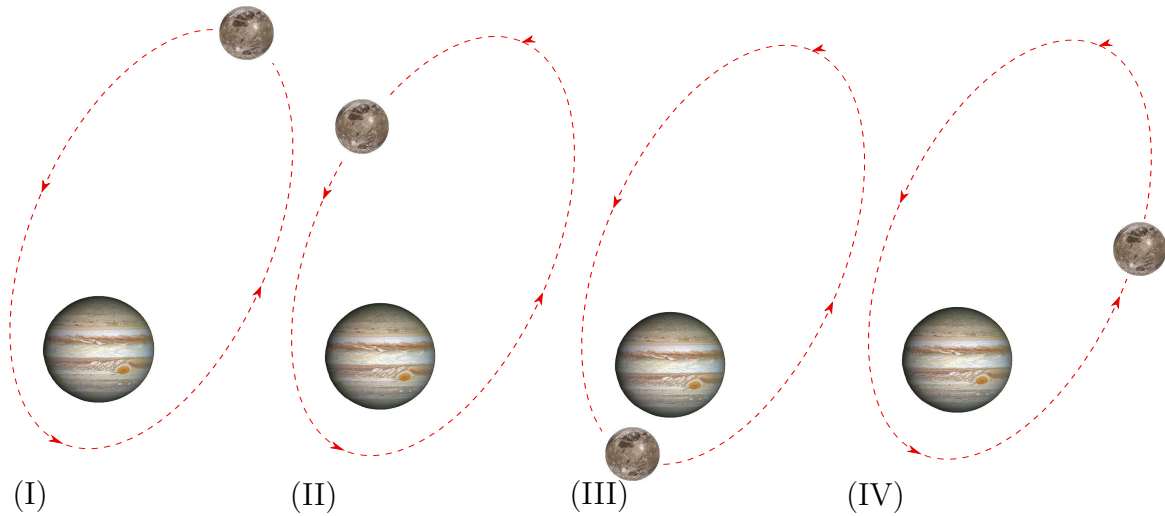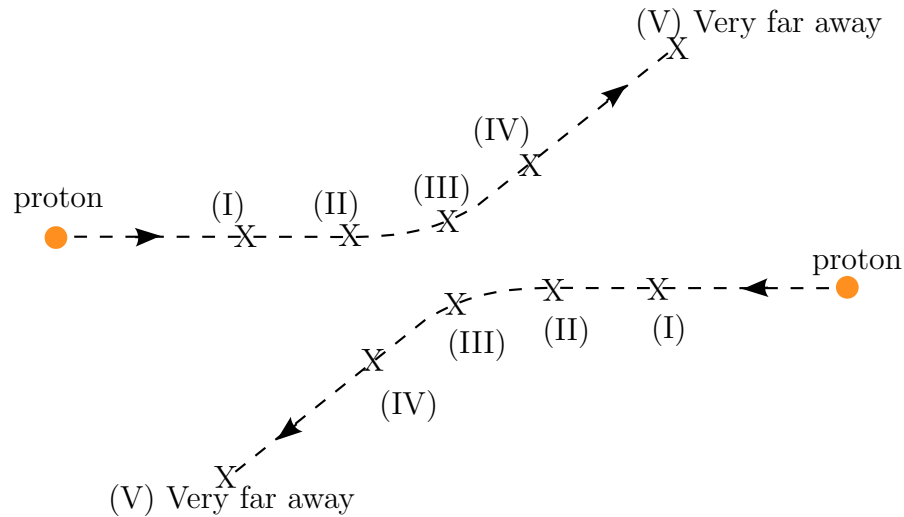


(I)　　　　　　(II)　　　　　　(III)　　　　　　(IV)

   (a) (2 points) At which instant (I, II, III, IV) is the *gravitational force* between Jupiter and Ganymede the *greatest*? **Why?**

   (b) (2 points) At which instant (I, II, III, IV) is the *gravitational potential energy* between Jupiter and Ganymede the *greatest*? **Why?**

   (c) (2 points) Assume energy is conserved in the Jupiter/Ganymede system. At which instant (if any) is the Ganymede's *speed* the *greatest*? **Why?**

2. **Free Diving:** In free diving, athletes hold there breath and descend as far as possible (*without* using air tanks, like in scuba diving). Often, they use a guide rope to descend and ascend back to the surface, as well as weights to pull them down and fins to rise. The image on the right shows a freediver with a guide rope. The graph below shows the *velocity as a function of time* for an athlete as she descends (from 0 to 31 seconds), pauses for a moment (from 31 to 35 seconds), and then ascends back to the surface (from 35 to 51 seconds).
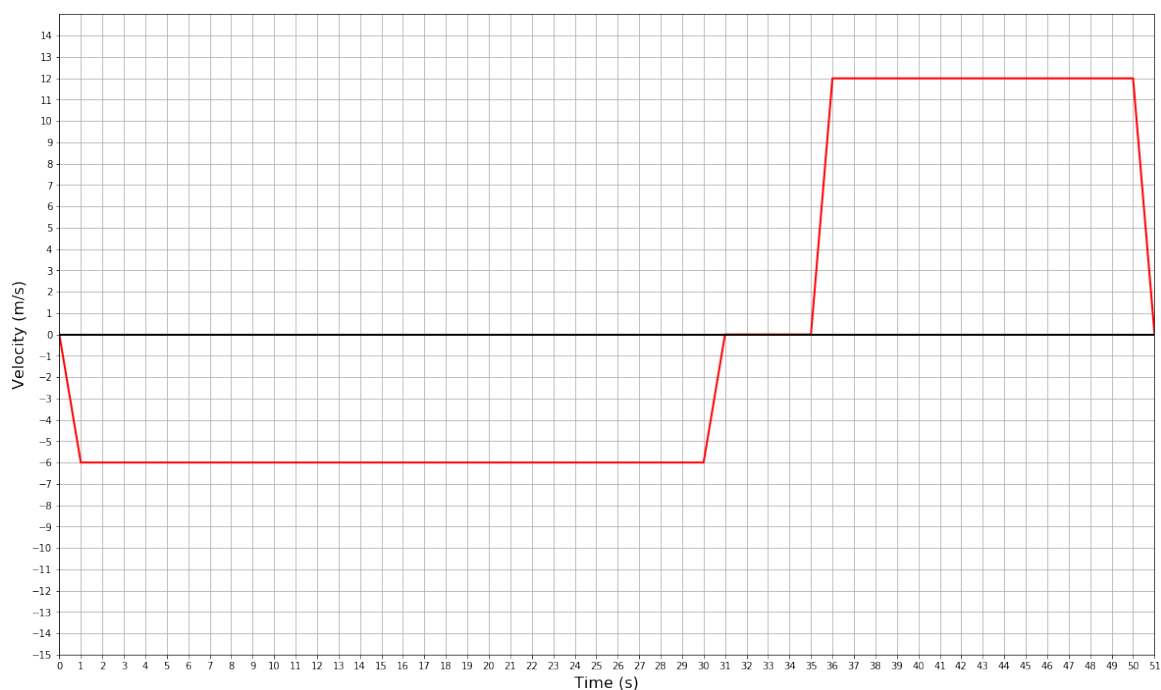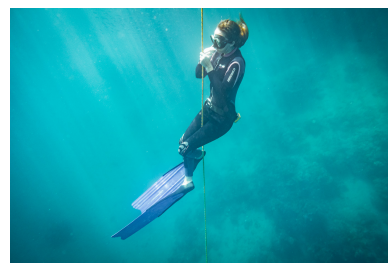


(a) (2 points) When during her dive does the athlete experience *zero acceleration*? Provide all time interval(s). If she never experiences zero acceleration, provide an explanation.

(b) (2 points) When during her dive does the athlete experience *negative acceleration* (accelerating *down*)? Provide all time interval(s). If she never experiences negative acceleration, provide an explanation.

(c) (2 points) How deep did the athlete descend?

3. **Smashing Protons:** In particle accelerators, subatomic particles (such as protons) are accelerated to very large speeds and then collide with one another. The resulting high-energy collisions produce other particles, which researchers use to test models of particle physics. However, not all particles in the accelerators collide (since they are very hard to align): Often their trajectories are off and they simply deflect. The diagram bellow illustrates a situation like this. Two protons are accelerated towards one another, but instead of colliding they deflect each other. The dashed lines illustrate their respective paths, and their simultaneous positions at different points in time are labeled as (I), (II), (III), (IV) and (V). Please use these labels to answer the following questions. **For each question, please also *explain your answer*.**



(a) (2 points) At what point(s) in time (I, II, III, IV, V) do the protons feel an electrical force? **Why?**

(b) (2 points) At what point(s) in time (I, II, III, IV, V) do the protons experience the *greatest electric force*? **Why?**

(c) (2 points) At what point(s) in time (if any) does the proton/proton system have the *greatest electric potential energy*? **Why?**

4. In *nuclear fusion*, atomic nuclei come together, forming larger nuclei. The process releases nuclear potential energy, and occurs naturally in stars. In the *triple-alpha process* three helium nuclei come together, forming carbon (by forming an intermediate beryllium nucleus). The figure bellow illustrates this process:
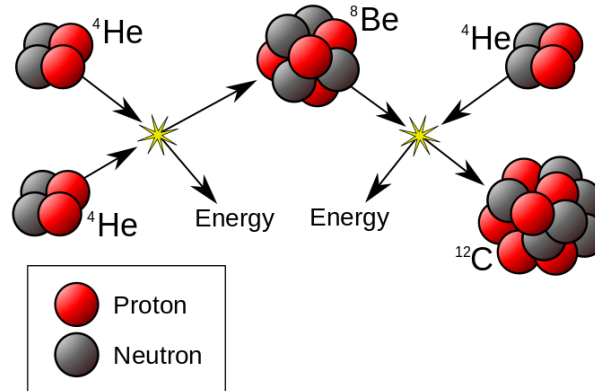


The creation of 1 carbon nucleus from 3 helium nuclei releases $1.2 \times 10^{-12} J$ of energy.

(a) (2 points) If the human body contains, on average, $1.6 \times 10^4 g$ of carbon and a carbon nucleus has a mass of $2 \times 10^{-23} g$, about how many carbon atoms exist in the human body?

(b) (2 points) If we assume all of this carbon was produced through the triple-alpha process in a star, then how many helium nuclei were consumed in the process?

(c) (2 points) How much energy was released to form the carbon contained in 1 average human?

5. (4 points (bonus)) Science is a process people engage in, founded in the idea that through rigorous experimental testing we can refine our models of the world and thus better understand it. However, people are imperfect. What are some problems that arise when people engage in science?

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