PHYSICS101 - Fall Semester 2010 - ODU

Final Exam - Solution

Part I: Self-paced Clicker Test

Instructions: This part is a self-paced clicker test – you can answer the following problems in any order and take as much time as you wish, as long as you complete the whole test before the 3 hours are up. You can also revisit each problem and change your answer, up to 3 times. Begin by working out the answer for each problem. When you are ready to submit an answer, make sure your clicker is on and joined PHYS101. Do not enter anything at the "TST:" prompt - just use the little buttons with up and down triangles (left side of the clicker) to select which problem you want to answer. Enter the answer (one or more digits/letters or True/False) followed by the green "enter" button. You should get feedback that your answer was received (which doesn't mean it's necessarily correct!) Keep your clicker on for the whole duration of the test – that way, you can check what you submitted. (Make sure you have fresh batteries installed)

JUST TO BE TOTALLY SAFE: ALSO mark/write the correct answers on this exam, write down your UIN and name, and turn it in! Cross-check your clicker answers one more time before turning your clicker off.

For the following multiple choice problems, just enter the letter that describes the **best** answer (only one). Each problem counts 2 points.

Problem 1

A heavy box is slowly sliding down a ramp, at constant speed. Which of the following forces is NOT acting on that box:

A. Gravity
B. Static Friction
C. Kinetic Friction
D. Normal Force

Problem 2

For the case described in Problem 1, which statement is true:

A. The normal force exactly compensates the force of gravity
B. The force due to kinetic friction points down the ramp
C. The net sum of all forces is zero
D. There is a net force in the direction of motion

Problem 3

A space probe is approaching the mighty planet Jupiter. Which of the following statements is correct?

A. The probe exerts no force on Jupiter
B. Both the probe and Jupiter accelerate towards each other with the same acceleration
C. The force exerted by Jupiter on the probe is equal in magnitude to the force exerted by the probe on Jupiter
D. Unless the space probe is really close to Jupiter, it will experience no force from Jupiter.

Problem 4

The space probe from the previous problem crashes into Jupiter. Which of the following statements is true:

A. Both Jupiter and the space probe change their velocities such that the total momentum of the two combined remains the same before and after the crash.
B. This is an elastic collision
C. Total kinetic energy is conserved in the collision
D. The impulse (change of momentum) of Jupiter is much smaller than for the space probe.

Problem 5

You fire 2 cannons at an angle of 45 degrees to the horizontal. The 2^{nd} one has double the muzzle speed (i.e. the projectile speed at the moment it leaves the canon) than the first one. How much farther away (distance to point of impact at same level as cannons) will the 2^{nd} canon fire its projectile? (Ignore air resistance)

A. Same distance as the first one
B. Double the distance as the first one
C. Four times the distance as the first one
D. It depends on the masses of the projectiles

Problem 6

Somebody sets down a tall box on an inclined ramp, standing it up on one of its small sides. As soon as it is released, it begins to topple over. Which statement is **not** true:

A. The box is in equilibrium

B. The angular momentum of the box starts to increase

C. There is a net torque acting on the box

D. The center of gravity of the box is not directly vertically above its "footprint" (the side on which it is standing)

Problem 7

A solid circular disk made of wood and a bicycle wheel with a steel rim (and very light spokes) have both the same total mass. Both are rotating with angular velocity $\omega = 70$ rad/sec. Which of the following statements is ***WRONG***?

A. The bicycle wheel has the larger angular momentum

B. The bicycle wheel has the larger kinetic energy

C. The wooden disk has the larger moment of inertia

D. It takes less torque to stop the wooden disk in the same amount of time as the bicycle wheel.

Problem 8

Two cars are driving around a 90 degree bend in the road. Car 2 has twice the velocity and twice the mass of car 1, and the lane it's in has twice the radius of curvature as the one for the first car. Which statement is correct:

A. Both cars have the same centripetal acceleration

B. The centripetal **force** on the 2nd car is the same as on the first car

C. The tires on the first car are more likely to squeal than for the 2nd car

D. Both cars complete the 90 degree bend in the same amount of time

Problem 9

Earth is moving around the sun on an elliptical orbit, which brings it closest to the sun in Winter and the furthest away in summer. When do you think will Earth be moving the ***slowest*** during its orbit?

A. Spring
B. Summer
C. Fall
D. Winter

Problem 10

A piece of copper is attracted electrostatically towards the metal dome of a large, operating Van-de-Graaf generator. What can you conclude, from this information, about the charge on the dome and the charge on the piece of copper?

A. The dome likely has some net charge, but we don't know for sure if the copper is charged (except it can't have a large charge of the *same* sign as the dome's).
B. The charge on the dome must be positive
C. The piece of copper must carry a positive net charge
D. Both the piece of copper and the dome ***must*** have a net charge, of opposite sign

Problem 11

Two identical light bulbs are connected in series to a battery. A third light bulb of the same kind is added in series to the circuit. Which of the following will happen:

A. The total light output of the circuit is increased.
B. All three light bulbs are significantly dimmer than each of the two were before the third one was added.
C. The first two light bulbs will emit the same amount of light, but the third one will be much dimmer.
D. The battery will melt.

Problem 12

You have a permanent iron dipole magnet (a rod of iron alloy permanently magnetized along its axis). You have laid out on the table a bunch of other rods of similar size. You bring your magnet close to each of these rods in turn, end to end (i.e. the end of your magnet is approaching one end of the respective rod). Some rods are not affected by the magnet at all, while others are attracted to it. But the last rod is pushed away strongly. Which of the following conclusions is most likely true?

A. That last rod is probably made of copper or aluminum.
B. All of the rods that are attracted to the magnet must be permanent magnets themselves.
C. If you turn the last rod around (end to end), it probably will now be attracted to your magnet.
D. The last rod must be paramagnetic.

End of multiple choice problems. For the following problems, just enter the correct numerical result (as many digits as needed and possibly a period) that answers the question, followed by the "enter" key. Each problem counts 2 points.

Problem 13

Two cars collide head on and come to an immediate stop. One car had a velocity of 20 m/s and a mass of 1000 kg. The other car had a velocity of -5 m/s. What was its mass? **4000 kg**

Problem 14

A ballerina is rotating on the tip of her toes (nearly frictionless), with arms outstretched, at a rotational speed of 3 rounds per second. She pulls her arms close to her body, thereby decreasing her moment of inertia from 25 kg m^2 to 15 kg m^2. What is her new rotational speed (in rounds per second)? **5 rounds per second**

Problem 15

The moon is 9 times further away from Earth than a typical geostationary satellite (e.g., a TV satellite). How much larger is the acceleration of the satellite towards Earth than the acceleration of moon towards Earth? **81** times (9 x 9)

Problem 16

A car is driving over the (level) edge of a cliff with a horizontal velocity of 25 m/s. At the exact same moment, somebody drops a rock from the edge of the cliff which hits the ocean below after 3 seconds. How far away from the foot of the (vertical) cliff does the car hit the ocean? **75** m

Problem 17

A speck of dust with a mass of 0.0001 kg (10^{-4} kg = 0.1 gram) carries a net charge of 10^{-6} C (1 micro-Coulomb). It is suspended in an electric field of 2000 N/C (V/m). What is its acceleration in m/s^2? **20** m/s^2

Problem 18

A light bulb with 4 Ohm resistance is attached to a 12 V battery. How much power (in Watt) does it consume (convert into heat and light)? **36** W (12V x 3A)

Cluster of Extra Credit Questions: (Each problem counts 1 point)

For the following problems, decide whether the object or person described in them experiences accelerated motion or not. If the motion is accelerated, enter green T(rue), else if $a = 0$, enter red F(alse), followed by the "return" button. All points you get are extra credit.

Problem 19

An apple falls freely from a tree. Accelerated? **T**/F

Problem 20

A space station is circling Earth on a stable orbit. Accelerated? **T**/F

Problem 21

An astronaut is floating freely inside the space station in Problem 20. Accelerated? **T**/F

Problem 22

A car is driving with constant speed along a freeway that makes a curve, changing the heading from North to West. Accelerated? **T**/F

Problem 23

A car is braking for a red light, before coming to a complete stop. Accelerated? **T**/F

Problem 24

A car going a steady 60 miles per hour on a straight freeway passes a car going 50 miles per hour in a different lane. Accelerated? T/**F**

Problem 25

A helicopter is rising straight up, increasing its height by 10 m every second. Accelerated? T/**F**

Problem 26

A proton is moving with constant speed perpendicular to a constant magnetic field of strength 1 Tesla. Is the motion of the proton going to be accelerated? **T**/F

Problem 27

An electron is situated exactly between a proton (charge $q = e$) and a Beryllium nucleus (charge $q = 4e$) . Its distance from the proton is ½ of its distance from the Be nucleus. If the only forces acting are due to these 2 charges, is the electron accelerating? T/**F**

Part II: Word Problems

Answer **three** of the following 4 questions with several complete sentences, written on a sheet of paper (or the back of this exam). 4 points for each problem you solve. **No extra credit** for solving all 4, so pick and choose!

Problem 28

A super-elastic rubber ball of mass 0.1 kg drops from rest, at an initial height of 1 m, onto a rigid stone floor, bounces back and comes to a (momentary) stand-still when it regains its initial height. Describe each type of energy it has during each of the following 5 points during its fall: Right before dropping, right before hitting the ground, during the bounce, right after the bounce, and when it reaches its original height. What are the relative magnitudes of these energy types at each stage? Is total mechanical energy conserved?

Answer: We can describe the motion of the ball by considering kinetic, gravitational potential and elastic potential energy. Initially, the K.E. is 0 and the potential energy mgh is maximal. All of this energy is converted to K.E. and $mgh = 0$ right before the ball hits the ground. During the bounce, the ball gets compressed and all of the kinetic energy gets converted into elastic (deformation) energy. This gets converted back to kinetic energy at the end of the bounce, and all 3 energy types are the same right before and right after the bounce. Finally, the ball rises to its initial height h and all K.E. is converted back to gravitational potential energy mgh.

Problem 29

For the same scenario as Problem 28, discuss the momentum of the rubber ball at each of the 5 points described. Is the ball's momentum conserved at each stage (transition from one point to the next)? If not, which other entity (object) absorbs the change in its momentum in each case? Is the collision with the floor elastic or inelastic?

Answer: Initially, the momentum of the ball is zero ($v = 0$). As it falls, it acquires negative momentum (non-conservation) – this must be balanced by an equal amount of positive momentum acquired by Earth (which is what causes the ball to fall). During the bounce, the ball exchanges twice its momentum with the floor (which takes up all of that negative momentum) and bounces back with positive momentum of equal magnitude. Finally, it loses all of that positive momentum while slowing down (Earth compensates again) until it arrives at the top with zero momentum.

Problem 30

Describe both the similarities and the differences between the gravitational force between two masses and the electrostatic force between two charges. You need to list at least 5 distinct properties/features of each force and tell me which ones are similar between the two.

Answer: Both the gravitational force $-GMm/r^2$ and the electrostatic force kQq/r^2 share several features: They depend only on a single property of the two objects that interact (mass vs. charge), they are proportional to the magnitude of these properties in both objects, and they fall of like the square of the distance between the two objects. Also, the force acts along the line connecting the two objects. The differences are as follows: Electrostatic forces act on charges, while gravity acts on masses. Charges can be both positive and negative, so the force can be both attractive and repulsive, while gravity is always attractive (hence the minus sign). Finally, for all elementary particles in the real world, the electrostatic force is hugely larger than the gravitational one. The only reason we can even detect the latter is because positive and negative charges can cancel out.

Problem 31

A battery is used to run a current through a straight piece of wire that is suspended between the poles of a horse-shoe magnet. The magnetic field between the poles is horizontal, and the current runs perpendicular to the field, also in the horizontal plane. As a net effect, the wire experiences a force upward that can be used to lift a weight attached to it.

List all of the forces (there are at least 3 different types) that act on the electrons in this circuit as they travel from the battery – pole trough the wire (both inside and outside the magnetic field) to the + pole of the battery and then, through the inside of the battery, back to the – pole. Where does the energy (work) needed to lift the weight ULTIMATELY come from (i.e., what is the original source of energy that is required to make this whole arrangement do work on the suspended weight)?

Answer: While moving from and back to the battery, the electrons experience an electrostatic force due to the electric field inside the wire (set up by the battery). While they go through the magnetic field, they experience in addition a magnetic (Lorentz) force pushing them up. Finally, inside the battery, some other force (not electrostatic) must be pushing them from low to high potential energy (e.g., a chemical reaction). This chemical reaction is also the ultimate source of the energy needed to lift the weight – it increases the potential energy of the electrons, which can then move from the high potential energy side of the battery (the – pole) to the low side (the + pole), converting electrostatic potential energy into kinetic one. The magnetic field simply serves to redirect that kinetic energy "upward", which leads to the lifting of the weight.