Additional PHYS2350 EV1 Fall 2017 Exam 2 Review Questions

Hints and Answers

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Chapter 5: Circular Motion & Gravity

1. A satellite is placed in orbit 6×10^5m above the surface of Jupiter. Noting that the mass of Jupiter is 1.90×10^{27}kg, and the radius is 7.14×10^7m, find the speed of the satellite?

   Hint: remember that this object is undergoing uniform circular motion, which has a definition form for the acceleration. Think about what force is causing the circular motion.

   Answer: 4.19×10^4km/s

2. A popular ride at amusement parks is one in which you lean against the wall of a cylindrical room which begins to rotate. At a high enough speed, you're pressed so firmly into the wall of the room that the floor can drop away and you won't fall (you're stuck to the wall, essentially). What force is responsible for producing your centripetal motion on the ride? What force is responsible for your not falling when the floor is dropped? If the room has a radius of 4m, and the walls rotate at a speed of 12m/s, how much centripetal force would a 65kg person experience on the ride?

   Hint: to answer the first questions, think about the fact that the person on the ride "wants" to move in a straight line (in the sense of Newton's first law), but something is preventing that and causing the person to turn. It might help to think about a physical object that's part of the ride that prevents the person from traveling in a straight line (as in, if you removed that object, the person would be free to move in a straight line). That object causes the force. For the second problem, you need to use the same logic, just with the modification that the person "wants" to fall due to gravity, but there is some force preventing that fall. Lastly, what formula do you think about when you think about circular motion? Does that formula depend upon speed and the radius of orbit?

   Answer: (in order) normal force, static friction, and 2340N

3. Suppose someone were on a roller coaster going over a hill, and remained upright during the trip over the hill. If the speed going over the hill was 15m/s, the hill had a radius of curvature of 45m (that is, if it were a circle, its radius would be 45m), and the person's mass were 55kg, what would the apparent weight of the person be at the peak on the hill? To help visualize the problem, imagine the person were sitting on a scale. What would the scale read at the top of the hill? How fast would the roller coaster have to go for the person to be in danger of being thrown off?

Hint: at the peak, the motion is roughly circular. What constraints does circular motion put on the physics? Also note that the apparent weight is not the same as the weight, hence the name. Lastly, you need to think about the implications (with regards to forces) that losing contact with your seat on a ride have. Just like at the maximum height, an object always has a y-velocity of zero, there is something about the forces on an object that's distinct for something just losing contact with a surface.

Answer: $W_{\text{apparent}} = 264\text{N}$, $v_{\text{max}} = 21\text{m/s}$

4. A jogger is running around a 400m, circular track at a speed of 5m/s. What is the orbital period of the jogger around the track? How many laps can the jogger complete in one hour?

   Hint: for the first question, recall that velocity is a distance over time. How far does the runner go each lap? What does the period represent with regards to running these laps? For the second question, the period represents how long (in s) it takes to perform 1 lap. How many 80s intervals does 1hr (3600s) have?

   Answer: $T = 80\text{s}$, $N = 45$ laps

5. A newly discovered planet in some distance solar system orbits its star at roughly the same distance that we are from the Sun (in the so-called "habitable zone"). If the star that this planet orbits is half the mass of our Sun, but twice the radius, how long, in days, would a year be on that planet?

   Hint: you have information about the mass of this star, the distance between the planet and the star, and the period of the orbit. What equation relates these three quantities? This is a proportionality problem, by the way; you can find you a year on this planet relates to a year on Earth, which is 365 days, and that'll tell you the number of days on the planet.

   Answer: 516 days

6. During an Olympic bobsled run, the Jamaican team rounds a corner of radius 8m at a speed of 30m/s. How many g's do they "pull" during this turn; that is, what is their centripetal acceleration in units of g?

   Hint: calculate the acceleration of the turn, and then figure out how many units of g this represents, i.e. how many times 9.8m/s^2 fits into your answer.

   Answer: $11.5g$

7. How rapidly is the Earth accelerating towards the Sun? You may find it useful to know that 1 year is approximately $\pi \times 10^7$s, the mass of the Earth is 5.97×10^{24}kg, and the average distance between the Earth and the Sun is 1.5×10^{11}m.

   Hint: the Earth isn't moving closer to the sun, but the Earth's acceleration is pointing towards the sun. Find the acceleration of the Earth given its motion around the sun. By the way, before using any equations involving a mass term, make sure you know what that mass represents.

   Answer: $.006\text{m/s}^2$

Chapter 6: Work & Energy

1. A 50 kg child goes down a slide starting from a height of 1.2m. If the friction of the slide was just enough to keep the child at a constant speed down the slide, how much work would friction have done by the time the child hits the ground?

   Hint: this problem involves energy during the motion of the child. If the child moves at a constant speed, what does that imply about the energy of the child? Because friction is acting on the child, energy is not conserved, but there is still a way to relate energy quantities that takes into account the amount of work done by a non-conservative force.

   Answer: -588J

2. If it takes 185kJ of work to accelerate a car from 25m/s to 30m/s, what is the car's mass?

   Hint: you can't assume the acceleration is constant in this problem, so you can't use kinematics. Without kinematics, you can't determine the magnitude of the force. So you need to find an equation that'll tell you something about the work that has nothing to do with forces. This equation will allow you to find the mass.

   Answer: 1345kg

3. If a 2500kg car is moving at a speed of 25m/s when a dog suddenly runs out into the road and the driver slams on the brakes. In coming to a stop, how much energy was released as heat from the brakes, assuming that the car never changed altitude?

   Hint: the two keys things about this problem are (1) that energy is not conserved in this system, and (2) since the energy isn't conserved, it is just "lost" into space as heat. Find a way to calculate the amount of energy lost, and that'll be the amount of heat released.

   Answer: 7.81×10^5J

4. If a pitcher can throw a baseball with a force of 100N, and her hand travels a distance of 1.5m over the throw, what is the speed of the ball when it leaves her hand? Assume that the throw occurs along a straight path, and that the baseball has a mass of 150g.

   Hint: you know the force and the distance traveled by the ball, so the work can be calculated directly. How the work done by the throw relate to the speed gained?

   Answer: 44.7m/s

5. Suppose a 60kg person could jump to a height of 35cm. How much work would the ground have to do on the person during the initial stages of the jump, prior to leaving the ground, in order for the person to jump this high?

   Hint: don't worry about how the mechanics of the jump work at all; they're not relevant to this problem. Reaching a maximum height will tell you the speed the person must leave the ground with. Knowing that speed, you can find how much work the ground must do on the person.

   Answer: 205.8J

6. A 50kg skateboarder skates through a course at a local park, beginning with a speed of 2.5m/s. Throughout the course, the skateboarder does an additional 70J of work by pushing himself along the ground with his foot and friction does a total of -250J of work on him. Consider both of these forces to be non-conservative. If the speed of the skateboarder is 6m/s at the end of the course, what was his total change in potential energy during the course? Is he above or below the height at which he began?

   Hint: don't forget that energy isn't conserved in this case; the problem specifically tells you how much work each non-conservative force does. There's a general equation that we use that allows us to incorporate non-conservative work which will allow you to solve the problem. How do you interpret ΔU to know whether you gained height or lost height?

   Answer: -924J, and the skater ends at a lower height

7. There was a very famous problem in physics, now known as the Brachistochrone problem, in which the goal was to find the shape of a downward curve that would allow an object to slide down under the influence of gravity in the least amount of time possible. This shape is known as a Brachistochrone, hence the name of the problem. The problem was solved by many prominent physicists at the time, including Isaac Newton, how had to invent a new form of mathematics for his solution. Without knowing anything about the shape of the curve, only that there is no friction on the surface, how fast will the object be going when it hits the bottom if it started out at a height of 20cm?

   Hint: the solution to this problem has nothing to do with the story being told, and it has nothing to do with the shape of the slope. Since there's no friction, there are no non-conservative forces doing work. How, then, can you relate the drop in the height of the object to the speed gained? Note that you cannot use kinematics because the acceleration isn't a constant.

   Answer: 1.98m/s

8. A 2000kg car drives up a hill, its engine doing 1×10^6J of work during the trip. If the car began at rest at sea level, and was moving at a speed of 25m/s after climbing a height of 150m, what is the total work due to all non-conservative forces *not ignoring air resistance or friction* on the car during the climb?

   Hint: don't worry about how air resistance works, since we've never discussed it. You can calculate the work due to all non-conservative forces by analyzing the net affect it has on the energy of the system. We have an equation that allows us to look at the way energies change based on non-conservative works.

   Answer: 2.56×10^6J

Chapter 7: Momentum

1. A 15kg object, moving at a speed of 12m/s, undergoes a perfectly inelastic collision with a 7kg object at rest. How much kinetic energy was lost by the system during the collision?

   Hint: you can't solve this directly, because there is no equation for how kinetic energy changes during a collision. But you do know something that is always conserved in a collision, and that will allow you to calculate the kinetic energy after the collision. Taking the difference of that with the initial kinetic energy is the change.

Answer: -344J

2. A bomb explodes in midair, sending a 100kg fragment at a speed of 50m/s at an angle of 28^o below the horizontal. At what speed would the rest of the fragmented bomb, with a mass of 135kg, move away from the explosion?

   Hint: there are two important things to note about this problem: (1) the explosion is an internal process, so even though energy isn't conserved, something else is, and (2) this problem is not a two-dimensional problem, even though it appears to be. Draw out the problem, and you'll see that everything interesting happens along one line, so it's really a one-dimensional problem.

   Answer: -37m/s

3. A 50N force is applied on a 40kg box for 2s. What is the box's gain in momentum during this push?

   Hint: this problem can be solved using kinematics, because the acceleration is constant, but there's a faster way to do it. How does a force relate to a change in momentum? This relationship will allow for a quick calculation of the answer.

   Answer: 100Ns

4. Two objects undergo a head-on collision after which they stick together. If one object had a mass of 1.5kg and was moving at a speed of 12m/s and the other had a mass of 2.7kg and was moving at a speed of 7m/s, what would the speed of the objects after the collision be? In which direction would they be moving: along the initial path of the 1.5kg or along the initial path of the 2.7kg object?

   Hint: what type of collision is this? What does that imply about the equation you're going to use to analyze the collision? The way to give the direction is weirdly worded, but it's easy to see when you choose one direction to be positive. Remember that the v's in the momentum conservation equation are vectors, so their sign matters.

   Answer: 0.21m/s in the direction the 2.7kg object was initially traveling.

5. A 1500kg car, moving at a 10m/s, collides head on with a 2500kg truck moving at an unknown speed. If their wrecked cars move as one after the collision, and the slide to a stop over a distance of 15m under the influence of a 0.4 coefficient of kinetic friction, what was the speed of the truck just before the collision?

   Hint: this problem occurs in two parts: what happens during the collision, which occurs in an instant, and what happens after the collision, as the wreckage slows to a stop. You need to treat each of these as independent problems. Writing down the equatuions to solve the collision, you'll see that you're missing a piece of information. The motion of the car after the collision (which, once again, has nothing to do with the collision; do not assume momentum is conserved) will tell you what that piece of information is.

   Answer: 11.3m/s

6. A super-bouncy ball is dropped from a height of 1.3m onto a floor. Assuming that the ball collides elastically with the floor, at what speed does the ball leave the floor? *Hint: use the formula specific for elastic collisions to solve this problem, not conservation of momentum.*

   Hint: the equation that I pointed out relates the velocity of each member participating in the collision. The ball's counterpart in this collision is the floor. What are the initial and final velocities of the floor? This will tell you how the final velocity of the bouncing ball relates to the initial velocity of the bouncing ball. Note that this initial velocity is not the initial velocity it's dropped with, but the velocity with which it begins the collisions, i.e. the velocity it hits the ground with. You can treat this part of the problem like you would any object falling some height under the influence of gravity.

   Answer: 5.04m/s

7. A 2.5kg bowling ball is tied to the end of a string and held at rest at a height of 2m. The bowling ball is to be dropped, swing towards a block of wood, and collide with the block of wood elastically at the bottom of its swing. If the bowling ball stops as a result of the collision, how much kinetic energy did the block of wood gain?

   Hint: this problem cannot be solved by using momentum conservation during the collision to find the speed of the block after the collision, and then calculating the kinetic energy of the block. This is because in order to calculate the kinetic energy with the speed, you need to know the mass of the block, which you don't. What you need to think about is what implications the type of collision that is occuring has on the energy of the system. This will tell you how to find the kinetic energy of the block. Also, you need to treat the dropping of the bowling ball as a separate process that occurs before the collision and has absolutely nothing to do with the collision; momentum is definitely not conserved during the drop.

   Answer: 49J

8. If a Boeing 747 engine can produce 250kN of thrust simply by moving air at around 170m/s through it. Considering that air has an average density of 1.2 kg/m^3, how many cubic meters of air must move through the engine per second in order to reach those thrust levels? In this case, note that

$$\frac{\Delta p}{\Delta t} = v\frac{\Delta m}{\Delta t}$$

   and that the density is the amount of mass contained in 1 cubic meter of air (in these units).

   Hint: this was included more as a challenge question. If you can solve this, you can probably solve any momentum problem. What you need to focus on is the fact that momentum is momentum is conserved in this system, and not worry about what the engine is doing specifically. Note that, when the engine is off, the air is stationary, but when the engine is turned on, the air starts to move through the engine. Does this air gain this velocity for free? Are there any consequences for the engine due to this gain in velocity of the air? The next thing to realize is that thrust is a force (look at the units, which are Newtons). A force is going to be related to the equation given in the problem. Next, you need to interpret the term $\delta m/\delta$, which is a change in mass over time. The change in mass is the amount of mass of air that moves through the engine, so what would $\delta m/\delta t$ represent? There is one last piece to the solution of this problem, which is that the answer is asking for how rapidly air must be moving through the engine by volume, not by mass. The density relates the mass to the volume, so if you can calculate how much air, by mass, moves through the engine in 1s, you can convert that to a volume by using the density.

Answer: $1225 \mathrm{m}^3/\mathrm{s}$