Things you should be able to answer for Exam II:

From the Lab, *Newton's Second Law of Motion*:

1. Why is the acceleration of the cart, once it is free of the "pushing hand" and before it collides with an end, predicted to be a constant if friction is ignorable? What does a constant acceleration imply for graphs of position-time, velocity-time, and acceleration-time? What is the value of the acceleration when the cart momentarily stops and turns around? Does the tension in the string change value or direction during the round trip motion under the stated friction-free assumption? Is the magnitude of the tension equal to the weight of the falling mass? Why? The tension is assumed to have approximately the same value throughout the string. Under what (artificial) conditions is the tension exactly the same throughout the string?
2. How do you *correctly* calibrate the force sensor? How do you *correctly* read force from one run to the next? What aspect of the force sensor design has to be especially accounted for to minimize frictional drag on the cart?
3. In the first set of exercises a "polynomial fit of degree 2" is used to examine position-time data. What does "polynomial of degree 2" mean? Why is a *polynomial of degree 2* used instead of some other degree or a sine function, for example? Be able to state correctly what each term in the statistical output for the fit represents.
4. For the same set of exercises a simple mean is found for the tension data; why? What does the statistic "standard deviation" tell you? How is standard deviation calculated? How do you use standard deviation to test whether two measured values are *consistent* with each other?
5. If the assumption that friction is ignorable is relaxed, then the acceleration of the cart is *not* constant over a round trip. The magnitude is greater when the cart is moving up the track than down. Why? Suppose that the magnitude of the frictional force is the same as the cart moves up and down the track. What do position-time, velocity-time, and acceleration-time graphs look like in this case? How do you find values for the "up" and "down" accelerations? Does the tension in the string change value or direction during the round trip motion when friction is important? Why? Were your data consistent with the assumption that the frictional force is due to kinetic friction? Why?

From the Lab, *Work and Energy*:

6. If friction can be ignored it is predicted that

$$W_{net\ on\ cart} = T_0 \Delta x \text{ and } W_{net\ on\ falling\ mass} = -(T_0 - mg)\Delta x \, .$$

What is the meaning of all of the symbols in this prediction? What mass is represented by m? What displacement is Δx? Why do both works depend on Δx? Are tension and gravity the only forces acting in this situation? If not, where is the work due the other forces? What is the sum of the above works explicitly equal to? What is the sum also equal to (using the work-energy theorem)? How does the latter result become a statement of the conservation of mechanical energy?
7. Were you able to detect a clear change in the tension in the string during the round trip motion? If the tension did not (appreciably) change, how do you calculate the work done by tension on the cart and on the falling mass during a displacement from x_i to x_f? Given a graph of position versus time identify a position where velocity is zero. How do the data you took allow you to compare the works done in an interval on both bodies to change in their kinetic energies?

8. What is Δx in a round trip? What should the work done by gravity and tension (if it is constant) be in a round trip? What should ΔK be in a round trip, if friction is absent? What should ΔK be in a round trip if friction is important? The Second Prediction says that the work done by friction in a round trip should be $-fd$. What is f, what is d? Why is this work *not* zero?

From the Lab, *Harmonic Oscillations*:

9. How do you measure the spring constant statically? The First Prediction says that $x = mg/k$ for a static measurement. What is x and what is mg? Why is this relation true? Why do you add a small mass to the spring before you begin measuring stretches? The force sensor was not used in this part of the experiment. If it was calibrated as instructed, what force would it have read in this part of the experiment—the force applied to the spring by the hanging mass or something else? Explain why the slope of the straight line from ForceFit is the desired value of k. What does a "regression coefficient" measure?

10. What is the relationship between the frequencies of the measured position-time data and the measured force-time data? Why? What is the phase relation between the measured position-time data and the force-time measured data? Why? (This is a slightly tricky point.) What is the phase relation between measured position-time data and inferred velocity-time data? (What does "infer" mean, here?) What is the phase relation between measured position-time data and inferred acceleration-time data? A plot of acceleration as a function of position is fit by a straight line. Why? The value of the slope is related to a frequency. How? The slope is also related to physical properties of the system. Which ones?

11. The analysis of your data shows that the measured value of ω^2 is *not* equal to the value of k/m. Why is that true?

12. What is the primary difference between oscillations of a mass on the end of a spring and a mass on the end of a rubber band? Explain the difference using the ideas: *total mechanical energy equals coherent plus incoherent mechanical energy* and *total mechanical energy is conserved*.

From 4.7-4.12

13. Be able to draw a free body diagram with all forces about the right size and with the bodies that are responsible for all forces correctly identified. Is ma one of the forces on a free body diagram? Why or why not?

14. Define static and kinetic friction. Write down formal expressions for the forces of static and kinetic friction. Why is it that when your car's tires roll without slipping you can get a larger acceleration than when they slip?

From 5.1-5.3, 5.5 and 10.3-10.4:

15. What is *uniform* circular motion? Define period and angular speed. Write speed in uniform circular motion in terms of radius and period and radius and angular speed.

16. Why is there acceleration in uniform circular motion? In which direction does the acceleration point? What is its magnitude in terms of radius and: speed? period? angular speed?

17. What is Hooke's Law? What is meant by "restoring force?" What are the dimensions and units of *spring constant*?
18. What is *simple harmonic motion* (SHM)? What is the *amplitude* of SHM? How are SHM and uniform circular motion related? Under what condition on ω, *k*, and *m* are SHM and uniform circular motion essentially the same thing?

From 6.1-6.5, 6.7, 6.9, and 10.5, and handout notes:

19. Define *work* done by a force in an infinitesimal displacement. What are the dimensions and units of work? What does this definition lead to for a constant force? (An equation) Be sure to be able to say when work is positive, negative, and zero.
20. Define *kinetic energy*. What are the dimensions and units of kinetic energy? State the *work-energy theorem.* Be able to use the work-energy theorem to solve problems (e.g., 15, 19, 24, 32, 36, 44, 50, and 54 from Ch. 6, 54 and 55 from Ch. 10).
21. What is the potential energy associated with the gravitational interaction of a mass and the Earth, near the surface of the Earth? What is the potential energy due to a spring-mass system? What are the dimensions and units of potential energy? How are these potential energies related to work?
22. What is *mechanical energy*? What is the difference between *coherent* and *incoherent* mechanical energies? What is the statement of conservation of mechanical energy? What is a *conservative force*? What do *nonconservative* forces do to mechanical energy?
23. What is *power*? What are the dimensions and units of power?
24. Sketch an energy versus position graph for a frictionless spring-mass system that contains potential energy and mechanical energy. From it, deduce that the motion is periodic and determine the amplitude of the motion.
25. Be able to state what differences there are between simple harmonic motion, damped harmonic motion, and damped, driven harmonic motion. Damped harmonic motion is said to have an *attractor*. What does that mean, and what is the attractor for damped harmonic motion? Does simple harmonic motion have an attractor?
26. A damped, driven harmonic oscillator is also said to have an attractor. Describe it. Be able to sketch a rough graph of the amplitude of the attractor of a damped, driven harmonic oscillator as a function of driving frequency. Where does the graph have its maximum? How does the maximum amplitude depend on friction and on driving force amplitude? What does *resonance* mean for attractor amplitude, and for energy dissipated by friction? What does resonance have to do with the design of bridges and skyscrapers?

From 7.1 and 7.2:

27. Define *momentum*. How is Newton’s Second Law expressed in terms of momentum? Under what condition is the total momentum of a system conserved? Why? Use conservation of total momentum of a system to do a simple problem (e.g., 16, 23 from Ch 7).