PHYSICS 131 EXAM 2 10 October 2000

INSTRUCTIONS: Write your name on the front of the blue exam booklet. The exam is closed book, and you may have only a pen/pencil and a calculator (no stored equations or programs and no graphing). Show all of your work in the blue book. For problems II−V, an answer alone is worth very little credit, even if it is correct − so show how you get it.

Suggestions: Draw a diagram when possible, circle or box your final answers, and cross out parts which you do not want us to consider.

In all problems neglect the effects of air resistance unless explicitly stated.

I. Multiple Choice Questions (4 points each). Read each question carefully. Write the SINGLE correct answer in the grid given inside your blue book. No explanation is required, and no partial credit will be given.

1. A mass m is traveling at an initial speed v_0 = 25.0 m/s. It is brought to rest in a distance of 62.5 m by a force of 15 N. The mass is

A.) 37.5 kg B.) 3.00 kg C.) 1.50 kg D.) 6.00 kg E.) 3.75 kg

2. A shopper steps on an escalator moving downward at a constant speed towards the bargain basement in a large department store. On his way down, the normal force exerted on him by the step of the escalator is

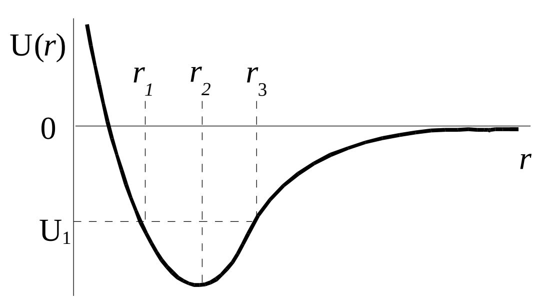
A.) greater than his weight when he is off the escalator.
B.) equal to his weight when he is off the escalator.
C.) less than his weight when he is off the escalator.
D.) dependent on how fast the escalator is moving.
E.) unknown; not enough information to answer.

3. Two objects are sliding at the same speed across a wooden surface. The coefficient of kinetic friction between the first object and the surface is twice that between the second object and the surface. The distance traveled by the first object before it stops is *S*. The distance traveled by the second object is

A.) 2*S*
B.) *S*/2
C.) *S*
D.) 4*S*
E.) impossible to determine without knowing the masses of the objects.

4. The potential energy of an atom bound into a diatomic molecule is shown in the figure below as a function of the radial separation of the two atoms. Which of the following is FALSE:

A.) The atom feels a strong force in the $-r$ direction when $r < r_1$.
B.) An atom whose total energy is less than U_1 will oscillate between r_1 and r_3.
C.) An atom given a total energy greater than zero will become unbound (i.e., can reach $r = \infty$.)
D.) A very large amount of energy is required to move the atom to $r = 0$.
E.) The atom feels a force in the $-r$ direction between r_2 and r_3.



5. Negative work done by an applied force implies that

A.) the kinetic energy of the object increases.
B.) the applied force is variable.
C.) the applied force is perpendicular to the displacement.
D.) the applied force has a component that is opposite to the displacement.
E.) nothing; there is no such thing as negative work.

Problems. (20 points each) Write the complete solutions in your blue book. Remember that no partial credit will be given for an answer with no supporting work.

II. A football is dropped from rest from a high altitude. In this problem, we will consider air resistance NOT to be negligible.

(a) Copy the following set of axes into your blue book and sketch the kinetic energy of the football as a function of the distance fallen.

(b) If the drag force on the football is given by $F = -bv^2$, use Newton's laws to find the terminal (asymptotic) velocity of the football. Take $b = 0.1$ kg/m, and the mass of the football to be 1.5 kg.

(c) Now, consider the following situation: fourth down and 33 to go, the Stanford punter is rushed and accidentally kicks the ball straight up in the air. Compare the time it takes for the football to reach the apex of its flight to the time it takes to fall back to the field: does it take the ball longer, shorter, or the same time to come back to earth as it does for it to reach its highest point? Explain.

III. U.S. Sprinter Marilyn Jones can run the 100m dash in 10.75 sec. We would like to calculate the maximum power output of a very fit human being. Let's assume that her mass is 60 kg, and that she reaches her maximum output power very quickly so that it is effectively constant over the race.

(a) Using the definition of power given on the formula sheet, derive a relation between her velocity, mass, output power, and the elapsed time. Hint: there is no change in potential energy here, so the work she does is equal to her change in kinetic energy.
(b) Using the fact that $v=dx/dt$, write an integral expression that will allow you to relate her position to the elapsed time.
(c) Evaluate this expression to yield an equation for x in terms of t. It should look like $x = (8P/9m)^{1/2}\, t^{3/2}$. What is her output power?

IV. A block of mass m slides along a frictionless table with velocity v and collides with a massless plate supported by two springs with different spring constants k_1 and k_2, as shown in Figure IVa, below.

(a) Assuming the plate remains completely vertical, calculate the maximum compression of the two springs.
(b) Now, assume that the springs are in series, rather than in parallel, as shown in Figure IVb. Calculate the total distance the two springs are compressed in this case.
(c) What is the force on the block at this point of maximum compression?

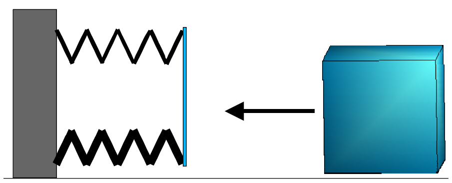


Figure IV a

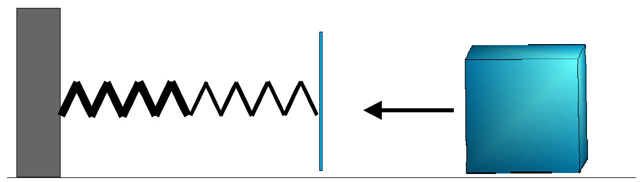


Figure IV b

V. In a recent debate on the proposed Anti−Ballistic−Missle defense system, an MIT physicist chastised some Defense consultants for not understanding freshman physics. The point of contention was their claim that the defense system would be able to distinguish between the real (heavy) warheads and light decoys of exactly the same shape by measuring their trajectories in space. To make this more concrete, assume you are the operator of the anti−missle missle system, and you see two nuclear warheads appear over the horizon, each traveling with an initial velocity v and an angle θ above your (horizontal) line of sight. You suspect that one of the warheads has mass M, the other has mass 1/1000 M. Neglecting air resistance (they're traveling in space, after all),

(a) what is the maximum height above your line of sight that each of them reaches? Assume gravity is perpendicular to your line of sight.
(b) Calculate the velocities of each of the masses at this point.
(c) Now, in reality, the force of gravity on an object is given by $F = GM_{\mathrm{Earth}}M_{\mathrm{object}}/r^2$, where M_{Earth} is the mass of the earth, G is the gravitational constant, and r is the distance of the object from the center of the earth. If you use this form of the force due to gravity in your calculation, will it change your answers to parts (a) and (b)? If so, how? (Hint: what is the acceleration as a function of r for each mass?)
(d) If you only have one shot, which of the warheads do you destroy? Why?