PHYSICS 131 FINAL EXAM 13 December 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.

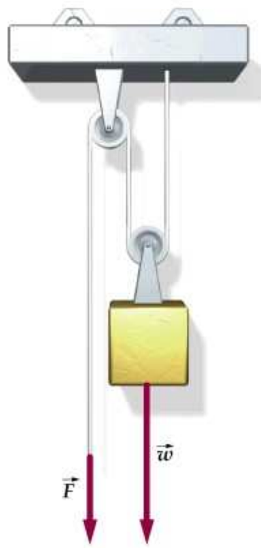
In all problems neglect the effects of air resistance unless explicitly stated.

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. The gravitational potential energy of an object changes by −6 J. It follows that the work done by the gravitational force on this object is

A. −6 J and the elevation of the object is increased.
B. −6 J and the elevation of the object is decreased.
C. +6 J and the elevation of the object is increased.
D. +6 J and the elevation of the object is decreased.

2. Consider the apparatus shown in the figure. If the weight of the block is 100.0 N, what force *F* is required to hold it up

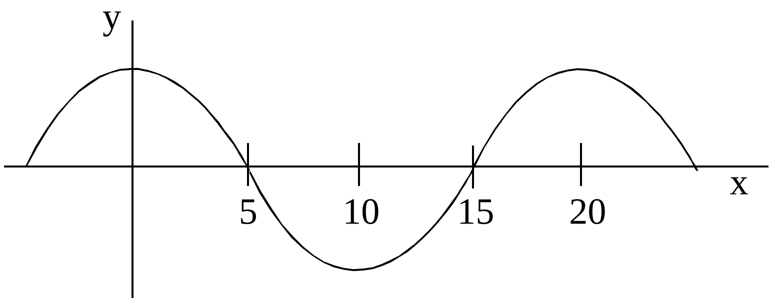


A. 50.0 N
B. 70.7 N
C. 90.0 N
D. 100.0 N

3. The gravitational force on a satellite of mass *m* orbiting at a speed *v* and at a height *h* above the surface of a planet of mass *M* and radius *R* is:

A. in the same direction as the velocity of the satellite.
B. equal in magnitude to $Mv^2/(R+h)$ (*M* is the planet's mass).
C. equal in magnitude to $mv^2/(R+h)$ (*m* is the satellite's mass).
D. equal and opposite to the normal force, so Fnet=0.
E. equal in magnitude to $mg(R+h)$.

The following three questions apply to the figure, below, which shows the picture of a travelling wave taken at time $t = \pi/4$ seconds. Assume for this question that the equation for a wave travelling to the right is given by $y = A\sin(kx - \omega t + \delta)$.



4. The wavenumber k of this wave is closest to

A. 20.0 B. 10.0 C. 3.14 D. 0.314 E. 0.157

5. Assuming the angular frequency ω of this wave is 0.5, what is the velocity v of the wave?

A. 10.0 m/s B. 0.0159 m/s C. 1.59 m/s D. 3.14 m/s E. 0.0796 m/s

6. At what time will the crest reach $x = 5.0$ m?

A. 3.412 s B. 3.925 s C. 1.571 s D. 10.00 s E. 6.675 s

7. The position **r** of a particle is given (in some units) as a function of time t by the following expressions. In which case is there NO force acting on that particle?

A. $\mathbf{r} = (1+2t)\mathbf{i} + (1-2t)\mathbf{j}$ B. $\mathbf{r} = 5t^3\,\mathbf{i}$ C. $\mathbf{r} = 10\cos(6t)\mathbf{i}$
D. $\mathbf{r} = 14\,e^{-3t}\,\mathbf{j}$ E. $\mathbf{r} = 3t\,\mathbf{i} + 5t^2\,\mathbf{j}$

8. Consider two carts, of masses m and $2m$, at rest on an air track. If you push each of them with the same constant force for 3s, the momentum of the light cart is

A. four times B. twice C. equal to D. one−half E. one quarter

the momentum of the heavy cart.

Problems:

II. (12 points) This is an actual article that appeared in the San Francisco Chronicle:

A. Assuming the car was travelling at 100 km/hr and the hoodlum had a pretty good arm and could throw a 1.0 kg turnip at 80 km/hr, find the turnip's momentum and kinetic energy, assuming its line of flight is parallel to the car's direction.

B. Now, assume that the impact on the hapless pedestrian lasted 0.01 seconds. Calculate the average force exerted by the turnip on the pedestrian while it is being stopped.

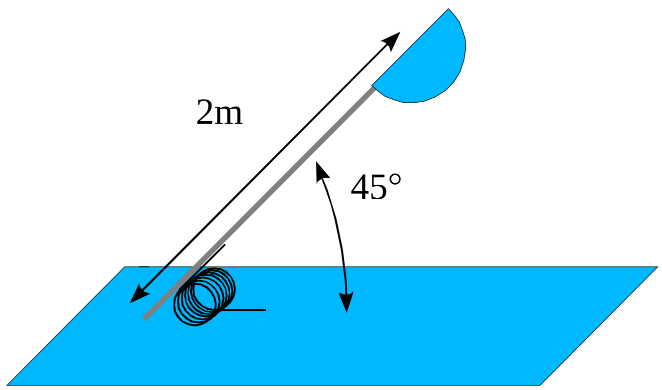
C. Ignoring part B, assume that the pedestrian was in fact wearing special frictionless rollerblades, so that he was free to recoil along the direction of the incident turnip. If the turnip−pedestrian collision was completely inelastic, find the final velocity of the pedestrian. You'll have to assume his mass is 80 kg, and that he was initially at rest.

III. (14 points) In a stunning breakthrough for suburban living, the Acme corporation announces the "Yard−A−Pult". No more paying your hard−earned money for trash removal! Just put your refuse in the launcher, and "zing!",out of sight, out of mind! An excellent way to take care of those pesky household wastes: old charcoal briquettes, dead pets, grass clippings − you name it, you can launch it into oblivion with the new "Yard−A−Pult."

A. The "Yard−A−Pult" mechanism is driven by a torsion spring which applies a torque that is proportional to the angle through which it has been turned, i.e.: $\tau = -\kappa\,\theta$. The hurling mechanism hits a stop at 45 degrees above the flat base of the device. How much work is required to crank the empty (massless) bucket from its highest point down to the flat bed so that it can be loaded up with trash? (Hint: the spring analogy works...)

B. Now, assume that we've placed M kg of highly toxic baby diapers in the launching bucket and are ready to fire away. Find the kinetic energy of the diapers as they leave the bucket, given that, for this part, the length of the hurling arm is L.

C. Some numbers: if the catapult arm is 2.0 meters long, κ=8000 Nm, and the diapers have a mass of 10 kg, how far does our toxic warhead travel horizontally (after it leaves the bucket) before impinging on someone's holiday barbeque?



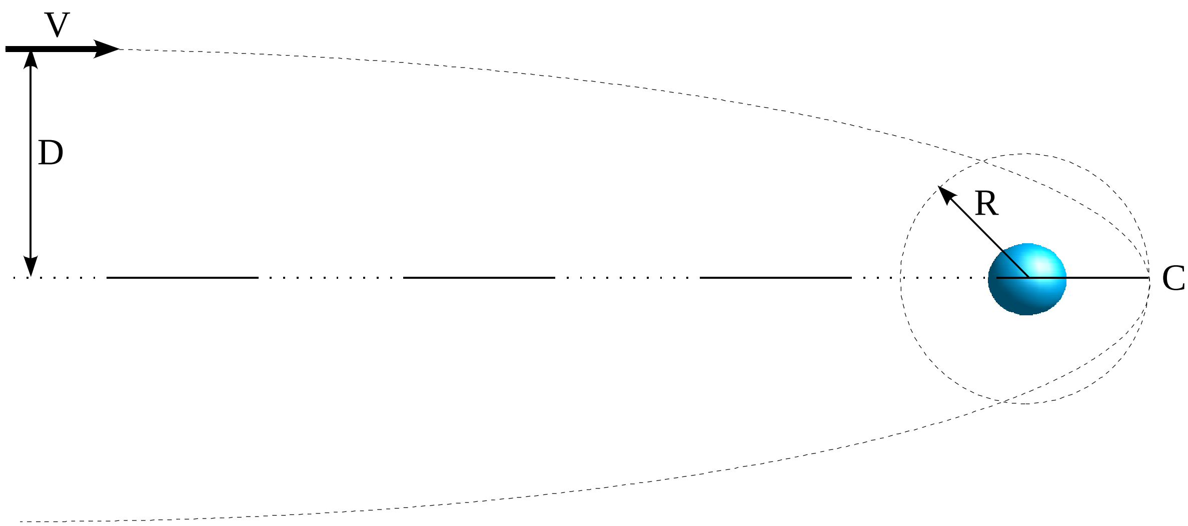
IV. (14 points) In order to stage the Moon landings, the Apollo spacecraft had to fall into a circular orbit around the Moon after their journey from Earth. Assume that the spaceship starts very far away from the Moon a distance D away from a line parallel to its velocity passing through the Moon's center (see diagram), and that its initial velocity there is V. The spaceship has mass m and the moon has mass M.

A. Calculate the initial angular momentum of the spaceship about the Moon's center.

B. For a circular orbit around the Moon of radius R ($R > R_{moon}$!), what is the value of the gravitational potential energy of the spaceship? Assume R is the total radius of the orbit.

C. What is its kinetic energy in this circular orbit?

D. The spaceship fires a thruster in a direction opposite its velocity when it reaches point C on the diagram. How much must its linear momentum change to put it into the circular orbit?



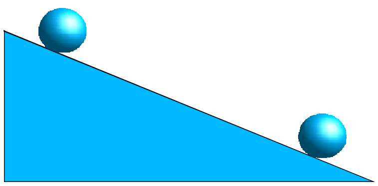
V. (14 points) A ball of radius R and mass M, initially at rest rolls without slipping down an inclined plane, as shown below, where the angle of incline is θ. The coefficient of static friction between the ball and the plane is μ_s, and the coefficient of kinetic friction is μ_k.

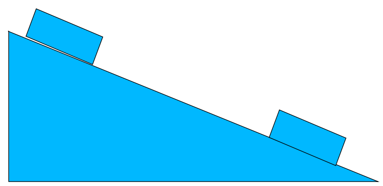
A. Draw a free−body diagram for the ball.

B. Which force causes the ball to roll by creating a torque about the center of the ball? What is the magnitude of the torque, in terms of R, M, θ, μ_s, and g?

C. Now consider a block, also of mass M, sliding down an identical inclined plane. The center of mass of the block travels the same vertical distance as the the ball's before arriving at the bottom. Which arrives at the bottom with more total kinetic energy? Why?

D. Which arrives at the bottom with more linear momentum? Why? Assume that the angle is sufficiently steep that the magnitude of the static frictional force is $\mu_s N$.





VI. A straight rod of negligible mass is mounted on a frictionless pivot as shown in the figure. Masses m_1 and m_2 are suspended at distances l_1 and l_2 from the pivot point.

A. Write an expression for the gravitational potential energy of the masses as a function of the angle θ made by the rod and the horizontal.

B. For the case that $m_1 > m_2$, for what angle is the potential energy a minimum? Is this a point of stable equilibrium? Please explain in a few short sentences.

C. Using the conditions for static equilibrium (i.e., the sum of the forces and torques must be zero), show that if $m_1 l_1 = m_2 l_2$, the balance is stable at any angle θ. Write the potential energy of the masses for this case. From the perspective of potential energy, why is the system stable?