Print name______________________________

ID number______________________________

Section in which you are registered (sec 1 = 9 AM lec, sec 2 = 10 AM lec)__________

Physics 142E, Test No. 1, test session 1

February 18, 2004, 5:30-7:00 PM

On the bubble sheet, fill in your student id number, and in addition write your name and your section in the appropriate spot. After you have found an answer, fill in the appropriate bubbles on your bubble sheet—note any special instructions on this point in the problem itself. The last problem is a multipart problem whose solution should be written out neatly. You can get partial credit for this problem, so make sure that your answers are written out and contain no ambiguities.

No notes or books are allowed during the exam, nor is any consultation with anyone but me. You should be taking the 5:30 exam if you are in section 1 (9 AM lecture) and the 7:30 exam if you are in section 2 (10 AM lecture).

Write out an authorized form of the pledge here, and sign it.

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Signed__________________________

formulas you might need: $\frac{d}{dx}x^n = nx^{n-1}; \int x^n dx = \frac{x^{n+1}}{n+1}$

$v(t) \equiv \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$; $a \equiv \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$

$\vec{v} = \vec{v}_0 + \vec{a}t$; $\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$; $v^2 = v_0{}^2 + 2a(x - x_0)$

$\vec{a} = -\frac{v^2}{r}\hat{r}$

$\vec{F}_{net} = m\vec{a}$

$\vec{F}_{BA} = -\vec{F}_{AB}$

$\vec{F}_g = m\vec{g}$

$0 \le f_s \le \mu_s F_N; f_k = \mu_k F_N$

$W_{net} \equiv F_{net}\Delta x$; $W = \lim_{\Delta \vec{r} \to 0} \sum \vec{F} \cdot \Delta\vec{r} = \int_{\vec{r}_A}^{\vec{r}_B} \vec{F} \cdot d\vec{r}$.

$K \equiv \frac{1}{2}mv^2$

$W_{net} = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 = \Delta K$

$P \equiv \frac{dW}{dt}$.

1. (10 points) True or false: The work done by gravity on a pointlike projectile is always positive.

(a) True.

*(b) False.

Think of an object tossed directly upward. As it rises, the force of gravity and the displacement are oriented in opposite directions. The work done is negative, corresponding in the work-energy theorem to a drop in kinetic energy.

2. (10 points) A 13-kg mass is acted on by two forces, one of magnitude 27 N and the other of magnitude 19 N. If the angle between the forces is 52°, the magnitude of the acceleration of the mass is

(a) 2.05 m/s²

(b) 0, the forces cancel

(c) 1.6 m/s²

*(d) 3.2 m/s²

(e) none of the above

The magnitude of the acceleration is the magnitude of the net force divided by the mass. $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$.

Suppose that force 1, the one with mag 27 N is oriented along the x-axis, while force 2 has an x and a y component. Then $F_{net,x} = F_{1,x} + F_{2,x} = F_1 + F_2 \cos\theta = (27\text{ N}) + (19\text{ N})\cos 52° = 39\text{ N}$ and $F_{net,y} = F_{1,y} + F_{2,y} = 0 + (19\text{ N})\sin 52° = 15\text{ N}$. The net force mag is $F_{net} = \sqrt{F_{net,x}^2 + F_{net,y}^2} = 41\text{ N}$ and $a = F_{net}/m = 3.2\text{ m/s}^2$.

3. (10 points) A car is moving along a straight line at an increasing speed. Given this fact, which of the following can you say is true?

(a) The acceleration is also increasing.

(b) The acceleration is a constant.

*(c) The acceleration may be decreasing.

Not enough info to say that the accel is constant (that would be a speed increasing linearly with time); not enough info to say that the accel is increasing (that would be a speed increasing faster than linearly with time). If the speed is increasing, but at a rate less than linear with time, then the accel remains positive but decreases in value. Thus the "may" in part (c) is operative.

4. (10 points) When two parallel plates, each of area A and separated by a distance y, move with relative speed υ with respect to each other in a fluid, there is a frictional force (the *viscosity*) given by the formula

$$F = \eta \upsilon A/y.$$

The dimensions (*i.e.*, the combination of dimensions mass M, length L, and time T) of the coefficient of viscosity η are

(a) $M \times L^2/T^2$

(b) kilograms, meters, and seconds

(c) L/T

*(d) $M/(LT)$

(e) $M \times T$

If you invert the relation you have $\eta = \dfrac{Fy}{vA}$. You now need only find the dim of the right hand side. Indicate dim with square brackets, and the fundamental ones are mass M, length L, and time T. $[F] = M \times L \times T^{-2}$; $[y] = L$; $[v] = L \times T^{-1}$; $[A] = L^2$. Combining, $[\eta] = M \times L \times T^{-2} \times L \times (L \times T^{-1} \times L^2)^{-1} = M \times L^{-1} \times T^{-1}$.

5. (10 points) What is the average acceleration in m/s² of a car accelerating in a straight line from 0 to 118 km/hr in 2.6 s?

*(a) 12.6 m/s²

(b) 0.118 m/s²

(c) 0.308 m/s²

(d) 59 km/s

(e) cannot be found without more information about the motion

Average, so just take overall changes: $a_{av} = \Delta v/\Delta t = (118 \text{ km/hr} - 0 \text{ km/hr})/(2.6 \text{ s}) = (118 \text{ km/hr})/(2.6 \text{ s})$. The units are mixed, and the only possible answers with the right dim are in units of m/s2. So convert the km to m and the hr to s: multiply by 1 = (10^3 m/km)[(1 hr)/(3600 s)] = 0.28 (m/km)(hr/s):

$$a_{av} = \frac{118}{2.6} \times 0.28 \text{ m/s}^2 = 12.6 \text{ m/s}^2 .$$

6. (10 points) A 7.2-kg mass is suspended from a light rope. The rope is being lowered with a downward acceleration of magnitude 5.6 m/s². The tension in the rope is

(a) 40.3 N

(b) 5.6 N

(c) 9.8 m/s²

(d) 0 as long as the acceleration is constant

*(e) 30.2 N

Let up be the positive direction—all motion is vertical here. The forces on the mass are the tension T (pos) and gravity –mg (negative, with g having the positive value 9.8 m/s^2) and the accel is a = –5.6 m/s^2 (negative). Thus F_{net} = ma reads

T – mg = ma, or solving for the tension, T = m(g + a) = m[(9.8 –5.6) m/s^2] = 30.2 N.

7. (10 points) A conservative force performs 80 J of work in moving an object from point A to point C, 68 J from point B to point D, and 36 J of work from point B to point C. How much work is done in moving the object from point A to point D?

(a) 56 J

(b) 224 J

*(c) 112 J

(d) 56 kJ

(e) cannot be determined from given information

Draw yourself a picture and this is easy. Algebraically, the force is conservative so $W_{A \to D}$ is the work by any path. In particular can go the path A → C → B → D, in which case

$$W_{A \to D} = W_{A \to C} + W_{C \to B} + W_{B \to D}.$$

But remember the calculaus result that an integral is reversed in sign if the limits are reversed, or for us that $W_{C \to B} = -W_{B \to C}$. Thus

$$W_{A \to D} = W_{A \to C} - W_{B \to C} + W_{B \to D} = (80\text{ J}) - (36\text{ J}) + (68\text{ J}) = 112\text{ J}$$

8. (30 points) Consider the system shown, which is released from rest. The string connecting the two masses is ideal (massless and unstretchable), while the pulley is massless and frictionless. Assume there is no friction between m_2 and the ramp surface, at least until you get to part (e).

(a) (5 points) Draw free body diagrams for m_1 and m_2.

I can't draw here. a free body diagram includes the object as a point, a coordinate sys, and the forces acting, approx in the direction you understand them to act. Here I am going to imagine a coord sys for m2 in which x points down along the ramp and y points up perp to the ramp and a coordinate sys for m1 in which y is vertical, with pos up. Then m1 has grav acting along –y, and tension T acting along + y, while m2 has gravity vertically down (both x and y comps), a normal force N along pos y, and the tension T of the string along neg x.

(b) (5 points) What is the set of equations that would allow you to determine the motion of each mass?

These are Newton's 2nd law applied to each mass. We note that the accel of the masses is related because the string is fixed in length: If m_1 has (unknown of course) a along y, then m_2 has a along x. Then 3 eqs for the 3 components:

m_1 along y: $T - m_1 g = m_1 a$

m_2 along x: $-T + m_2 g\sin\theta = m_2 a$

m_2 along y: $N - m_2 g\cos\theta = 0$

Have taken the components of gravity along the axes for m_2. Also have used fact that m_2 doesn't move perp to the ramp.

(c) (5 points) Suppose $m_2 < m_1$. Is there any ramp angle(s) θ_c (between 0° and 90°) for which the system is in equilibrium (i.e. remains at rest if it is released from rest)? If so, what is that angle?

You can guess no. If the ramp is infinitely steep (θ = 90degrees) this is an atwood machine and m_1 drops while m_2 rises. As the ramp gets less steep gravity is "diluted" for m_2 and the movement is even easier. To see this quantitatively, solve the motion eqs. The third eq above doesn't do much, while the sum of the first two eliminates T and gives the accel directly:

$m_2 g\sin\theta - m_1 g = m_2 a + m_1 a$, or $a = -\dfrac{m_1 - m_2 \sin\theta}{m_1 + m_2} g$

If $m_1 > m_2$, m_1 is bigger than $m_2\sin\theta$, and a is negative and nonzero, corresponding to falling m_1.

(d) (5 points) Suppose $m_2 > m_1$. Is there any ramp angle(s) θ_c (between 0° and 90°) for which the system is in equilibrium (i.e. remains at rest if it is released from rest)? If so, what is that angle?

We look at the soln for part (c): If m2 > m1, then it is always possible to find a critical angle θ_c so that the numerator in the expression for a is zero: $m_1 - m_2 \sin\theta_c = 0$, or

$\sin\theta_c = m_1/m_2$, with the ratio on the right properly less than one.

(e) (5 points) The coefficients of static and kinetic friction between m_2 and the ramp are no longer zero, but rather μ_s and μ_k, respectively; the ramp angle is fixed at θ. Write the equations that determine the motion now. Remember that static friction is variable, not necessarily with the value $\mu_s N$.

This part and the next are quite involved and I won't try to do it completely. Friction acts along the ramp, i.e. in the x-direction for m2, and its sign corresponds to a direction opposite to the direction the motion would take if there were no friction. Its magnitude is generally f, which for static friction is variable, from a minimum of 0 to a maximum of $\mu_s N$ – whatever is necessary to keep the system motionless up to the maximum. Once movement takes place the magnitude is the one appropriate to sliding, namely $f = \mu_k N$. N is given by the third eq above, $N = mg\cos\theta$. Thus I would write for the eqs only

m_1 along y: $T - m_1 g = m_1 a$

m_2 along x: $f - T + m_2 g\sin\theta = m_2 a$

m_2 along y: $N - m_2 g\cos\theta = 0$

(f) (5 points) Suppose $m_2 > m_1$. Find a range of ramp angles for which there is no motion, once again assuming that the system starts from rest. It will be enough here to give the equations that determine this range, although you should make sure that you give them in a form for which the solution is evident. You get extra credit if you actually solve the equations.

Best to start from $\theta = \theta c$ and systematically lower or raise the ramp. If youraise the ramp, increasing θ, then without friction the system would slide with m2 moving down (think the atwood machine). Thus friction acts up the ramp (negative sign) and the max no-slide angle θmax occurs when f has its max magnitude, namely $f = \mu_s N = \mu_s m_2 g\sin\theta_{max}$. The relevant eqs are then

m_1 along y: $T - m_1 g = 0$

m_2 along x: $-\mu_s N - T + m_2 g\sin\theta_{max} = 0$

m_2 along y: $N - m_2 g\cos\theta_{max} = 0$

(Note that the accel is zero – the situation is static) Use the last of these to get N, then add the first two to find a condition for θ_{max}:

$$-\mu_s\, m_2 g\cos\theta_{max} + m_2 g\sin\theta_{max} - m_1 g = 0.$$

Generally hard to solve algebraically—have to do some squaring and some trig tricks.

To find the min angle θ_{min}, lower the ramp starting at θ_c. This time friction points down the ramp (to pos x), but otherwise the equations look alike and one has the condition for θ_{min}:

$$+\mu_s\, m_2 g\cos\theta_{max} + m_2 g\sin\theta_{max} - m_1 g = 0.$$