Physics 200 Name KEY

Exam 2 – Friction, Energy and Momentum

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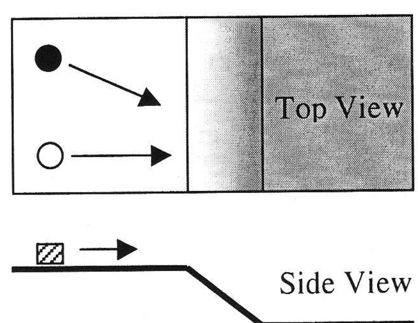
October 29, 2009

This is a closed book examination; however, you may use an index card during the exam. There is extra scratch paper available. Your explanation is worth ¾ of the points. Explain your answers!

A general reminder about problem solving:

- Focus
    - Draw a picture
    - What is the question?
    - List known quantities and unknown quantities
    - List assumptions
- Physics
    - Determine approach – What physics principles will you use?
    - Pick a coordinate system
    - Simplify picture to a schematic (if needed)
- Plan
    - Divide problem into sub-problems
    - Modify schematic and coordinate system if needed
    - Write general equations
- Execute
    - Write equations with variables
    - Simplify and solve
- Evaluate
    - Check units
    - Is answer reasonable? Check limiting cases!
- Show all work! Use extra paper if needed.

The next two questions concern two identical pucks moving on a flat surface that then slide down a ramp. Both pucks have the same initial magnitude velocities. The white puck travels straight down the ramp while the black puck travels at an angle down the ramp (see picture to the right). Assume that there is no friction.



1. [4 PTS] Which puck has more total energy at the bottom of the ramp?
    A. The white puck has more energy than the black puck.
    (B.) Both pucks have the same energy.
    C. The black puck has more energy than the white puck.
    D. Not enough information given.

PE = 0

$KE = \frac{1}{2}mv^2$ KE_i is the same for both pucks

$E_i = E_f$ (no friction)

$KE_i + PE_i = KE_f$ $PE_f = 0$ defined Ø at bottom

PE_i is same for both pucks ∴ E_f is same (independent of path)

2. [4 PTS] Which puck has ~~more~~ a greater magnitude momentum ($|\vec{p}|$) at the bottom of the ramp? $KE = \frac{1}{2}\frac{p^2}{m}$

A. The white puck has more momentum than the black puck.

(B) Both pucks have the same momentum.

C. The black puck has more momentum than the white puck.

D. Not enough information given.

KE_f is same so since $m_W = m_B$ both pucks have same velocity and momentum ($p = mv$)

The next two questions concern a large fluffy animal (LFA) that you are tossing into the air. Immediately after being released (vertically) the LFA has a total energy of 45 J. <u>Do not neglect air drag</u>.

3. [4 PTS] The <u>total energy</u> of the LFA at the tippy-top of the toss is

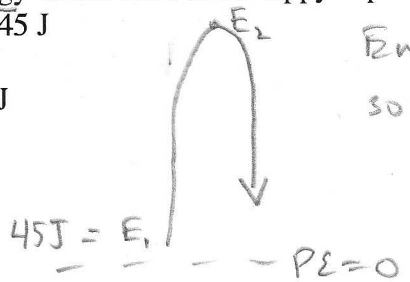
A. greater than 45 J

B. equal to 45 J

(C) less than 45 J

D. equal to 0 J

E. less than 0 J



Energy is lost due to air drag so $E_2 < E_1$

4. [4 PTS] The potential energy of the LFA when it is 1/3 of the distance from the top of its trajectory coming back down

A. is greater than the potential energy at the top of the trajectory ✗

(B) is equal to 2/3 of the potential energy at the top of the trajectory

C. is twice the initial kinetic energy

D. is equal to 1/3 of the potential energy at the top of the trajectory

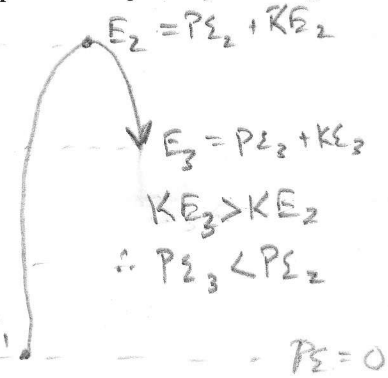
E. zero joules

F. less than zero joules

$PE = mgh$

$PE_2 = mgh$

$PE_3 = mg(\frac{2}{3}h) = \frac{2}{3}PE_2$



The next two questions involve two carts that are identical except they have different masses. The mass of cart 1 is twice the mass of cart 2 ($m_1 = 2m_2$).

5. [4 PTS] The two carts have the same initial velocity and approach an incline. Cart 1 just barely makes it up the incline. What happens to cart 2? <u>Ignore friction</u>.

A. Cart 2 does not make it up the incline.

(B) Cart 2 also just barely makes it up the incline.

C. Cart 2 makes it up the incline with some extra velocity.

D. Not enough information is given.

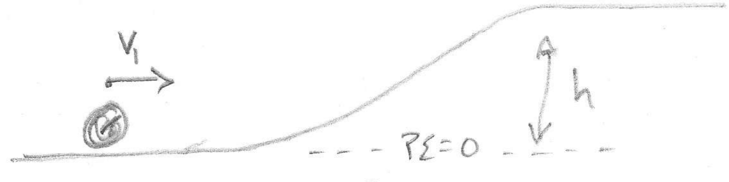
$\frac{1}{2}mv^2 = mgh$

$h = \frac{v^2}{2g}$ independent of mass

$m_1 = 2m_2$

$KE_1 = \frac{1}{2}m_1v^2$

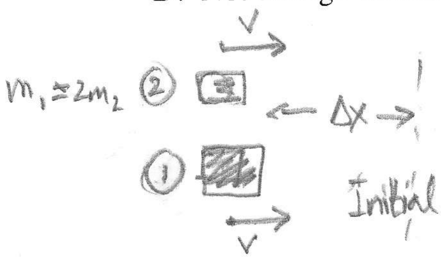
$KE_2 = \frac{1}{2}(\frac{1}{2}m_1)v^2 = \frac{1}{2}KE_1$



$E_i = E_f$

6. [4 PTS] The two carts have the same initial velocity and are pushed with the same force for the same distance. Which cart has a greater kinetic energy after being pushed? Ignore friction.

   A. Cart 1 has the greatest kinetic energy.
   B. Both carts have the same kinetic energy.
   C. Cart 2 has the greatest kinetic energy.
   D. Not enough information is given.



$W = \Delta E = -\int \vec{F} \cdot d\vec{x}$ in this case change in energy is all in KE

ΔE is the same

Initial $KE_1 = 2KE_2$ so final $KE_{1_f} > KE_{2_f}$

$KE_{1_i} > KE_{2_i}$

7. [12 PTS] Suppose that a 0.23 kg ball is traveling at 28.0 m/s (horizontally).
   A. How much work must be done on the ball to stop it?
   B. If it is brought to rest in 3.0 cm, what average force must act on the ball?
   C. What impulse is required to stop the ball?
   D. How long does it take to stop the ball?

8. [12 PTS] You have been asked to determine the velocity of a car at an accident scene on Interstate 94 just across the ND/MN border. The car, a blue late model car with copious quantities of rust, is sitting on the side of the road where it came to a rest after skidding 37 meters. You can clearly see the rubber left on the road from the skidding tires. After consulting the car's manual you note that this model does not have power steering or antilock brakes and has an unloaded mass of 1000 kg. The trunk is open and empty but there are 150 kg of barbells sitting on the side of the road (the police think the driver dumped them after stopping). You assume the driver, a very nervous looking college student, slammed on the brakes the whole time. You consult your physics book and find that the value of the coefficients of friction for rubber tires and a dry concrete road are μ_k=0.80 (kinetic) and μ_s=0.98 (static). Assuming a constant acceleration determine the initial velocity of the car. Justify and explain all assumptions.

Possibly useful mathematical relationships:

Law of Cosines $c^2 = a^2 + b^2 - 2ab\cos(\theta)$ which for θ=90° is the Pythagorean theorem $c^2 = a^2 + b^2$

Trigonometric identities: $\sin^2(\theta) + \cos^2(\theta) = 1$, $\sin(2\theta) = 2\sin(\theta)\cos(\theta)$ and

$\cos(2\theta) = \cos^2(\theta) - \sin^2(\theta) = 2\cos^2(\theta) - 1 = 1 - 2\sin^2(\theta)$

Derivative of a polynomial $\frac{d}{du}Cu^n = nCu^{n-1}$

Anti-derivative (integral) of a polynomial $\int Cu^n du = \frac{1}{n+1}Cu^{n+1} + const.$

The Chain Rule $\frac{d}{dz}f(u) = \frac{d}{dz}u\frac{d}{du}f(u)$

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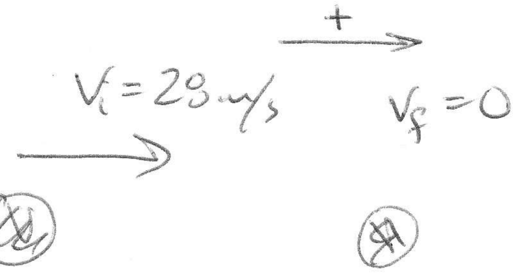

$M = .23\ kg$

(A) $\Delta KE = W$ so $KE_f - KE_i = W$ needed to stop ball

$0 - \frac{1}{2} m v_i^2 = W$

$W = -90.2\ J$

(B) Assume force is constant

$W = \int \vec{F} \cdot d\vec{x} = F \int dx$ where Force is horizontal and $\int dx = \Delta x = 3.0\,cm$

$W = F \Delta x$

$\frac{-90.2\,J}{3.0 \times 10^{-2}\,m} = F = -3005\ N$

(C) $\Delta p =$ Impulse so $m v_f - m v_i = m \Delta v$

$0 - m v_i =$ Impulse

$I = -6.44\,Ns$

(D) $\Delta p = \int F \cdot dt$ use constant (average) force

$\frac{\Delta P}{F} = \int dt = \Delta t$ $\Delta t = \frac{-6.44\,Ns}{-3005\,N} = .0021\,s = 2.1\,ms$

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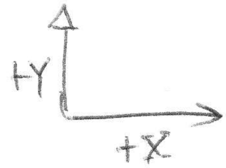
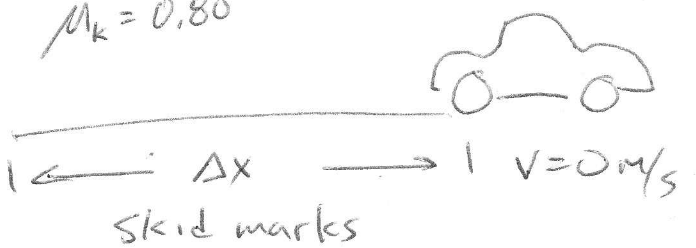
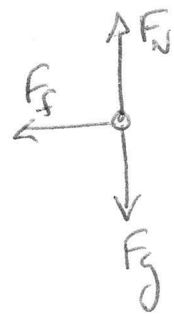


Since car was moving use $\mu_k = 0.80$

Possible added mass

$m = 1000\,kg\ (+\ 150\,kg)$





Y: $F_N - F_g = ma_y = 0 \qquad F_N = F_g = mg$

X: $-F_f = ma_x = -\mu_k F_N$

$$a_x = \frac{-\mu_k(mg)}{m} = -\mu_k g$$

· constant acceleration mass independent!

$$v(t) = \int a_x\,dt = -\mu_k g \int dt = -\mu_k g t + v_0$$

$$x(t) = \int v(t)\,dt = -\frac{\mu_k g}{2} t^2 + v_0 t + x_0$$

Combine to remove time ...

$$v^2 - v_0^2 = 2a_x \Delta x = -2\mu_k g\,\Delta x \qquad V = 0\ m/s,\ V_0 = ?$$

$$v_0 = (2\mu_k g\,\Delta x)^{1/2}$$

units ✓

$\Delta x \uparrow \quad v \uparrow$

$\mu_k \downarrow \quad v \downarrow$ slides longer for same v if less friction

$$V_0 = \left(2 \cdot 0.80 \cdot 9.81\,\frac{m}{s^2} \cdot 37\,m\right)^{1/2}$$

$= 24\ m/s$

$= 53.9$ mph so a "guilty looking" college student was <u>not</u> speeding —