Exam-II Solutions (Fall '07)

1.) *Multiple Choice* *(18 pts.)*

For each statement below, circle the correct answer (TRUE or FALSE, no reasoning required).

(a) In circular motion, a centripetal force does nonzero work.
TRUE FALSE

(b) In satellite motion, for a fixed radius of a stable orbit, the speed of the satellite can only assume one value.
TRUE FALSE

(c) If a nonzero net work is done on an object, the speed of that object must change.
TRUE FALSE

(d) For a nonconservative force, it is possible to define a corresponding potential energy.
TRUE FALSE

(e) If a tennis ball hits a wall head on and bounces back, the magnitude of the momentum transfer on the ball is larger than the magnitude of its momentum before the collision.
TRUE FALSE

(f) In 3 spatial dimensions, the conservation of linear momentum in a collision provides 3 equations for the velocity components of the in- and outgoing particles.
TRUE FALSE

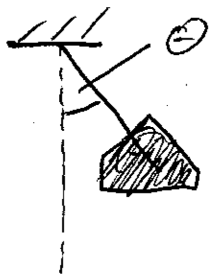
No.	Points
1	TS
2	SR
3	PJ
4	RR
5	SM
6	MS
Sum	

2.) *Circular Motion* (*14 pts.*)

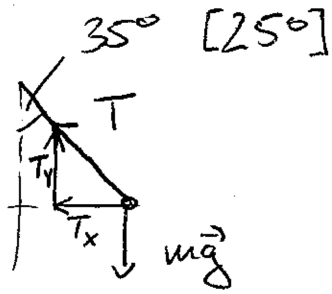
A train drives through a flat curve at constant speed. A bag of weight $16N$, suspended from the luggage compartment by a cord, is found to hang at rest relative to the train, but with the cord making an angle of 35° [25°] relative to the vertical. In this position, the bag is $105m$ from the center of the circle which it describes.

(a) What is the tension in the cord?

(b) What is the speed of the train?



(a)



y-dir. $\sum^{+} F_y = 0$

$T_y - mg = 0$

$T\cos\theta - mg = 0$

$\Rightarrow \boxed{T = \frac{mg}{\cos\theta} = 19.5N}$ [17.7N]

(b) x-dir. $\sum^{+} F_x = F_c = \frac{mv^2}{r}$

$T_x = \frac{mv^2}{r}$

$\frac{mg}{\cos\theta}\sin\theta = \frac{mv^2}{r}$

$\boxed{v = \sqrt{gr\tan\theta} = 26.8\frac{m}{s}}$ $[21.9\frac{m}{s}]$

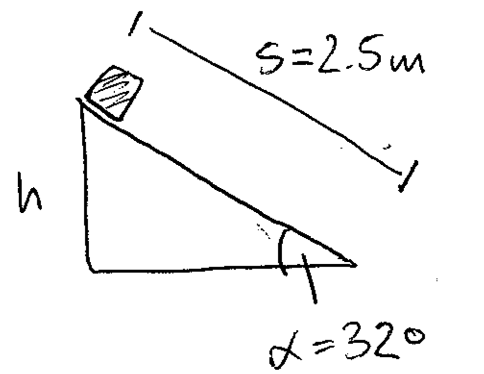
3.) *Nonconservative Work* (21 pts.)

A factory worker is standing on a loading deck, which is connected to the ground by a 2.5m [3.5] long ramp running down at an inclination angle of 32° relative to the horizontal. The worker puts a box of weight 370N at the top of the ramp. The box starts from rest and slides down to the bottom of the ramp. The kinetic friction coefficient between box and ramp is μ_k=0.28.

(a) What is the work done on the box by the friction force?

(b) What is the work done on the box by the gravitational force?

(c) What is the speed of the box at the bottom?



(a) $W_{fr} = -f_k s$

$= -\mu_k F_N s$, $F_N = mg\cos\alpha$

$W_{fr} = -220J$ [$-308J$]

(b) $W_{grav} = -\Delta U = -(U_f - U_i) = mgh$, $h = s\sin\alpha = 1.325m$

$W_{grav} = 490J$ [$686J$]

(c) $W_{nc} = \Delta E = E_f - E_i = \frac{1}{2}mv_f^2 - mgh$

$v_f = \sqrt{\frac{2}{m}(W_{grav} + W_{fr})} = 3.79\frac{m}{s}$ [$4.48\frac{m}{s}$]

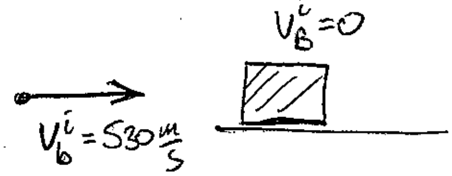
4.) *Collision and Energy Loss* *(16 pts.)*

A bullett of mass $6.7g$ and horizontal velocity $530m/s$ is fired into a block of wood (mass $1.8kg$) which is initially at rest. The bullett penetrates the block and emerges with a horizontal velocity of $85m/s$.
[135m/s]

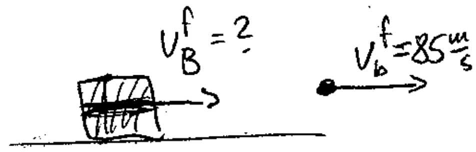
(a) What is the velocity of the block after the collision?

(b) How much energy has been dissipated due to the deformation in the block?

(a) before collision:



after



$$P_i = P_f \qquad m_b V_b^i = m_b V_b^f + m_B V_B^f$$

$$\Rightarrow V_B^f = \frac{m_b}{m_B}(V_b^i - V_b^f) = 1.656\ \frac{m}{s} \qquad [1.47\frac{m}{s}]$$

(b) $$W_{nc} = \Delta E = K_f - K_i = \frac{1}{2}m_B V_B^{f2} + \frac{1}{2}m_b V_b^{f2} - \frac{1}{2}m_b V_b^{i2}$$

$$W_{nc} = 2.468 + 24.2 - 941 = -914.3J \qquad [-878J]$$

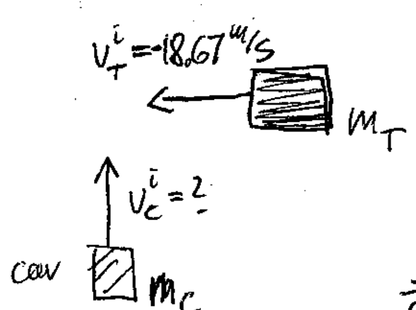
5.) *Inelastic Collision* [2000 kg] (16+1 pts.)

A car (mass 1200kg) and a truck (mass 2900kg) collide at an intersection. Initially, the car has been going due north at unknown speed, while the truck has been going due west at a speed of 42mph. After the collision, the vehicles are stuck together, and the tire tracks reveal that they have been sliding off from the collisions point at an angle of 38° north of west. ($1m/s$=2.25mph)

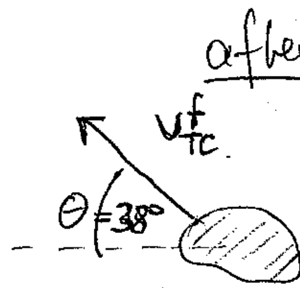
(a) What is speed of the stuck-together vehicles right after they collide?

(b) What was the initial speed of the car? Did it violate the speed limit of 45mph?

(a) before



after



$$\vec{P}_i = \vec{P}_f$$

x-dir: $m_T v_T^i = m_{TC} v_{TCx}^f$ $\qquad m_{TC} = m_T + m_c$

$$v_{TCx}^f = \frac{m_T}{m_{TC}} v_T^i = -13.2\,\frac{m}{s}$$

$$v_{TCx} = -v_{TC}^f \cos\theta \Rightarrow \boxed{v_{TC}^f = \frac{-v_{TCx}^f}{\cos\theta} = +16.8\,\frac{m}{s}} \quad [14.8\,\tfrac{m}{s}]$$

(b) y-dir: $m_c v_c^i = m_{TC} v_{TCy}^f = m_{TC} v_{TC}^f \sin\theta$

$$\Rightarrow \boxed{v_c^i = \frac{m_{TC}}{m_c} v_{TC}^f \sin\theta = 35.2\,\frac{m}{s}} \quad [24.3\,\tfrac{m}{s}]$$

$= 79.3$ mph $\quad$ much above speed limit

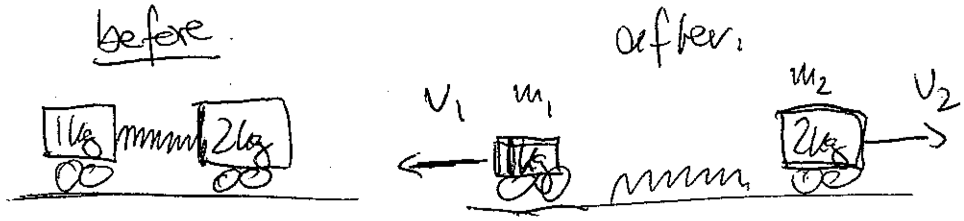
[54.7 mph]

6.) *Energy and Momentum Conservation* (*14 pts.*)

Two masses ($1kg$ and $2kg$) are pressed against opposite ends of a massless spring of force constant $3N/cm$, compressing the spring by $15cm$ [20cm] relative to its uncompressed state. The system is then released from rest. Neglect friction.

(a) How much potential energy is initially stored in the spring?

(b) What are the speeds of mass 1 and mass 2 after moving free of the spring?



(a) $$U_{elast} = \frac{1}{2}kx^2 = \frac{1}{2} 300 (0.15)^2 = 3.375 J$$ [6J]

(b) $\Delta E = 0$ $\quad E_i = E_f$ energy conservation

$$U_{elast} = \frac{1}{2}kx^2 = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 \quad (1)$$

momentum conservation:

$$\underline{p}_i = \underline{p}_f \qquad 0 = m_1 v_1 + m_2 v_2$$

$$\Rightarrow v_1 = -\frac{m_2}{m_1} v_2 \qquad \text{insert into eq. (1):}$$

$$U_{elast} = \frac{1}{2}kx^2 = \frac{1}{2}m_1 \frac{m_2^2}{m_1^2} v_2^2 + \frac{1}{2}m_2 v_2^2 = \frac{1}{2}\left(\frac{m_2^2}{m_1} + m_2\right) v_2^2$$

$$v_2 = \sqrt{2U_{elast} \Big/ \left(\frac{m_2^2}{m_1} + m_2\right)} = \left(\frac{2U_{elast}}{m_2\left(1 + \frac{m_2}{m_1}\right)}\right)^{1/2} = 1.06 \frac{m}{s}$$ [1.41 m/s]

$$|v_1| = \frac{m_2}{m_1} v_2 = 2.12 \frac{m}{s}$$ [2.83 m/s]