Physics 121, Exam 1

(Dated: February 12, 2007)

Name .... **Total score:**

If you write on the back of a page, please indicate this on the front.

No calculators; no other material allowed.

Formula sheet is on the last page.

Show your work.

Good luck!

(For grading only)

Problem 1. (20 pts.)

Problem 2. (20 pts.)

Problem 3. (20 pts.)

Problem 4. (20 pts.)

Problem 5. (20 pts.)

Problem 1, 20pts. (Exact wording need not be perfect, but physical content should be.)

(a) State Newton's first law of motion.

(b) State Newton's second law of motion.

(c) State Newton's third law of motion.

Problem 2, 20pts. You are standing on a highway overpass with an egg in your hand. Your arch-rival emerges from a tunnel at a horizontal distance of $L = 500m$ away, driving his car at a constant speed of $v = 100m/s$, coming directly toward you. When he emerges from the tunnel, you start your clock. The vertical distance from your hand to windshield height is $h = 20m$. **(a)** If you want to nail him on the windshield with your egg, at what time should your clock read when you drop the egg (from rest)? (Neglect air friction, and approximate $g = 10m/s^2$)

(b) What will be the egg's speed when impact takes place?

Problem 3, 20pts. You are practicing your golf swing at a golf practice range. With the club you are holding (a 9-iron), the loft (angle of initial trajectory) is 45° relative to the horizontal. Suddenly, you sight the armored golf-ball retriever vehicle, and want to hit it with your next shot, without bouncing the ball on the ground first (a direct hit). If the vehicle is in front of you at a distance of $L = 90m$, and is moving *away* from you at a constant velocity of $v_c = 10\sqrt{2}m/s$, what velocity should you impart to the ball after impact with the golf club? (Neglect air friction, neglect the size of the vehicle, and approximate $g = 10m/s^2$.

Problem 3, continued

Problem 4, 20pts. A child is playing on his sled outside on an icy sidewalk (so friction can be neglected), next to the wall of a house. The child pushes against the wall to the right (perpendicular to the vertical wall) with a constant force of $80N$. Treat the child and sled as one physical unit.

(a) Draw the force vector acting on the wall from the child/sled.

(b) Draw the force vector acting on the ice from the child/sled.

(c) Draw all force vectors acting on the child/sled and identify where they come from.

(d) If the combined mass of the sled and child is $40kg$, what is the acceleration *vector* of the child/sled unit, while the constant force is being applied?

Problem 5, 20pts. The 'grinch that stole Christmas' is on the top of Mount Crumpit, where after having a change of heart, he is trying to save all the Christmas presents in his sled. Unfortunately, the grinch and his sled are on frictionless ice, so only his mass can serve as a counter-weight to the sled, connected to each other by a massless chord, strung over the peak of Mount Crumpit by a massless pulley (see figure). The sled is hanging off of a cliff that slopes at an angle $\theta = 150°$ to the vertical, and the grinch is on an incline that slopes at an angle $\phi = 135°$ to the vertical (as in figure). The only hope is the grinch's faithful dog, Max, who is standing on rock and can therefore pull with his teeth on the grinch (in the direction shown in the figure).

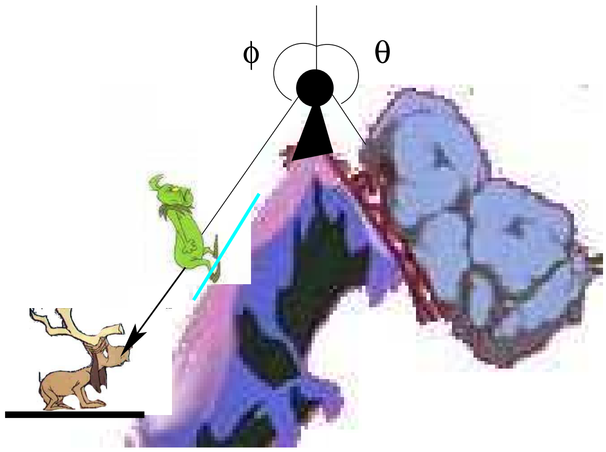

FIG. 1: If the mass of the sled is $M = (50/\sqrt{3})kg$, the mass of the grinch is $m = 20\sqrt{2}kg$, what minimum force does Max need to exert in order to save the day? (Approximate $g = 10m/s^2$)

(a) Draw the force body diagram for the sled.

(b) Draw the force body diagram for the grinch.

(c) Choose x and y axes for the above free body diagrams, and find the x and y components of all relevant forces.

(d) Apply the correct law of Newton.

(e) Put in relevant information from the problem and solve for the minimum force Max needs to pull.

Physics 121, Exam 1, Equations

$$\text{average velocity} = \frac{\text{displacement}}{\text{time elapsed}}, \text{ or } \bar{v} = \frac{\Delta x}{\Delta t} \tag{1}$$

$$\text{average acceleration} = \frac{\text{change in velocity}}{\text{time elapsed}}, \text{ or } \bar{a} = \frac{\Delta v}{\Delta t} \tag{2}$$

$$\text{instantaneous velocity } v = \frac{dx}{dt}; \qquad \text{instantaneous acceleration } a = \frac{dv}{dt} \tag{3}$$

Kinematics equations (acceleration a is constant)

$$v = v_0 + a\,t \tag{4}$$

$$x = x_0 + v_0\,t + \frac{1}{2}a\,t^2 \tag{5}$$

$$v^2 = v_0^2 + 2a\,(x - x_0) \tag{6}$$

$$\bar{v} = (v + v_0)/2 \tag{7}$$

Quadratic formula is solution of equation $a\,z^2 + b\,z + c = 0$,

$$z = \frac{-b \pm \sqrt{b^2 - 4\,a\,c}}{2a} \tag{8}$$

Trig identities:

$$\sin(\text{angle}) = \frac{\text{opposite}}{\text{hypotenuse}}, \quad \cos(\text{angle}) = \frac{\text{adjacent}}{\text{hypotenuse}} \quad \tan(\text{angle}) = \frac{\text{opposite}}{\text{adjacent}} \tag{9}$$

$$(\text{hypotenuse})^2 = (\text{opposite})^2 + (\text{adjacent})^2 \tag{10}$$

$$\sin 45^\circ = 1/\sqrt{2}, \quad \cos 45^\circ = 1/\sqrt{2}, \quad \tan 45^\circ = 1 \tag{11}$$

$$\sin 30^\circ = 1/2, \quad \cos 30^\circ = \sqrt{3}/2, \quad \tan 30^\circ = 1/\sqrt{3} \tag{12}$$

$$\sin 60^\circ = \sqrt{3}/2, \quad \cos 60^\circ = 1/2, \quad \tan 60^\circ = \sqrt{3} \tag{13}$$

$$\sin 120^\circ = \sqrt{3}/2, \quad \cos 120^\circ = -1/2, \quad \tan 120^\circ = -\sqrt{3} \tag{14}$$

$$\sin 135^\circ = 1/\sqrt{2}, \quad \cos 135^\circ = -1/\sqrt{2}, \quad \tan 135^\circ = -1 \tag{15}$$

$$\sin 150^\circ = 1/2, \quad \cos 150^\circ = -\sqrt{3}/2, \quad \tan 150^\circ = -1/\sqrt{3} \tag{16}$$

$$\mathbf{v} = \frac{d\mathbf{r}}{dt} = \frac{dx}{dt}\mathbf{i} + \frac{dy}{dt}\mathbf{j} + \frac{dz}{dt}\mathbf{k} = v_x\mathbf{i} + v_y\mathbf{j} + v_z\mathbf{k} \tag{17}$$

$$\mathbf{a} = \frac{d\mathbf{v}}{dt} = \frac{dv_x}{dt}\mathbf{i} + \frac{dv_y}{dt}\mathbf{j} + \frac{dv_z}{dt}\mathbf{k} = a_x\mathbf{i} + a_y\mathbf{j} + a_z\mathbf{k} \tag{18}$$

Vector kinematics ($\mathbf{a}$ is constant):

$$\mathbf{v} = \mathbf{v_0} + \mathbf{a}t, \quad \mathbf{r} = \mathbf{r_0} + \mathbf{v_0}t + \frac{1}{2}\mathbf{a}t^2 \tag{19}$$

Circular motion: $a_R = v^2/r$, $T = 1/f$, $v = 2\pi r/T$.

$$\Sigma\,\mathbf{F} = m\mathbf{a} \tag{20}$$

$$F_{\text{fr}} = \mu_k F_N \text{ (kinetic)}, \quad F_{\text{fr}} \le \mu_s F_N \text{ (static)} \tag{21}$$

Rotational force: $\Sigma\,F_R = ma_R = mv^2/r$