

**Physics 31B Midterm (200pts MAX)**  
**Winter, 2004**

1. (a) A 2000-kg car is traveling east at 20.0 m/s when it's rammed in the rear by a 1000-kg car that was traveling at 30.0 m/s just before impact. The two cars tangle together and move off together at a speed that we now wish to determine – please do so.  
  
(b) Two billiard balls, one heading north at 15.0 m/s and one heading south at 10 m/s, collide head-on. Take the collision to be perfectly elastic. What is the post-impact speed of each ball?
2. (a) A 100-kg rocket held in place on the launchpad fires its engines. Once it is released, the rocket experiences a net upward force given by the expression:  $\vec{F}(t) = [40.0 \text{ kN} - (2.00 \text{ kN/s})t - mg]\hat{k}$ , for about 20.0 s. Assuming the mass is constant, find the change in momentum during the first 10.0 s.  
  
(b) The momentum of a vehicle traveling in a straight line is given in SI units by the equation  $\vec{p}(t) = (8.0t^2 + 4.0t)\hat{j}$ . Find an expression for the force acting on it as a function of time.
3. (a) A 70-kg passenger riding in a typical automobile is involved in a 17.9-m/s (i.e., 40 mi/h) head-on collision with a concrete barrier. Taking the stopping time as 100 ms, compute the average force exerted by the seat belt and shoulder strap on the person.  
  
(b) A 100.0-kg vehicle is traveling along a straight track according to the expression  $x(t) = 5.00t + 1/t^2$ , where the units are SI. Determine its kinetic energy after 2.00 s of travel.
4. (a) Energy is being delivered to a system by a force at a rate of  $P(t) = (60.0 \text{ W/s}^2)t^2$ . Determine the average amount of power supplied during the interval from  $t = 1.00 \text{ s}$  to  $t = 4.00 \text{ s}$ .  
  
(b) The express elevator in the Sears Tower in Chicago averages a speed of 9.144 m/s (i.e., 1800 ft/min) in its climb to the 103<sup>rd</sup> floor, 408.4 m (i.e. 1340 ft) above ground. Assuming a load of  $1.0 \times 10^3 \text{ kg}$ , what average power must the lifting motor supply?
5. (a) What is the change in potential energy of a 100-kg meteorite if it free-falls from an altitude of 1000 km down to the surface of the Earth? Take the mass of the planet to be  $6.0 \times 10^{24} \text{ kg}$  and the diameter to be  $1.28 \times 10^7 \text{ m}$ .  
  
(b) Determine the rate-of-change of  $g_{\oplus}$  with distance at the surface of the Earth. Compute a numerical value for this quantity in meters-per-second-squared per meter.
6. A projectile (of mass  $m$ ) is to be fired straight up from the surface of a planet (of mass  $M$ ) having a radius  $R$ . Show that the equation for the *minimum* speed at which the projectile must be launched if it is to rise to a distance  $r$  from the center of the planet is given by  $v = \sqrt{2GM(1/R - 1/r)}$ .

7. (a) A ball is thrown straight down from the roof of a dormitory at 10.0 m/s. If the building is 100-m tall, at what speed will the ball hit the ground? How long will the trip take?
- (b) Each of two runners at either end of a 1000-m straight track jogs toward the other at a constant 5.00 m/s. How long will it take before they meet?
- (c) A circular track with a 20-m radius is to be banked at an angle  $\theta$  appropriate for a "4.0-min mile", which is equivalent to  $1.609 \times 10^3$  m in 240 s. Compute  $\theta$ .
8. A greasy flatbed truck is carrying a crate weighing 2.0 kN. The truck accelerates uniformly from rest to a speed of 30 km/h in a distance of 30.0 m. In that time, the crate slides 1.0 m back toward the end of the truck. Compute the coefficient of friction between bed and box.