Part I

1. Consider two blocks stacked one above the other on a table. Someone pulls the bottom block to the right with a rope in such a way that both blocks accelerate to the right but no slipping occurs at the interface between the top and bottom blocks. Friction at the interface between the two blocks does

   (a) no work on the top block

   (b) positive work on the top block.

   (c) negative work on the top block

   (d) first positive then negative work on the top block.

   Answer: (b) The displacement is in the same direction as the force of friction.

2. A force of 10 N is applied to a 2.0 kg mass at rest on which the force of friction is 4.0 N. The net work done on the mass after two seconds will be:

   (a) 36 J (b) 60 J (c) 72 J (d) 100 J

   Answer: (a) A mixture of kinematics and energetics. First acceleration = Fnet/m=3 m/s^2 so $v = at = 6$ m/s But $W = \Delta KE = \frac{1}{2}mv^2 - 0 = 36J$

3. A cart on an air track is moving at 0.5 m/s when the air is suddenly turned off so that friction between the cart and the track now acts. The cart comes to rest after traveling 1 m. The experiment is repeated, but now the cart is moving at 1 m/s when the air is turned off. How far does the cart travel before coming to rest?

   (a) 1 m (b) 2 m (c) 3 m (d) 4 m

   Answer: (d) $\frac{1}{2}mv^2 = f\Delta x$ so if velocity is doubled then distance traveled will be four times as great.

4. When a satellite orbits the earth it moves through a very thin layer of air and hence encounters air resistance. As a consequence the satellite gradually

   (a) moves to a lower orbit and slows down

   (b) moves to a lower orbit and speeds up.

   (c) moves to a higher orbit and slows down.

   (d) moves to a higher orbit and speeds up.

   Answer (b) It loses energy so drops to a lower orbit. In lower orbits the centripetal force is greater and hence the speed must be greater.

5. Two satellites, HIGH and LOW, orbit the earth in circular orbits with HIGH in an orbit with a larger radius than LOW. Comparing the HIGH satellite with the LOW satellite which of the following statements is true.

   (a) HIGH is moving faster and has more total energy.

   (b) HIGH is moving more slowly and has more total energy.

   (c) HIGH is moving faster and has less total energy.

   (d) HIGH is moving more slowly and has less total energy.

   Answer (b). Higher orbits have more total energy (further from earth) but move more slowly (the force of gravity is less).

Part II

1. Superman is on top of the 10 km high Metropolis StratoScraper and hurls a cannon ball ball horizontally off the top. If the speed of the cannon ball is not too large the ball falls down to earth under the influence of gravity and speeds up as it falls. If he throws the cannon ball at the right speed it goes into a circular orbit and its speed does not change.

   (a) Explain why in one case gravity causes the ball to gain kinetic energy and in another case it doesn't?

   In both cases the Earth's gravity acts on the ball causing it to accelerate. If the ball moves slow enough gravity pulls it to Earth. However if the ball moves fast enough the acceleration just causes a change in direction but not a change in speed. The result is a circular orbit.

   (b) Find the speed at which Superman must throw the ball for it to go into circular orbit around the earth?

   The centripetal acceleration required for circular orbit must be equal to the acceleration due to gravity at the location of the ball. So $\frac{v^2}{r} = g \Rightarrow \ v^2 = gr \ \Rightarrow v = \sqrt{gr}$. Here $g = 9.8$ m/s^2 and $r = 6.4 \times 10^6$ m. Note that although the tower is 10 km high this only changes the value of g and r at the third significant figure.

   So working to two significant figures $v = \sqrt{(9.8)(6.4 \times 10^6)} = 7900$ m/s

   (c) How long will it be before the the cannon ball makes a complete orbit of the earth and returns and hits Superman in the back of the head?

   To find the period T we relate it to the speed v by $v = 2\pi r/T$

   $\Rightarrow \ T = 2\pi r/v = 2\pi(6.4 \times 10^6)/7900 = 5100$ sec $= 85$ minutes.

   (d) If he throws the ball at a speed that is slightly less than the speed in part (b) what will happen to the ball? What if he throws it at a slightly higher speed? If the speed is slightly less the ball will go into an elliptical orbit that is closer to the earth on average. It will not crash to earth unless the speed is substantially less. If the speed is greater it will go into an elliptical orbit that is further from the earth on average. It will not escape from earth unless the speed is substantially more.