Problem 1. Experiment 5 b) Analysis.

a) We know that when the string is about to slide, the tension varies as $T(\theta) = T_0 e^{-\mu_s \theta}$. It means that $T_2 = T_1 e^{-\mu_s \pi}$. On the other hand, analyzing the free-body diagrams for the masses, we conclude that $T_1 = m_1 g$ and $T_2 = m_2 g$. Thus the maximum ratio of the masses before the string starts to slide is

$$\frac{m_1}{m_2} = e^{\mu_s \pi}$$

b) If we assume that the string is massless, the derivation of the tension of the string, which is given in the description of Experiment 5 b) is unchanged, except that the friction force is now $\mu_k N$. Thus the tension varies as $T(\theta) = T_0 e^{-\mu_k \theta}$. Since both masses move with the same acceleration, $T_1 - m_1 g = -m_1 a$ and $T_2 - m_2 g = m_2 a$. Thus

$$m_2(g + a) = m_1(g - a)e^{-\mu_k \pi}.$$

The solution of this equation is

$$a = g\frac{m_1 e^{-\mu_k \pi} - m_2}{m_2 + m_1 e^{-\mu_k \pi}}$$

Problem 2. Experiment 6 Pre-Lab Question.

a) The work done on the cart by the force of gravity before is comes in contact with the spring is

$$W = (mg \sin\theta)l$$

and is equal to the change in the kinetic energy of the cart $W = K_f - K_i = mv_f^2/2$. Thus the velocity of the cart when it first contacts the spring is

$$v_c = \sqrt{2gl\sin\theta}.$$

b) The peak force is achieved when the spring compression is at maximum, i.e. just before the spring is about to bounce back. Assuming this point is a distance d from the point where the cart first contacts the spring, the work done by the spring on the cart during the collision is $W = -kd^2/2$. The gravitational force does positive work $W = mg\sin\theta d$ on this part of the trajectory. Again, the change of the cart's kinetic energy is equal to the work done by the external forces:

$$W_{total} = mg\sin\theta d - \frac{kd^2}{2} = K_f - K_i = 0 - mv_c^2.$$

Solving for d, we obtain

$$d = \frac{mg\sin\theta}{k}\left(1 + \sqrt{1 + \frac{2lk}{mg\sin\theta}}\right).$$

The corresponding force is

$$F_{max} = kd = mg\sin\theta\left(1 + \sqrt{1 + \frac{2lk}{mg\sin\theta}}\right)$$

Problem 3. Concept Question:Work.

Since the block starts at rest and ends at rest, the change in the block's kinetic energy is $\Delta K = 0$. Thus the total work done on the block $W_{total} = W_1 + W_2$ must be zero. Thus the amounts of work done by the two people are equal in magnitude and are of the opposite sign.

Problem 4. Work-kinetic energy.

a) It is easier to do the problem using Work-Kinetic Energy theorem. The problem is naturally split into two part: motion on the inclined plane and motion on the horizontal plane.

b) The work done by the friction force on the way down is

$$W_{fd} = -\mu_{k1} lmg\cos\theta.$$

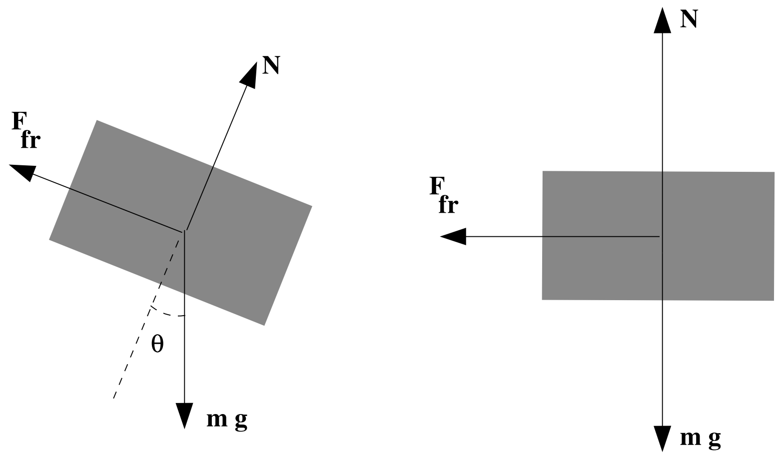

Figure 1: Free-body diagrams for the block sliding on the inclined plane (left) and the same block on the horizontal plane (right)

c) The work done by the gravitational force on the way down is

$$W_g = (mg\sin\theta)l.$$

d) The change in kinetic energy is $\Delta K = K_b - 0 = W_{fd} + W_g$. Thus at the bottom of the plane the kinetic energy is

$$K_b = mgl(\sin\theta - \mu_{k1}\cos\theta).$$

e) The work done by the friction force while the object is sliding on the horizontal surface is

$$W_{fs} = -\mu_{k2}mgx,$$

where x is the distance the object has slid on the horizontal plane.

f) Again, the change in kinetic energy is equal to the work done by friction $0 - K_b = -K_b = W_{f2}$, thus

$$-mgl(\sin\theta - \mu_{k1}\cos\theta) = -\mu_{k2}mgd$$

and for the distance d we find

$$d = l\frac{\sin\theta - \mu_{k1}\cos\theta}{\mu_{k2}} \approx 3.27\,m$$