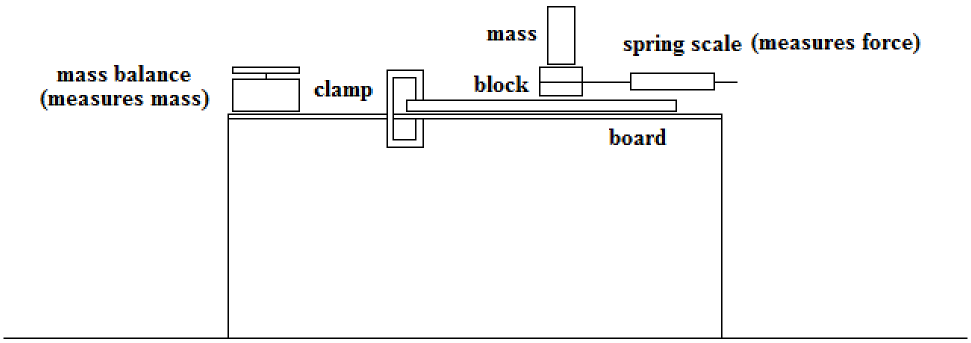
1.a. A=D=E > B=C

Suppose each battery has a potential difference V_B. By Kirchhoff's loop rule, the voltage across A, D, and E must be $-V_B$. The potential differences across B and C must add to $-V_B$ and, by symmetry, have the same value of $\frac{-V_B}{2}$.

1.b. Circuit 3. Circuit 2.

The energy expended by a battery is equal to the power output of that battery multiplied by the time span over which the power is output. If each battery has the same stored energy, the greater the power output, the lesser the time for which the power can be produced. By conservation of energy, the power output by the bulb systems equals in magnitude the power input by the battery, and the power output of the systems can be determined with the equation $P = \frac{-V^2}{R}$ where V is the voltage across the system and R is the resistance of the system. Because the batteries are identical, V across each system is the same by Kirchhoff's loop rule. Therefore, the greater the resistance of the system, the lesser the power output of the system. Assuming each bulb has a resistance *R*, the resistance of Circuit 1 is *R*, the resistance of circuit 2 is *2R*, and the resistance of circuit 3 is $\frac{R}{2}$.

2.a.i.



2.a.ii.

- Use the mass balance to find the mass of the given block (m_B) in kilograms.

- Securely clamp the board flat to a lab table.

- Securely tie a string around the center of the block and connect that string to a spring scale.

- Place a 1kg mass on top of the block and the block on top of the board.

- Use the spring scale to pull the block horizontally, gradually increasing the force applied. Record the force (F_{max}) applied by the spring scale at the instant just before it slips and begins sliding across the board.

- Repeat the above step ten times and then find the average maximum force applied (F_{avg})

2.b.

At the instant before the block slips, $|F_{\text{static friction}}| = |F_{\text{spring scale}}| = F_{avg}$ because $\Sigma F = ma$ and $a = 0$

$F_{\text{static friction, max}} = \mu \cdot F_N$ and $F_N = (1 + m_B)g$

$F_{avg} = \mu \cdot (1 + m_B)g$ therefore $\mu = \dfrac{F_{avg}}{(1 + m_B)g}$

2.c. The static and kinetic coefficients are not equal. Although the average kinetic coefficient equals the average static coefficient, six of the seven groups determined that the kinetic coefficient was less than the static coefficient. Therefore, it is more likely that lab group five reached erroneous values than there being an actual equivalence of static and kinetic values, with the differences due to random errors and uncertainty.

2.d. Remains the same. The coefficient of static friction is a property of the two surfaces and independent of the force pushing them together. Adding mass to the block will increase the F_{avg} described above, but it will also increase the normal force proportionally.

If $\mu_{\text{static friction}} = \frac{F_{avg}}{F_N}$, the coefficient of static friction will stay the same.

3.a. To the right of C.

If the rod is much more massive than the disk, $I_{rod + disk} \approx I_{rod}$ and the final angular momentum of the system will be $L \approx I_{rod} \cdot \omega_{final}$. Angular momentum is conserved in the collision, so the greater the initial angular momentum, the greater the final angular momentum, thus the greater the final angular velocity. The initial angular momentum of the disk is the cross product of its radius (from the pivot) and linear momentum (which is constant). The point to the right of C has the highest radius of the three choices.

3.b. Yes. The equation provided shows that, as *x* increases, ω increases. This is the same result described above and agrees with the prediction that ω will be highest when the disk strikes a point to the right of C.

3.c. This equation shows that the higher the rotational inertia of the rod, the higher the angular velocity. This does not make sense because rotational inertia is a measure of resistance to changes in angular velocity. Therefore, the higher the rotational inertia of the rod, the smaller should be the final angular velocity caused by the torque applied by the sliding disk collision.

3.d.

$L_i = L_f$

$m_{disk} \cdot v_0 \cdot x = (I + m_{disk} \cdot x^2) \cdot \omega$

$\omega = \frac{m_{disk} \cdot v_0 \cdot x}{I + m_{disk} \cdot x^2}$

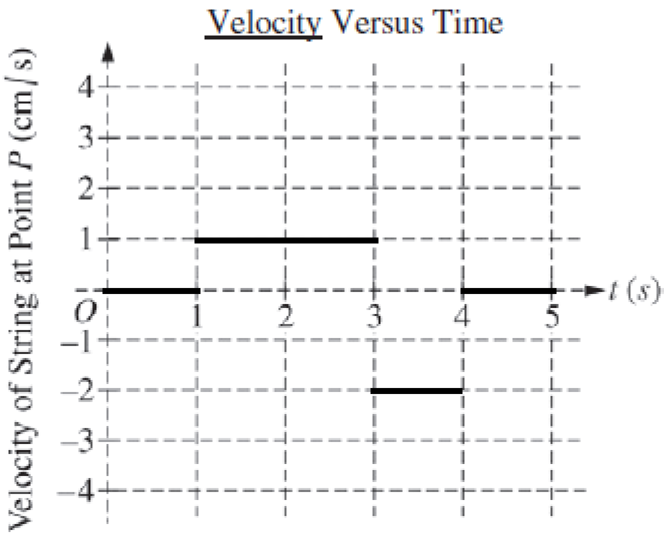
3.e. Greater than. If angular momentum is conserved for the disk/rod system, then the change in angular momentum of the disk plus the change in angular momentum of the rod equals zero. When the disk bounces backwards, its change of angular momentum is greater in magnitude than when it sticks to the rod, therefore the change in angular momentum of the rod is also greater in magnitude. This implies the change in the rod's angular velocity is greater.

4.a. No. From its point of release to the point at which is leaves the table, Block 1 has a greater vertical descent. If energy is conserved, this greater loss of gravitational potential energy implies a greater increase in kinetic energy. Block 1 therefore leaves the table at a higher velocity. Blocks 1 and 2 fall the same distance, *h*, during their flights and have the same vertical initial velocity of zero and the same acceleration due to gravity. The times of the two flights are then the same, so if Block 1 is moving faster horizontally during that time, it will travel farther.

4.b.i. The blocks land the same distance from their respective tables. The logic is the same as in 4a. From the points of release to the points at which the blocks leave the table, both have the same vertical descent, same loss of gravitational energy, same gain of kinetic energy, and same increase in speed. In flight, the two blocks have the same distance of descent, initial vertical velocity of zero, and gravitational acceleration, therefore the same time of descent. If the two blocks leave the table with the same horizontal speed and fly for the same time, the two horizontal distances before landing will be the same.

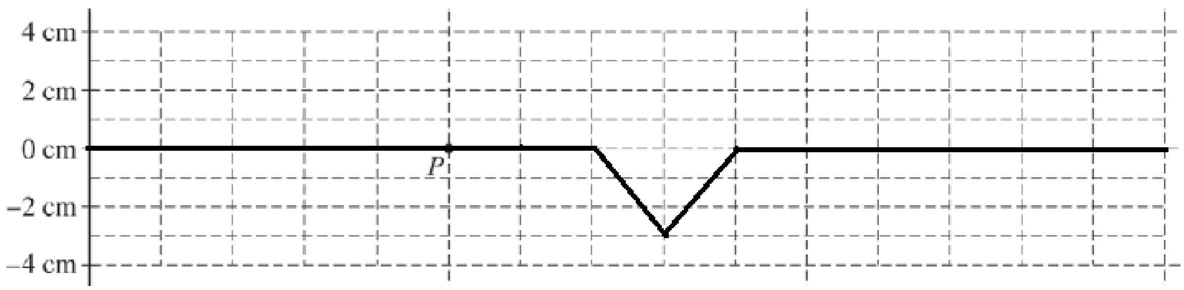
4.b.ii. Block 1. As described above, in flight, the two blocks have the same distance of descent, initial vertical velocity of zero, and gravitational acceleration, therefore the same time of descent. However, the times with which they descend the ramps will be different. For a path involving vertical descent and horizontal displacement, the least time traveled is achieved along the path of a brachistochrone. The ramp for Block 1 is closer to this curve than the ramp for Block 2, so Block 1 will descend its ramp in less time, making the total time less for Block 1.

5.a.



Velocity Versus Time
Velocity of String at Point P (cm/s)
4
3
2
1
O
−1
−2
−3
−4
1
2
3
4
5
t (s)

5.b.



4 cm
2 cm
0 cm
−2 cm
−4 cm
P