Stage Design: Force Body Diagrams and the Normal Force

Materials for each group:

- Metal track with adjustable height on one side
- Angle detector (protractor)
- Digital Scale
- Two weights: 100 g and 500 g

Imagine that you're a stage designer and you're trying to determine how much force your raked stage can withstand. Use the following experiment to estimate the change in measured force depending on the angle of the stage.

1. Place the electronic scale securely on the track (match the rubber feet to the grooves in the track) and place the 100 g mass on it. Record the mass in the table below (angle = 0).

2. Tilt the track such that the angle detector reads 10 degrees. Record the new mass readout.

3. Tilt the track to 10, 15, and 20 degrees and record the new mass readout in the table at the end of the worksheet for each tilt angle.

4. Calculate the theoretical mass of the 100 g weight using the following equation:
   Calculated mass = m_0*cos(angle)
   where m_0 is the recorded mass when the angle is 0 degrees. Make sure that you are calculating the cosine in degrees and not in radians!

5. Calculate the difference in the recorded and the calculated mass by subtracting one from the other. How different are the recorded mass and the calculated mass? If they are different, what could explain the difference?

6. Repeat steps 1 - 5 with the 500 g weight. How different are the recorded mass and the calculated mass? If they are different, what could explain the difference?

100 g Mass			
Angle	Recorded Mass (g)	Calculated Mass (g)	Difference in Mass (g)
0	m_0 =		
10	m_{10} =		
15	m_{15} =		
20	m_{20} =		

500 g Mass			
Angle	Recorded Mass (g)	Calculated Mass (g)	Difference in Mass (g)
0	m_0 =		
10	m_{10} =		
15	m_{15} =		
20	m_{20} =		

– – PAUSE HERE FOR LECTURE PART TWO – –

7. Draw a force body diagram of the 100 g (0.1 kg) mass on the 15 degree inclined plane. Clearly label the normal force (F_N), the force of gravity (F_g), and the force of friction (F_f). Use the following table to calculate each of the forces. Assume the friction coefficient (μ) is equal to 0.3.

F_g = Mass * 9.8 m/s^2	N
$F_N = F_g * \cos(\text{angle})$	N
$F_f = \mu * F_N$	N

8. (Not related to problem 7): As a stage designer, you need to choose the right stage material that can handle the weight of your performers. You want a stage that has a 5 degree incline. The cheapest material available to you can only withstand 5,000 N of force. Assuming your dancers weigh around 60 kg (60,000 g) on average, how many performers can safely stand on your stage? Be sure to show your work.

9. Consider the ethical and design implications of a raked stage. What is the largest tilt angle you would design? Why did you choose this angle?