1. Physical (not simple) pendulum: *Q* value (too easy to be reasonable).
I don't like this one because it's done in both Intermediate Lab and in Classical Mechanics, and so it really belongs in "category 2". If you pick it, you better do an incredible job. You better understand the ways that a physical pendulum is different from a simple pendulum. You may not use the equipment already in Junior Lab. Your main data will be some form of $\theta(t)$.

2. Fidget Spinner (or bicycle wheel, etc.) spin down decay rate(s).
The goal is to compute both the kinetic friction coefficient μ in the bearing, and an "air resistance" coefficient. It should go without saying that you'll need to define what that coefficient means. If you do a free body diagram of the wheel, using Newton's 2nd Law (for rotation: $\Sigma\tau = I\alpha$), you'll get some little differential equation. There is a torque from each of the two kinds of friction. You'll record a video so that your direct measurement is $\theta(t)$. Make sure the range of speeds is both high enough and simultaneously not too blurry! Then you'll use that to find a curve fit of your data of the form $\omega(t) = mt + b + Ae^{-kt}$. These coefficients ($m$, b, A, k) can be used in your torque analysis to determine the unknowns we're after.

3. Air resistance using coffee filters.
The goal is to determine the coefficient of drag for a falling filter. The measurements are total mass and the time required to fall through some set distance. You'll need a couple other numbers, like the distance, their size, and the density of air. Even though coefficient of drag assumes that drag force is proportional to v^2, you can also directly determine the exponent of v.

4. Complex Index of Refraction using a stack of microscope slides (or transparencies).
You make a small stack of glass slides. You shine a laser pointer through it at some angle. A beam will come out the other side, but it will be displaced some amount, and it will also be dimmer. You need a way to measure this output brightness and position. You add another slide and repeat the measurement.

5. Torsional elastic coefficient for a string holding an object.
Tie a simple object to a string, fix the top of the string, and then twist the object through some horizontal angular displacement. Then let go. Record $\theta(t)$ (perhaps using a camera). Use $\Sigma\tau = I\alpha$. The torque of a torsional spring is $\tau = \kappa\Delta\theta$, analogous to $F = k\Delta x$. You'll have a wee little differential equation to solve to determine the spring constant of the string.

6. Precession Rate of the ISC Foucault Pendulum
This requires a long-term data acquisition process. You'll want to take your measurements over at least a full day. Maybe make measurements every 2 hours or so. Your measurements don't need to be evenly spaced, but you need to record the actual time. You'll record the current pendulum angle (perhaps north = zero degrees?) as a function of (time of day).

7. The neck size of a falling liquid dish soap (or glycerin) stream vs. height.
This is similar to a free fall problem. Place a small round hole (perhaps 1 cm) in the floor of a flat-bottomed container. Fill the container with shampoo and let it drain out of the hole. Do it twice. The first time, capture the falling liquid in a measuring cup over some "small" time period so you can get a number for how much mass comes out of the container per second. The second time, take a single great photo of the falling liquid stream from the side. Use the photo to measure the diameter of the stream as a function of height. Calculate the cross-sectional area as a function of height. Then use mass conservation to determine speed as a function of height. Use the speed (and the height) to compute the

kinetic energy + potential energy as a function of height. How does total energy depend on height? Where did the lost energy go?

8. Cantilever bending of a ruler.

Take two identical rulers, and lay them on top of each other, protruding from the side of a table. Use some weight to hold them in place. Add a known weight near the end of the lower ruler, so that it bends away from the upper ruler. Take a single awesome photo of the two rulers from the side (you know, no parallax, no bad aim, some way to determine scale, etc.), and measure the displacement as a function of horizontal position from the table. Use the principles of beam bending to determine the elasticity of the material.

9. Resonant frequency of cantilevered plastic ruler.

Fix a ruler to the side of a table as in the previous experiment. Determine the portion of the length that protrudes. Use your finger to flex and release the ruler. Use a microphone or cell phone app to record the resulting sound. Measure how frequency depends on length. How should it depend on length? Or, if your ruler is metal and well-clamped, you could ping it with a mallet (like a xylophone bar) to make the sound.

10. Smartphone accelerometer riding on a swing (hard).

Your phone has an accelerometer. If you can get accelerometer data for your phone, you could tape it to a playground swing and let it go for a few swings with a small angle. Make independent measurements of L and the period, and confirm that they agree. Now that you know the expected motion of the swing, you'll also know the (x, y) components of the acceleration of the phone. The acceleration components from your phone will be in the reference frame of the phone, which is continually rotating, so you'll need to transform them into a consistent reference frame. Two of the axes should show sinusoidal variations with the same period. You could use them to come up with two estimates of g, for example.

11. Electro-Mechanical Properties of #43362 Lego Motor

We do this experiment in both ECA and in LabVIEW. Use a motor to lift a known weight at constant speed. Measure the input voltage and current to the motor. Measure the output speed. Vary both independent variables (voltage and torque) over a reasonable range. Some primary outputs would be current as a function of torque, and angular speed as a function of (torque and driving voltage). But you now have enough info to compute output power, efficiency, and impedance as functions of the independent variables.

12. Response and efficiency of a photodiode (possible circuit online…)

We do something similar to this in a mini-lab in ECA. Use an LED to shine light into a photodiode. Control the power of the LED by varying it's voltage (be careful! You naturally have a resistor in series with the LED, so the voltage of your source is not the same as the voltage of the LED). Measure the output power of the photodiode. Determine the efficiency as a function of the total power. Something to plan for is to make sure you get a sufficient range of brightnesses so that you can really determine the proper "working range" for the photodiode.

13. Amplification ratio of npn transistor PN2222A (possible circuit online…)

Unlike the previous lab, this idea is *identical* to a mini-lab in ECA. Again, drive an LED to create light that is sensed by a photodiode. Amplify this light using an npn transistor. There are many basic transistor properties that can be determined, but the main one is probably to use i_C/i_B to determine β (also sometimes called h_{FE}). Naturally, you need to drive the transistor through all the stages ("off", to "on", to "saturated"), but only use the "on" results to compute β.

14. Resonance frequency of a 2 liter bottle as water is added.
Use the bottle as a Helmholtz resonator by filling it with some water, then blowing over the spout. Record the resulting frequency with a microphone or cell phone app. You need to plot frequency vs. "unused" volume of the bottle, so you'll need to start by making a more careful measurement of the total bottle… it's a little more than 2 liters!

15. Newton's cradle: coefficient of restitution of each collision.
You'll need to take good (no parallax!) video from the side. Choose one of the balls on the end, and use the video to record the maximum angle for each individual swing. Convert this angle into potential energy (or kinetic energy). Determine the kinetic energy lost per hit. One way to do this is to plot the fractional lost energy as a function of counted hits. Is it constant? **As a variation**, you could do this with a ping-pong ball on the floor, etc., provided that you can get enough bounces (recall that you are required to get 10 valid data points).

16. The pitch of a plucked string with an attached weight (similar to a PHYS 126 Lab)
Record the frequency of the string (using a microphone, cell phone app, or guitar tuner) as a function of tension. Since there will be multiple harmonics, you just want the main frequency. You'll also need the length of the string. You should be able to determine the linear mass density of the string by plotting frequency vs. tension.

17. Coefficients of friction using inclined planes of various angles (too easy).
This is a good one for a middle school science fair. Getting the static coefficient is super easy… just tilt your board until it slides! To get the kinetic coefficient, you'll need some way to measure the resulting acceleration. So, it would be like the spark timer lab from PHYS 124 in some way. This experiment is so trite that you'll face severe grading penalties for every minor mistake.

18. Index of Refraction of corn oil using Snell's Law and a laser pointer (too easy).
This is another good middle school science fair project. You'll need a fish tank with clear glass. Some of the "difficulties" are making sure your laser pointer hits the exact some point each time, and figuring out a way to get a high-quality measurement of the laser input angle. The output angle should be easy. Again, this experiment is so trite that you'll face severe grading penalties for every minor mistake.

19. Trajectory motion with air resistance (still might be too easy).
This is like another PHYS 124 lab, except with the addition of air resistance. You do this as a homework problem in PHYS 311. Your goal will be to determine the coefficient of drag of your ball. To get a decent measurement, you want the drag force to be at least 2% of the ball's weight.

20. Conductivity of glycerin mixed with water by mixing fraction (probably too hard).
You need really pure water. Also, the range of conductivities goes from 0 to infinity over a small range of mixing fractions, so it's really hard to find a workable range that will give you a reasonable plot. The same thing happens with salt water. Also, because resistance depends on geometry, you need to

invent a great way to hold your sample such that it has a really well known length and cross sectional area.

21. Rate of cooling of a heated metal block (probably too hard).
I'd probably do this in one dimension. Get a metal stick. Insulate it somehow, perhaps by encasing it in Styrofoam (except for a few inches at either end). Place a small hole near the midpoint so that you can insert a thermometer there so that the thermometer makes good contact with the stick. Refrigerate the stick before doing the experiment. Place the cooled, insulated stick on a table. Place a bag of ice water on one end. Place a heat source (perhaps a butane lighter) under the other end in such a way that it stays on by itself, and such that it doesn't burn the insulation. Use your thermometer at the midpoint of the stick to determine $T(t)$, and use it to determine the conductivity of the stick. You'll need to solve a PDE!

22. Heat capacity of corn oil using resistive heating. Requires some electronics.
You get a very low resistance, very high power resistor. You immerse it in a cup of oil. The cup is somehow insulated. You run current through the resistor. You keep the oil stirred enough so that it is all at the same temperature. You use Ohm's Law to determine the power (energy per time) delivered to the oil. It needs to be a lot higher than the rate at which energy radiates, conducts, or convects away from the cup. You determine the temperature of the oil as a function of time. You should be able to determine the specific heat of the oil. I think a major problem has to do with numbers… the experiment may require several hours before generating sufficient data. You should calculate a time estimate before doing anything else!

23. The changing radius of an air bubble rising in a tall tank of water.
An air bubble in water has more or less a constant mass of air within it. However, the volume will change depending on the pressure, according to the ideal gas law. Use a long flexible tube to blow a bubble into the lower part of a tall tank. As the bubble rises, the pressure will decrease because of the hydrostatic pressure difference, and the bubble will expand. Record a video of the bubble rising so that you can determine the volume as a function of depth. By comparing the expected diameter of the bubble with the measured value, you can probably find a way to determine the surface tension of the bubble. I think that over a mere 30 cm tall water depth, the variation in bubble diameter will be too small to be accurately measurable with a camera.

24. Frequency response of series RLC circuit.
This is a solved problem in your Physics I textbook, and I think it's also a PHYS 311 homework problem. Build a series RLC circuit, and apply a sinusoidal driving voltage. Measure the voltage across the resistor and compute the current. Perform two analyses: measure the bandwidth, the peak frequency, and the peak amplitude. From these determine R, L, and C. Also, use the expected form of the solution to the differential equation to do a best fit (perhaps using Solver) to get another set of results for R, L, and C.

25. Magnets on a Torque Arm
Tape a button magnet to a table, perhaps with North up. Tape one end of a ruler to the table, so that the tape forms a light hinge. Make sure that the other end of the ruler covers the magnet on the table. Tape another button magnet to the end of a ruler, with North down, so that when the ruler falls, the two magnets are right above each other. Then, add small known masses onto the ruler at some known location. Use Newton's Second Law ($\Sigma\tau = 0$ for the ruler with 1 magnet and various weights) to

determine the magnetic force. Also, measure the separation distance r between the magnets. Plot F vs r… or even better, plot $\ln(F)$ vs $\ln(r)$ to determine how F depends on r.

26. Radius of the Earth Using Sunset

On a sunny day, find a good spot looking west before sunset. Place your camera as low as it can go but still see the sun. Make sure you also have a way to measure the vertical position of the camera. When the arc of the sun has mostly disappeared behind the horizon, start recording a video of the last moments before complete sunset. You need to record the time (within a second) that the arc of the sun completely disappears. Perhaps use audio to count down, or have a stopwatch in front of the camera, too. As soon as the arc of the sun is gone, move the camera up some fixed distance… perhaps 10 cm, and repeat. If 10 cm is too small, try 20 cm, and so on. If you can't get 10 points from one sunset, use multiple days' worth of trials. Knowing Δh and Δt will allow you to compute the radius of the earth (assuming that a day is known to be 24 hours).

27. Orbital Radius of a Satellite

On a clear night, if you stare at the sky, you can see individual satellites going overhead. They have a brightness similar to regular stars, but they move across the sky in only a minute or two. Make sure your phone camera can actually see stars, instead of just blackness. Aim your phone at a constellation that you know (Orion, or the Big Dipper). You'll need to use the NASA website to look up the angular positions of at least 2 stars in a known constellation to be able to set the scale for the portion of the sky you can see in your phone images. That is, "this many pixels = this many degrees of sky". Then, look for a satellite! Keep your camera aimed at the satellite as is passes. Try to get as much of the total motion as you can. You'll use the positions of the various background stars to set a "fixed" background even though your camera is moving. If video is too low-res, use a series of snapshots, getting the time info from the time stamp of each photo. From your video, you'll get the angular velocity of the orbit, and then you can use Kepler/Newton to compute the orbital radius (or altitude) of the satellite.

28. Rotational Speed of the Sun using sunspots

Make a pinhole camera with a sheet of cardboard, and use it in the window of a room that is otherwise really dark. Place a screen behind the pinhole as far as you can get it and still see the image of the disc of the sun. Trace the outline with a pencil, and also mark any sunspots you see in the image. Repeat at 1 hour intervals, or even better, over several days. Use the position of one sunspot to compute the angular speed of the sun.