IPT Fair Problems

Difficulty Rating

(1) Short-term project. For those working with strong time constraints.
(2) Medium-term project. For motivated students who can dedicate weeks to a project.
(3) Long-term project. For those seeking a challenging, multi-disciplinary, open-ended project.

Acoustics

1. **Chladni Figures (2)**
   When a plate is driven by sound, sand can accumulate along nodal lines. Investigate how the observed patterns depend on the **driving frequency**, plate **material/thickness**, and **boundary conditions** (clamping, support points). Can you predict resonance frequencies or reconstruct mode structure from the patterns?

2. **Warbling Bird Whistles (2)**
   Many simple whistles produce a “warbling” sound rather than a steady tone. Explain how the warble is generated and investigate how the sound depends on **airflow rate**, **cavity geometry**, and **mouthpiece** design. Can you design a whistle that maximizes (or minimizes) warble?

3. **Blowing Horn (2)**
   Ancient societies used horns for calling people. How far can a person hear it? With the constraint that the whole design fits within a **30 cm cube**, propose a design that maximizes this distance. If one wants to blow toward the wind, does the design change?

4. **Paper Popper (1)**
   A folded “paper popper” makes a loud sound when struck through the air. What defines how loud the sound is? Explain and explore the phenomenon. Can this break the paper?

5. **Helmholtz Window (2)**
   Investigate the loud thumps you hear when a single car window is open. Can we reproduce it in a controlled setting? How does the size of the window or the relative speed of the air affect the frequency?

Mechanics & Fluids

6. **Soap Jets (2)**
   When dish soap is poured onto a small pile of soap, jets can shoot out. Explain the

mechanism and investigate how jet length and repeatability depend on **pour height**, **pour rate**, and **soap composition/temperature**. How can one maximize the jet range?

7. **Stable Points on a Spinning Turntable (2)**
   A ball on a rotating surface can exhibit stable radii or "preferred" positions. Explain the phenomenon and how it depends on **rotation rate**, **surface friction**, and **ball properties**. Can you map the regions of stable/unstable behaviour and optimize for the strongest stability?

Materials & Pattern Formation

8. **Self-Organizing Steel Balls (2)**
   Vibrated steel balls can form ordered domains with defects and grain boundaries. Devise a method to quantify ordering (e.g., defect density, domain size) and investigate how ordering depends on **vibration amplitude**, **frequency**, **ball size distribution, ball deposition rate**. Can you design an "annealing" protocol that minimizes defects?

9. **Snow Clones (3)**
   Devise a method to grow snowflakes that optimizes the reproducibility of their geometry.

Optics & "Quantum-adjacent"

10. **Two-Slit Interference (1)**
    Build a double-slit (or multi-slit) setup and investigate how fringe spacing and visibility depend on **slit separation**, **slit width**, **wavelength**, and **source size**. How accurately can you infer an unknown slit separation from the pattern, and what limits the precision?

11. **Planck's Constant (LED method) (2)**
    Propose a method to estimate Planck's constant using LEDs. Measure an LED's characteristic wavelength (with a simple spectrometer) and relate it to a well-defined electrical threshold. What systematic errors dominate (temperature, series resistance, spectral width, threshold definition), and how can you reduce them?

12. **Quantum Colors (Fluorescence) (2)**
    Many materials absorb higher-energy light and re-emit at longer wavelength. Investigate how emission brightness and apparent color depend on **excitation intensity**, **concentration/thickness**, and **geometry**. Can you design a setup that maximizes fluorescence while minimizing background and reflection, and quantify the gain?

13. **Afterglow (Phosphorescence lifetimes) (2)**
    Glow-in-the-dark materials decay over time. Devise a method to measure the decay curve quantitatively and investigate how it depends on **charging time**, **charging wavelength**, **temperature**, and **material type**. Can you optimize for maximum afterglow duration while keeping a measurable brightness?

14. **Milky Water: Diffraction / Scattering (2)**
    Suspending milk (or another scatterer) in water makes light spread and blur. Investigate how transmission and angular spreading depend on **concentration**, **path length**, and **wavelength**. Can you define a quantitative "scattering strength" metric and optimize your setup to measure it reproducibly?

Astronomy & Atmosphere

15. **Exoplanet Transit Photometry (2)**
    Construct a tabletop model of a star and a transiting planet that produces measurable light curves. How accurately can you infer **planet radius ratio** and **orbital period** from noisy data? Which design choices (diffuser quality, stray light control, detector choice, rotation smoothness) most improve parameter-recovery accuracy?

16. **Atmospheric Extinction (3)**
    Devise a photometry method to measure stellar brightness vs altitude and extract an atmospheric extinction coefficient. How does extinction depend on **humidity/aerosols**, **wavelength** (e.g., camera color channels/filters), and time? How can you calibrate and minimize systematic errors?

17. **Twinkling as Turbulence Diagnostics (3)**
    Record and quantify intensity fluctuations of a bright star (or alternatively, a point source of light) and investigate how fluctuation strength and characteristic timescale depend on **wind**, **local heat sources** (rooftops vs open field), and **target altitude**. Can you separate atmospheric effects from sensor noise and optimize the setup to make turbulence easiest to measure?

18. **Aurora Borealis (3)**
    Aurora arises from excited gases driven by charged particles in magnetic fields. Build a tabletop analog (plasma/discharge source + magnets) and investigate how the glow structure depends on **magnetic field geometry**, **distance**, and **operating conditions**. Can you define a quantitative "structure/curvature" metric and optimize it?

Measurement / Metrology

19. **Smallest Forces Device (3)**
    Devise a method to measure the smallest forces possible with a homemade instrument. How do sensitivity, drift, and response time trade off? Can the same instrument also measure large forces accurately? Define calibration protocols and quantify precision and accuracy.
21. **The Best Randomness Source (1)**
    Devise a physical source of randomness and a method to test its quality. Compare at

least two sources and quantify **bias**, **correlations**, and **repeatability**. Which tunable parameters improve randomness, and why?

22. **The Best Clock (2)**
    Build a timer that is capable of precisely and accurately measuring an elapsed time of 5 minutes, without relying on a mechanical mechanism (like gears, springs or oscillators). Can your contraption also be used to measure an elapsed time of 1 minute and 1 hour?