Science Olympiad: Physics Lab.

- Students will compete in lab activities in the areas of geometric and physical optics.

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- This presentation is available on-line from
  www.nscl.msu.edu/~starosta

Event Parameters:

- Students may bring and use any type of calculator.
- No resource material may be used unless provided by the event supervisor.
- Students will work in teams of up to 2.
- Approximate time for the lab is 45 minutes.

The Competition:

- The competition will consist of experimental tasks and questions related to geometric optics and physical optics
- All answers will need to be provided in SI units

  (such as Watts, Joule, Newtons, Kilograms, Apere, Ohm, Seconds, lumen, candela, lux).
- All answers will need to be provided with proper significant figures.

Data Presentation:

- Brief (~3 min) demonstration on how to collect and present data will be provided to the students at the beginning of the lab.
- Students will be expected to analyze and/or interpret simple graphs and/or tables.
- Presentation of the data in forms of graphs and tables will be expected from the students.
- Computers will NOT be permitted for data collection, analysis or presentation.

Geometric optics:

may include topics such as:

- Wave fronts and rays (Huygens Principle);
- Reflection (Law of reflection, specular reflection, diffuse reflecion);
- Refraction (measurement of index of refraction, Snell’s law)
- Critical angle (measurement of critical angle, fiber optics)
- Dispersion due to a prism;
- Simple lens and mirrors (ray tracing, measurement of focal length, mirror equation, thin lens equation, magnification, lens maker’s equation).

Physical Optics

may include topics such as:

- Interference and superposition of waves;
- Double slit interference, Young’s experiment (location of peaks but not intensity distribution.);
- Laser (theory of operation, difference between coherent and non-coherent light);
- Electromagnetic spectrum (wavelenght, frequency, velocity, nomenclature of EM spectrum, inverse square law applied to the intensity of light, Doppler shift, energy and momentum of photons, line spectra, absorption spectra).

At the National Tournament

In honor of the World Year of Physics and Einstein's 100th anniversary of his three papers that changed physics, the lab will also include Photoelectric effect, Work Function, and Thermionic Emission topics. See www.physics2005.org for more details

Scoring:

- Points will be awarded for correct measurements, calculations, analysis, and answers.
- Standardized forms will be provided for students to show all measurements and calculations.
- Ties will be broken using a designated task(s) or question(s).
- The tiebreaker question(s) or task(s) will be identified on the answer form provided to the students at the beginning of the competition period.

Skills to be tested:

- Understanding of physics concepts.
- Laboratory skills.
- Data analysis and presentation.

Example for:
understanding of physics concepts.

Doppler shifted energies of photons emitted from a moving source depend on the source velocity and the angle of emission. Students should recognize that photons are shifted to lower energies/longer wavelengths when emitted from sources moving away from the observer (redshift) or to higher energies/shorter wavelengths when emitted from sources moving towards the observer (blueshift). The students should also recognize, that the above observation implies an existence of an angle (close to 90 deg. for low velocities of the source) at which the observed and true energies of the photons are identical.

Example for:
data analysis and presentation.

Tables provide a neat and convenient way to gather the experimental data. These are hard, however, for recognizing physical trends and relationships.

Tab. 1. Hourly temperatures forecasted for Sunday, Dec. 7, 2003.

Time [h]	**7**	**8**	**9**	**10**	**11**	**12**
Temperature [F]	**25**	**26**	**27**	**28**	**30**	**32**
Time [h]	**1**	**2**	**3**	**4**	**5**	**6**
Temperature [F]	**34**	**35**	**35**	**34**	**32**	**29**

Example for:
data analysis and presentation.

Graphs are great for recognizing physical trends and relationships!

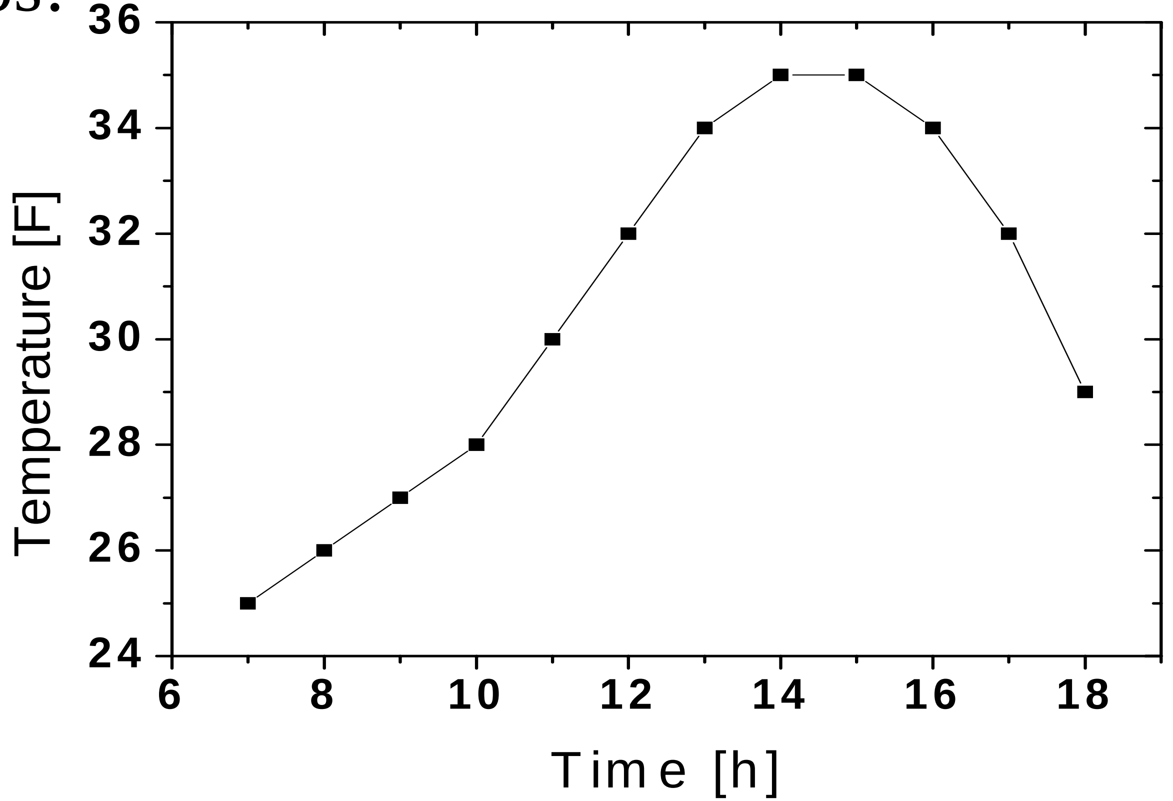
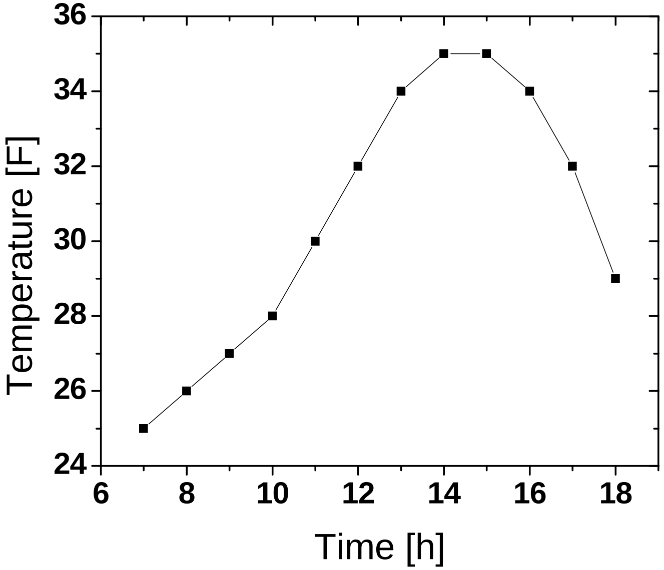
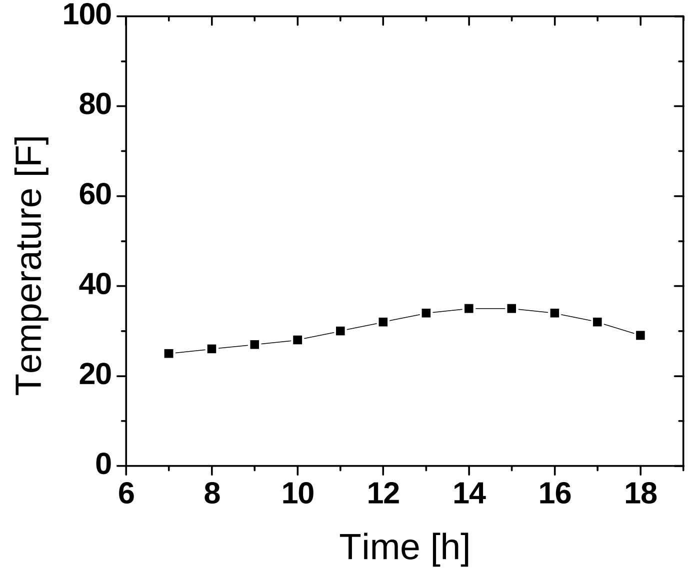


Fig. 1. Hourly temperatures forecasted for Sunday, Dec. 7, 2003.

Example for:
data analysis and presentation.

Preparing a good graph is a skill! Both graphs below present the same data.





Example for:
laboratory skills.

Physical quantities are never known with exact precision (unless they are merely definitions). We imply a certain degree of uncertainty in a quantity when we assign a certain number of digits to its numerical value. Thus, when we say that an object is 2.00 m long, we mean that it is between 1.995 and 2.005 m long. If we wanted to say that the length is somewhat between 1.9995 and 2.0005 m, we would say that the length is 2.000 m. In the first case, 3 significant figures are used to describe the object’s length; in the second case, the number of significant figures is 4.

Example for: laboratory skills.

Calculations should be reported only to as many significant figures as are contained in the input parameter with the fewest significant figures. The quantity in a calculation that contains the most uncertainty largely dictates the accuracy of the final result. Calculators make it all easy to violate this rule. For example, when asked to calculate the ratio of 3.0 to 11.0, the students might be tempted to write 0.27272727… . But in this case, the number 3.0 has the fewest significant figures (2) and thus the reported result should be given with two significant figures, as 0.27.

The above discussion regarding the significant figures is based on the undergraduate text book "Physics for Scientists and Engineers" by P. Fishbane, S. Gasiorowicz and S. Thornton, Prentice Hall, 1996, ISBN 0-13-432980-5.

However, this convention may not always fully comply with the convention familiar to the students, since there is no unified way to treat the significant figures the full community agrees on.

The problem with conventions regarding significant figures is easily resolved for measured quantities, if the results are quoted with experimental errors. Examples below discuss the convention which will be used for the Physics Lab. event.

Example for:
error analysis.

For each instrument used in the lab. the students will be expected to estimate its accuracy and, consequently, each measurement performed should be quoted with a relevant experimental error.

The above estimate has to be reasonable. For a number of instruments it is possible to determine the result of the measurement with accuracy better than the smallest increment indicated on the instrument's scale.

Example for:
error analysis.

For example, a meterstick graduated in millimeter marks has a resolution of about 0.5 mm since we can reasonably expect to read the difference between 2.50 and 2.55 cm.

On the other hand, a meterstick graduated in centimeter marks has a resolution of about 1 mm since it is reasonably possible to read the differences on the order of 1/10 of a single mark.

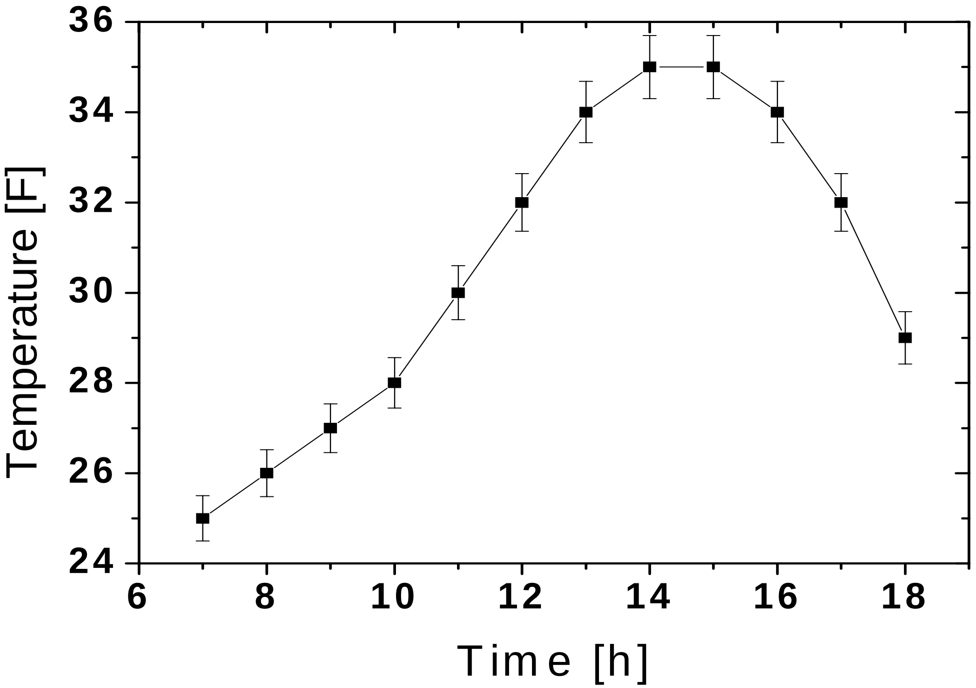
Example for: error analysis.

The error for the measurement should be quoted with one significant figure. The result of the measurement should be quoted with the same number of decimal places as the experimental error.

For example: $T=0.937\pm0.005$ F is quoted correctly, while $T=0.937\pm0.05$ F should be quoted as $T=0.94\pm0.05$ F.

Example for:
error analysis.

If the graph is used to present the data, the students should plot the data points with experimental errors.



Example for:
error analysis.

If the computation involving measured quantities are required, the experimental errors should be properly propagated to calculate the error for the final result. The convention for quoting the final result is the same as for quoting the result of a single measurement.

For example, for measured mass $m=1.23\pm0.02$ kg and volume $V=1.671\pm0.001$ l the calculated density is:

$d=m/V=0.73609$ kg/l,

the errors should be propagated as:

$(\Delta d/d)^2 =(\Delta m/m)^2 + (\Delta V/V)^2$, $\Delta d=0.01198$,

and the final result should be quoted as :

$d=0.74 \pm0.01$ kg/l.

The above convention regarding the data analysis should resolve all possible issues concerning significant figures in the Physics Lab. event by relating the number of significant figures to the accuracy of the measurement. If physical constants are needed in the computations, these will be provided by the event supervisor and the number of significant figures for the constants will be indicated.