[Pre-Selection Test for IPhO-2023]

NePhO-2022	December 10, 2022
Duration: 3 H 15 m	Maximum Marks:100

INSTRUCTIONS

- This question paper consists of Six (6) pages.
- There are altogether Eleven (11) questions. Section A contains Five (5) short questions and Section B contains Six (6) long questions. Most of them are divided into sub-questions.
- All questions are compulsory. Answer to each question should begin on a new page.
- Permitted materials: a non-programmable, non-graphical calculator, blue and black pens, lead pencils, an eraser, and a ruler.
- A suitable diagram in each question is desirable and ensure that your diagrams are clear and labelled.
- All numerical answers must have correct units and with proper significant figures.
- Marks will not be deducted for incorrect answers but deducted for improper significant figures.

SUGGESTED TIME (3 Hrs. 15 minutes)

Reading Questions and prepare for exam:	15m
Section A: Short Questions Answers types:	36m
Section B: Long Questions Answers types:	144m
Total time:	195m

TABLE OF INFORMATION

Speed of light in vacuum (c)	=	3.00×10^{8} m s^{-1}
Planck's constant (h)	=	6.63×10^{-34} J s
Universal constant of Gravitation (G)	=	6.67×10^{-11} N m^{2} kg^{-2}
Magnitude of the electron charge (e)	=	1.60×10^{-19} C
Permittivity constant (ε_0)	=	8.85×10^{-12} F m^{-1}
Universal Gas Constant (R)	=	8.314 J K^{-1} mol^{-1}
Avogadro's number (N_A)	=	6.023×10^{23} mol^{-1}
Coefficient of volume expansion of Hg	=	18.0×10^{-5} K^{-1}
Sp. heat capacity of water	=	4200 J kg^{-1} K^{-1}
Sp. heat capacity of Al	=	910 J kg^{-1} K^{-1}
Refractive index of glass	=	1.52
Refractive index of water	=	1.33
Refractive index of oil	=	1.43
Atomic mass m_H	=	1.007825 u
Atomic mass m_{Cu}	=	63.55 g mol^{-1}
Atomic mass m_n	=	1.008665 u
Mass of electron m_e	=	9.11×10^{-31} kg
Mass of proton m_p	=	1.67×10^{-27} kg

Section A: Short Questions

QN1. **(A)** A raindrop with mass *m* falls vertically near the earth's surface with terminal velocity *v*. If it experiences a retarding force αv due to the air, where α is a constant, find an expression for the raindrop's kinetic energy in this situation. [2.5]

(B) Obtain an expression for the kinetic energy of a coin of mass m rolling without slipping along a horizontal path with velocity *v*. In the same scenario, if the coin's diameter doubles but its mass remains the same, what will happen to its kinetic energy? [2.5]

QN2. **(A)** Obtain volume occupied by 1.0 mol of each for ideal oxygen and hydrogen gases at standard temperature and pressure (STP), defined as T = 273.15 K and P = 101.3 kPa? [2.5]

(B) A physicist pours coffee of mass 0.300 kg at a temperature of 70.0 ^{o}C into an aluminum cup of mass 0.300 kg at a temperature of 10.0 ^{o}C. (i) Calculate the equilibrium temperature of the coffee and the cup. (ii) Compare the equilibrium temperature with the average temperature of coffee and the cup. Why the equilibrium temperature you calculated is not equal to the average temperature? Explain. (Assume that the coffee has the same specific heat as water and that there is no heat exchange with the surroundings.) [2.5]

QN3. **(A)** A concave mirror has a radius of curvature of 10.0 cm. (i) What is its focal length? (ii) If the mirror is immersed in oil, what is its focal length? [2.5]

(B) A submarine periscope uses two totally reflecting 45^{o}-45^{o}-90^{o} prisms with total internal reflection on the sides adjacent to the 45^{o} angles. Explain why the periscope will no longer work if there is a leak and the bottom prism is submerged in water. [2.5]

QN4. **(A)** Suppose a physicist wants to store 1.00 J of electric potential energy in 1.00 m^3 of vacuum space. (i) How large of an electric field is necessary? (ii) If the magnitude of the field is 10 times larger than you obtained in (i), how much energy is stored per cubic meter? [2.5]

(B) Consider Fig. 1. Is it possible to increase the current flowing through R by short-circuiting one of the sources, say $\mathcal{E}_2$ as indicated in the figure? You may neglect the internal resistance of the sources. [2.5]

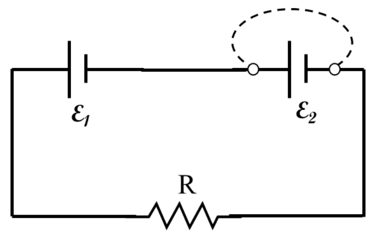


Figure 1: QN4. (B)

QN5. (A) Uranium isotope, ${}^{238}_{92}U$, has atomic mass 238.05 u. Calculate its (i) mass defect; (ii) binding energy (in MeV); (iii) binding energy per nucleon. Explain the results on the basis of the values obtained. [2.5]

(B) During a photoelectric-effect experiment with light of a certain frequency, a reverse potential difference V is required to reduce the current to zero. Find the expression for the maximum speed of the emitted photoelectrons. Also find the value of the maximum speed of the emitted photoelectrons when the stopping potential is 1.25 V. [2.5]

Section B: Long Questions

QN6. (A) A baby playing on a very heavy smooth uniform sphere of radius 1 m, starts sliding off the top of as shown in figure 2. Draw a free body diagram in this case. Find the angle θ in the figure that corresponding to the point at which the baby detached from the sphere, and also find the baby's velocity at the time of separation. Comment on your answers. [10]

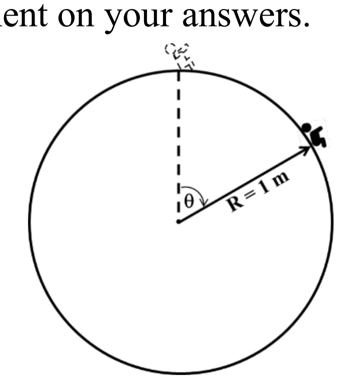


Figure 2: QN6. (A)

(B) A glass flask whose volume is at 1000.00 cm^3 at 0.0 °C is completely filled with mercury at this temperature. When the flask and mercury are warmed to 55.0 °C, 9.00 cm^3 of mercury overflow. Find the coefficient of the volume expansion of the glass. [5]

QN7. **(A)** Find the expression for the moment of inertia of (a) a uniform copper disc relative to the symmetry axis perpendicular to the plane of the disc, if its thickness is equal to t and its radius to R; (b) a uniform solid cone relative to its symmetry axis, if the mass of the cone is equal to m and the radius of its base to R. [10]

(B) A vacuum pump can easily attain pressures of the order of 10^{-13} atmosphere in the laboratory. Consider a volume of air and treat the air as an ideal gas. How many molecules are present in a volume of 1.00 cm^3 at a pressure of 9.00 x 10^{-13} atm and temperature of 300.0 K? [5]

QN8. **(A)** In the figure 3, each capacitance C_1 is 13.8 μF, and each capacitance C_2 is 9.2 μF (a) Compute the equivalent capacitance of the network between terminals a and b. (b) Compute the charge on each of the three capacitors nearest to the terminals a and b when V_{ab} = 420 V. (c) With 420 V across the terminals a and b, compute V_{cd}. [7.5]

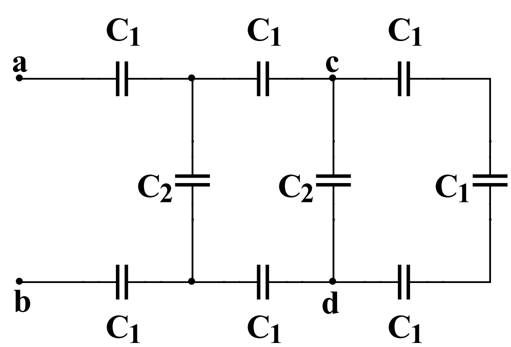


Figure 3: QN8. (A)

(B) Compute the interaction force between two copper spheres, each of mass 0.1 g, separated by a distance of 1.0 m, if the total electronic charge on them differs from the total charge of the copper nuclei by 1%. [5]

QN9. **(A)** Consider two vibrations of equal amplitude and frequency but differing in phase, one along the X-axis,

$$\frac{x}{A} = \sin(\omega t - \alpha) \dots\dots\dots\dots (1)$$

and the other along the Y-axis

$$\frac{y}{A} = \sin(\omega t - \beta) \dots\dots\dots\dots (2)$$

(i) Multiply Eq. (1) by $\sin\beta$ and Eq. (2) by $\sin\alpha$, and then subtract one of the resulting equations from another one. (ii) Multiply Eq. (1) by $\cos\beta$ and Eq. (2) by $\cos\alpha$, and then subtract one of the resulting equations from another one. (iii) Square and add the results of parts (i) and (ii). (iv) Now obtain the equation $x^2 + y^2 - 2xy\,cos\theta = A^2 sin^2\theta$ where $\theta = \alpha - \beta$ (v) Use the above results to justify each of the following figures in figure 4 i.e a diagonal straight line for $\theta = 0$ and a circle for $\theta = \frac{\pi}{2}$. In the figure 4, the angle given is the phase difference between two simple harmonic motions of the same frequency and amplitude, one along the X-axis and the other along the Y-axis. The figure thus shows the resultant motion from the superposition of the two perpendicular harmonic motions. [6.5]

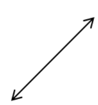
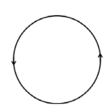
Angle (θ)	0	$\frac{\pi}{2}$
Shape		

Figure 4: QN9. (A)

(B) A man runs at a velocity v in a straight line forming an angle θ with the plane of a mirror. Determine the velocity $v_{relative}$ at which he approaches his image, assuming that the object and its image are symmetric relative to the plane of the mirror. [3.5]

QN10. (A) A student has two packets of resistors, one marked as 10 kΩ and the other as 15 kΩ with a tolerance of 5%. And each packet contains 10 pieces of resistors. He measured each resistor individually and tabulated the resistances as follows:

R_1(kΩ)	9.51	9.39	9.41	9.36	9.60	9.52	9.53	9.39	9.62	9.60
R_2(kΩ)	14.98	14.83	14.74	14.90	14.59	14.74	14.73	14.49	14.80	14.85

(i) Determine the values of R_1 and R_2 with their uncertainties.

(ii) Check whether the labeled values on the packets are valid or not.

(iii) Calculate the values of R_1 and R_2 when they are connected in series and also when they are connected in parallel. [7.5]

(B) Another student took a resistance from the same packet of QN10. (A) labeled as 15 kΩ with a tolerance of 5%. He tried to determine the resistance of that resistor by measuring the voltage across it and the corresponding current through it as follows:

Voltage (V)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Current (mA)	0.032	0.069	0.102	0.130	0.162	0.196	0.230	0.263	0.297	0.350

(i) Plot a graph between current and voltage with error bar.

(ii) Determine the resistance from the graph with uncertainty. [5]

QN11. (A)(i) Show that in the Bohr model, the frequency of revolution of an electron in its circular orbit around a stationary hydrogen nucleus is $\nu = me^4/4\varepsilon_o^2 n^3 h^3$. (ii) In classical physics, the frequency of revolution of the electron is equal to the frequency of the radiation that it emits. Show that when n is very large, the frequency of revolution is indeed equal the radiated frequency calculated from the relation $h\nu = \frac{hc}{\lambda}(= E_i - E_f)$ for a transition from $n_1 = n+1$ to $n_2 = n$. [6.5]

(B) The potential difference between the two plates in the figure 5 is 50.0 V. What will be the speed of a proton released from plate B just before it hits plate A? Assume the system is in vacuum. [3.5]

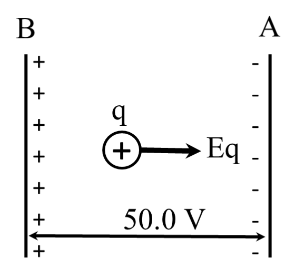


Figure 5: QN11. (B)

************************Good Luck******************************

Syllabus for NePhO (Pre-selection Test)

This syllabus is mostly based on the Secondary Education Curriculum-2076 of grade 11 and a few from grade 12. Problems will mainly focus on testing creativity and understanding of physics rather than testing mathematical skills or speed of working. Additionally, the processing and analysis of scientific data will focus on testing common experimental techniques.

1. Mechanics:

Kinematics; Dynamics; Work, energy and power; Circular motion; Gravitation; Elasticity; Rotational dynamics; Periodic motion.

2. Heat and thermodynamics:

Heat and temperature; Quantity of heat; Ideal gas; First and second law of thermodynamics.

3. Optics:

Reflection at curved mirrors; Refraction: at plane surfaces, through prisms; Dispersion.

4. Electricity and Magnetism:

Electric charges; Electric field; Potential; Capacitor; DC circuits; Electrical circuits; Thermoelectric effects.

5. Modern Physics:

Nuclear physics; Solids; Recent trends in physics; Electrons; Photons; Quantization of energy.

6. Experimental uncertainty & Data analysis:

Identification of dominant error sources, and reasonable estimation of the magnitudes of the experimental uncertainties of direct measurements; Standard deviation; Converting any equation to a straight line; Plotting graphs containing data points with error bars; Fitting a straight line to the data points; Finding slopes and intercepts of the line.

Syllabus for NePhO (Final Selection Test)

This syllabus is mostly based on the Secondary Education Curriculum-2076 of grade 12, and a few advanced topics are also covered. Problems will mainly focus on testing creativity and understanding of physics rather than testing mathematical skills or speed of working. Additionally, experimental techniques for measuring physical quantities will focus on testing experimental skills.

1. Wave and Optics:

Mechanical waves; Acoustic phenomena; Nature and propagation of Light; Interference; Diffraction; Polarization.

2. Electricity and Magnetism:

Magnetic field; Magnetic properties of materials; Electromagnetic induction; Alternating currents.

3. Modern Physics:

Semiconductor devices; Radioactivity and nuclear reaction; Recent trends in physics.

Quantum Physics: Particles as waves; Uncertainty principle.

Statistical physics: Planck's law; Wien's displacement law; the Stefan-Boltzmann law.

4. Experimental uncertainty & Data analysis:

Identification of dominant error sources, and reasonable estimation of the magnitudes of the experimental uncertainties of direct measurements; Distinguishing between random and systematic errors; Finding absolute and relative uncertainties of a quantity determined as a function of measured quantities using any reasonable method (such as linear approximation, addition by modulus or Pythagorean addition). Standard deviation; Transformation of a dependence to a linear form by appropriate choice of variables and fitting a straight line to experimental points. Finding the linear regression parameters (gradient, intercept and uncertainty estimate). Selecting optimal scales for graphs and plotting data points with error bars.

IPhO Syllabus

Accepted 2014 in Astana, amended 2015 in Mumbai.

1 Introduction

1.1 Purpose of this syllabus

This syllabus lists topics which may be used for the IPhO. Guidance about the level of each topic within the syllabus is to be found from past IPhO questions.

1.2 Character of the problems

Problems should focus on testing creativity and understanding of physics rather than testing mathematical virtuosity or speed of working. The proportion of marks allocated for mathematical manipulations should be kept small. In the case of mathematically challenging tasks, alternative approximate solutions should receive partial credit. Problem texts should be concise; the theoretical and the experimental examination texts should each contain fewer than 12000 characters (including white spaces, but excluding cover sheets and answer sheets).

1.3 Exceptions

Questions may contain concepts and phenomena not mentioned in the Syllabus providing that sufficient information is given in the problem text so that students without previous knowledge of these topics would not be at a noticeable disadvantage. Such new concepts must be closely related to the topics included in the syllabus. Such new concepts should be explained in terms of topics in the Syllabus.

1.4 Units

Numerical values are to be given using SI units, or units officially accepted for use with the SI.

It is assumed that the contestants are familiar with the phenomena, concepts, and methods listed below, and are able to apply their knowledge creatively.

2 Theoretical skills

2.1 General

The ability to make appropriate approximations, while modelling real life problems. Recognition and ability to exploit symmetry in problems.

2.2 Mechanics

2.2.1 Kinematics

Velocity and acceleration of a point particle as the derivatives of its displacement vector. Linear speed; centripetal and tangential acceleration. Motion of a point particle with a constant acceleration. Addition of velocities and angular velocities; addition of accelerations without the Coriolis term; recognition of the cases when the Coriolis acceleration is zero. Motion of a rigid body as a rotation around an instantaneous centre of rotation; velocities and accelerations of the material points of rigid rotating bodies.

2.2.2 Statics

Finding the centre of mass of a system via summation or via integration. Equilibrium conditions: force balance (vectorially or in terms of projections), and torque balance (only for one- and two-dimensional geometry). Normal force, tension force, static and kinetic friction force; Hooke's law, stress, strain, and Young modulus. Stable and unstable equilibria.

2.2.3 Dynamics

Newton's second law (in vector form and via projections (components)); kinetic energy for translational and rotational motions. Potential energy for simple force fields (also as a line integral of the force field). Momentum, angular momentum, energy and their conservation laws. Mechanical work and power; dissipation due to friction. Inertial and non-inertial frames of reference: inertial force, centrifugal force, potential energy in a rotating frame. Moment of inertia for simple bodies (ring, disk, sphere, hollow sphere, rod), parallel axis theorem; finding a moment of inertia via integration.

2.2.4 Celestial mechanics

Law of gravity, gravitational potential, Kepler's laws (no derivation needed for first and third law). Energy of a point mass on an elliptical orbit.

2.2.5 Hydrodynamics

Pressure, buoyancy, continuity law, the Bernoulli equation. Surface tension and the associated energy, capillary pressure.

2.3 Electromagnetic fields

2.3.1 Basic concepts

Concepts of charge and current; charge conservation and Kirchhoff's current law. Coulomb force; electrostatic field as a potential field; Kirchhoff's voltage law. Magnetic B-field; Lorentz force; Ampère's force; Biot-Savart law and B-field on the axis of a circular current loop and for simple symmetric systems like straight wire, circular loop and long solenoid.

2.3.2 Integral forms of Maxwell's equations

Gauss' law (for E- and B-fields); Ampère's law; Faraday's law; using these laws for the calculation of fields when the integrand is almost piece-wise constant. Boundary conditions for the electric field (or electrostatic potential) at the surface of conductors and at infinity; concept of grounded conductors. Superposition principle for electric and magnetic fields; uniqueness of solution to well-posed problems; method of image charges.

2.3.3 Interaction of matter with electric and magnetic fields

Resistivity and conductivity; differential form of Ohm's law. Dielectric and magnetic permeability; relative permittivity and permeability of electric and magnetic materials; energy density of electric and magnetic fields; ferromagnetic materials; hysteresis and dissipation; eddy currents; Lenz's law. Charges in magnetic field: helicoidal motion, cyclotron frequency, drift in crossed E- and B-fields. Energy of a magnetic dipole in a magnetic field; dipole moment of a current loop.

2.3.4 Circuits

Linear resistors and Ohm's law; Joule's law; work done by an electromotive force; ideal and non-ideal batteries, constant current sources, ammeters, voltmeters and ohmmeters. Nonlinear elements of given V-I characteristic. Capacitors and capacitance (also for a single electrode with respect to infinity); self-induction and inductance; energy of capacitors and inductors; mutual inductance; time constants for RL and RC circuits. AC circuits: complex amplitude; impedance of resistors, inductors, capacitors, and combination circuits; phasor diagrams; current and voltage resonance; active power.

2.4 Oscillations and waves

2.4.1 Single oscillator

Harmonic oscillations : equation of motion, frequency, angular frequency and period. Physical pendulum and its reduced length. Behaviour near unstable equilibria. Exponential decay of damped oscillations; resonance of sinusoidally forced oscillators: amplitude and phase shift of steady state oscillations. Free oscillations of LC-circuits; mechano-electrical analogy; positive feedback as a source of instability; generation of sine waves by feedback in a LC-resonator.

2.4.2 Waves

Propagation of harmonic waves: phase as a linear function of space and time; wave length, wave vector, phase and group velocities; exponential decay for waves propagating in dissipative media; transverse and longitudinal waves; the classical Doppler effect. Waves in inhomogeneous media: Fermat's principle, Snell's law. Sound waves: speed as a function of pressure (Young's or bulk modulus) and density, Mach cone. Energy carried by waves: proportionality to the square of the amplitude, continuity of the energy flux.

2.4.3 Interference and diffraction

Superposition of waves: coherence, beats, standing waves, Huygens' principle , interference due to thin films (conditions for intensity minima and maxima only). Diffraction from one and two slits, diffraction grating, Bragg reflection.

2.4.4 Interaction of electromagnetic waves with matter

Dependence of electric permittivity on frequency (qualitatively); refractive index; dispersion and dissipation of electromagnetic waves in transparent and opaque materials. Linear polarisation; Brewster angle; polarisers; Malus' law.

2.4.5 Geometrical optics and photometry

Approximation of geometrical optics: rays and optical images; a partial shadow and full shadow. Thin lens approximation; construction of images created by ideal thin lenses; thin lens equation . Luminous flux and its continuity; illuminance; luminous intensity.

2.4.6 Optical devices

Telescopes and microscopes: magnification and resolving power; diffraction grating and its resolving power; interferometers.

2.5 Relativity

Principle of relativity and Lorentz transformations for the time and spatial coordinate, and for the energy and momentum; mass-energy equivalence; invariance of the spacetime interval and of the rest mass. Addition of parallel velocities; time dilation; length contraction; relativity of simultaneity; energy and momentum of photons and relativistic Doppler effect; relativistic equation of motion; conservation of energy and momentum for elastic and non-elastic interaction of particles.

2.6 Quantum Physics

2.6.1 Probability waves

Particles as waves: relationship between the frequency and energy, and between the wave vector and momentum. energy levels of hydrogen-like atoms (circular orbits only) and of parabolic potentials; quantization of angular momentum. Uncertainty principle for the conjugate pairs of time and energy, and of coordinate and momentum (as a theorem, and as a tool for estimates);

2.6.2 Structure of matter

Emission and absorption spectra for hydrogen-like atoms (for other atoms — qualitatively), and for molecules due to molecular oscillations; spectral width and lifetime of excited states. Pauli exclusion principle for Fermi particles. Particles (knowledge of charge and spin): electrons, electron neutrinos, protons, neutrons, photons; Compton scattering. Protons and neutrons as compound particles. Atomic nuclei, energy levels of nuclei (qualitatively); alpha-, beta- and gamma-decays; fission, fusion and neutron capture; mass defect; half life and exponential decay. photoelectric effect.

2.7 Thermodynamics and statistical physics

2.7.1 Classical thermodynamics

Concepts of thermal equilibrium and reversible processes; internal energy, work and heat; Kelvin's temperature scale; entropy; open, closed, isolated systems; first and second laws of thermodynamics. Kinetic theory of ideal gases: Avogadro number, Boltzmann factor and gas constant; translational motion of molecules and pressure; ideal gas law; translational, rotational and oscillatory degrees of freedom; equipartition theorem; internal energy of ideal gases; root-mean-square speed of molecules. Isothermal, isobaric, isochoric, and adiabatic processes; specific heat for isobaric and isochoric processes; forward and reverse Carnot cycle on ideal gas and its efficiency; efficiency of non-ideal heat engines.

2.7.2 Heat transfer and phase transitions

Phase transitions (boiling, evaporation, melting, sublimation) and latent heat; saturated vapour pressure, relative humidity; boiling; Dalton's law; concept of heat conductivity; continuity of heat flux.

2.7.3 Statistical physics

Planck's law (explained qualitatively, does not need to be remembered), Wien's displacement law; the Stefan-Boltzmann law.

3 Experimental skills

3.1 Introduction

The theoretical knowledge required for carrying out the experiments must be covered by Section 2 of this Syllabus.

The experimental problems should contain at least some tasks for which the experimental procedure (setup, the list of all the quantities subject to direct measurements, and formulae to be used for calculations) is not described in full detail.

The experimental problems may contain implicit theoretical tasks (deriving formulae necessary for calculations); there should be no explicit theoretical tasks unless these tasks test the understanding of the operation principles of the given experimental setup or of the physics of the phenomena to be studied, and do not involve long mathematical calculations.

The expected number of direct measurements and the volume of numerical calculations should not be so large as to consume a major part of the allotted time: the exam should test experimental creativity, rather than the speed with which the students can perform technical tasks.

The students should have the following skills.

3.2 Safety

Knowing standard safety rules in laboratory work. Nevertheless, if the experimental set-up contains any safety hazards, the appropriate warnings should be included in the text of the problem. Experiments with major safety hazards should be avoided.

3.3 Measurement techniques and apparatus

Being familiar with the most common experimental techniques for measuring physical quantities mentioned in the theoretical part.

Knowing commonly used simple laboratory instruments and digital and analog versions of simple devices, such as calipers, the Vernier scale, stopwatches, thermometers, multimeters (including ohmmeters and AC/DC voltmeters and ammeters), potentiometers, diodes, , lenses, prisms, optical stands, calorimeters, and so on.

Sophisticated practical equipment likely to be unfamiliar to the students should not dominate a problem. In the case of moderately sophisticated equipment (such as oscilloscopes, counters, ratemeters, signal and function generators, photogates, etc), instructions must be given to the students.

3.4 Accuracy

Being aware that instruments may affect the outcome of experiments.

Being familiar with basic techniques for increasing experimental accuracy (e.g. measuring many periods instead of a single one, minimizing the influence of noise, etc).

Knowing that if a functional dependence of a physical quantity is to be determined, the density of taken data points should correspond to the local characteristic scale of that functional dependence.

Expressing the final results and experimental uncertainties with a reasonable number of significant digits, and rounding off correctly.

3.5 Experimental uncertainty analysis

Identification of dominant error sources, and reasonable estimation of the magnitudes of the experimental uncertainties of direct measurements (using rules from documentation, if provided).

Distinguishing between random and systematic errors; being able to estimate and reduce the former via repeated measurements.

Finding absolute and relative uncertainties of a quantity determined as a function of measured quantities using any reasonable method (such as linear approximation, addition by modulus or Pythagorean addition).

3.6 Data analysis

Transformation of a dependence to a linear form by appropriate choice of variables and fitting a straight line to experimental points. Finding the linear regression parameters (gradient, intercept and uncertainty estimate) either graphically, or using the statistical functions of a calculator (either method acceptable).

Selecting optimal scales for graphs and plotting data points with error bars.