

Remote laboratory experiments and participant responsibilities

JOOUST Remote Laboratory Demonstration Centre



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Overview

This manual describes one proposed experiment for each of the 13 stations. It explains how distant researchers and students plan measurements, operate permitted controls, analyze real data and report results, with support from an on-site technician.

Scope and implementation

These activities are experimental specifications rather than approved operating procedures. Each must be adapted to the selected instrument, manufacturer instructions, accessories, samples and institutional requirements. Controls described here are conditional on a supported remote interface; manual sample changes and adjustments are performed on-site.

Remote session workflow

Before the session, book access, read the experiment, complete the theory preparation and submit a measurement plan. Researchers should provide sample composition, intended measurements and acceptance criteria.

At session start, view the apparatus, review calibration and instrument status, confirm allowed settings and establish contact with the technician.

During acquisition, operate authorized controls, monitor live results, record changes and request physical actions through the technician. Pause or repeat questionable measurements with justification.

After acquisition, download original data and metadata, retain an untouched copy, document processing and submit a reproducible report.

Responsibilities and session safeguards

The technician prepares samples, calibrates and aligns equipment, authorizes operating ranges and manages physical handling. The distant participant controls only approved settings. The host must provide session limits, logging, technician override and a safe response to lost connectivity. SEM, TEM and biological sessions require supervision.

Group participants may rotate as instrument operator, experiment coordinator, data recorder and analyst. Reports must distinguish remote actions, technician actions and post-session analysis.

Station 1 Mechanics

Newton second law on a dynamics track

Purpose

Determine how acceleration depends on driving force and total moving mass, including friction.

Apparatus

Track, cart, pulley, string, calibrated masses, force sensor, motion detector or photogates, release mechanism, DAQ and camera.

Theory

For the cart–hanger system: $m_h g - f = M_{\text{total}} a$. String tension is not the net force on the complete system.

Preparation by the distant participant

Draw free-body diagrams; define the system; predict acceleration; choose sampling and identify track slope and pulley resistance as possible errors.

On site preparation

Level the track, measure masses, calibrate sensors and verify end stops and safe travel.

Experimental procedure

1. Review sensor baselines.
2. Select an approved mass configuration and start acquisition.
3. Trigger release and record force and motion.
4. Repeat each configuration at least three times.
5. Vary hanging mass while keeping total moving mass constant.
6. Run a second series varying total mass at approximately constant driving force.
7. Flag collisions, slipping string and irregular motion.

Role of the distant researcher or student

Select trials, start acquisition and release, inspect live graphs and decide which measurements to repeat. Request physical mass changes unless automated. Researchers may compare friction models.

Analysis and interpretation

Fit velocity–time slopes for acceleration; plot acceleration against driving force; compare slope with $1/M_{\text{total}}$; evaluate friction and propagate measurement uncertainty.

Required submission

Free-body diagrams, raw data, fitted graphs, uncertainty and model comparison.

Station 2 Thermal physics

Newton law of cooling

Purpose

Measure cooling and test an exponential model under different conditions.

Apparatus

Heated metal block, block and ambient sensors, controlled heater, optional fan, DAQ and camera.

Theory

$T(t) = T_a + (T_0 - T_a) \exp(-kt)$; thermal time constant $\tau = 1/k$, assuming approximately constant ambient temperature.

Preparation by the distant participant

Explain model assumptions; predict airflow effects; select sampling interval and fit method.

On site preparation

Install sensors, check heater protection and establish temperature limits.

Experimental procedure

1. Record ambient and initial temperatures.
2. Select an approved heating setpoint.
3. Allow suitable stabilization.
4. Switch off heat and record cooling.
5. Continue over a sufficient temperature range.
6. Repeat at another initial temperature and approved airflow condition.
7. Record ambient changes.

Role of the distant researcher or student

Choose temperature and airflow settings, monitor trends and determine whether the record is adequate. Check ambient stability before fitting.

Analysis and interpretation

Fit the cooling curve directly; report k and τ with uncertainty; inspect residuals; discuss sensor response and internal temperature gradients.

Required submission

Cooling curves, fit parameters, residuals and assessment of model validity.

Station 3 Optical characterization

Diffraction and laser wavelength

Purpose

Determine wavelength and compare single-slit intensity patterns.

Apparatus

Enclosed low-power laser, known grating, selectable slits, motorized mounts, calibrated screen distance and imaging camera.

Theory

$d \sin \theta = m\lambda$; $\theta = \arctan(y/L)$. Single-slit minima: $a \sin \theta = m\lambda$ for nonzero integer m .

Preparation by the distant participant

Predict order positions; assess small-angle approximation; plan uncertainty in grating spacing, distance and image position.

On site preparation

Enclose and align beam, calibrate image scale and check mount limits.

Experimental procedure

1. Select grating.
2. Adjust exposure to avoid saturation.
3. Capture central and higher orders.
4. Measure both sides of the central maximum.
5. Repeat image acquisition.
6. Select two slit widths and capture patterns.
7. Preserve originals before background correction.

Role of the distant researcher or student

Select supported elements, adjust exposure, choose measurement regions and extract intensity profiles. Request any physical alignment.

Analysis and interpretation

Calculate wavelength from multiple orders; compare opposite sides; propagate uncertainty; compare slit minima with theory and discuss resolution.

Required submission

Annotated images, profiles, wavelength and uncertainty.

Station 4 Atomic force microscopy

Thin-film topography and roughness

Purpose

Compare nanoscale surface features and roughness across prepared films.

Apparatus

AFM, suitable cantilevers, calibration specimen, films, vibration isolation, controller and analysis software.

Theory

$R_a = \text{mean}(|z - \text{mean}(z)|)$; $R_q = \sqrt{\text{mean}((z - \text{mean}(z))^2)}$. Roughness depends on scan area and processing.

Preparation by the distant participant

Define features, scan sizes, resolution and number of regions; review tip and feedback effects.

On site preparation

Install tip and sample, align, approach and establish stable imaging; verify calibration.

Experimental procedure

1. Review calibration image.
2. Acquire overview scan.
3. Select smaller feature regions.
4. Record height and supporting channels.
5. Repeat across multiple regions.
6. Compare trace and retrace.
7. Repeat an approved scan-rate condition.
8. Retain original data and processing log.

Role of the distant researcher or student

Choose scan regions and approved settings; assess artifacts and request repeat scans. Researchers can compare treatments or aging using approved sample sets.

Analysis and interpretation

Level with a documented method; calculate roughness and line profiles; compare consistent scan conditions; discuss tip convolution and sampling.

Required submission

Height maps, profiles, roughness statistics and artifact assessment.

Station 5 Scanning tunneling microscopy

Graphite imaging and tunneling current

Purpose

Examine graphite structure and current sensitivity to separation.

Apparatus

STM, conductive tip, graphite, vibration isolation, controller and software.

Theory

I is approximately proportional to $\exp(-2\kappa z)$. Contrast reflects electronic structure as well as geometry.

Preparation by the distant participant

Explain conductive-sample requirement; compare imaging modes; propose scan sizes and bias conditions.

On site preparation

Prepare surface and tip, establish stable tunneling and protected limits.

Experimental procedure

1. Acquire larger stability scan.
2. Reduce scan area progressively.
3. Compare approved bias and current settings.
4. Repeat to assess drift.
5. Request a supervised current–distance curve if supported.
6. Save images and metadata.

Role of the distant researcher or student

Select authorized parameters and regions, evaluate drift and compare contrast. Tip preparation and coarse approach remain on-site.

Analysis and interpretation

Measure apparent periodicity; compare bias-dependent images; plot $\ln(I)$ against separation when suitable; discuss drift and tip effects without assuming each bright feature is an atom.

Required submission

Images, line profiles, periodicity and tunneling interpretation.

Station 6 UV Vis spectrophotometry

Beer Lambert calibration

Purpose

Determine unknown solution concentration from absorbance.

Apparatus

Programmable UV–Vis instrument, cuvettes, blank, standards, unknown and supported sample changer.

Theory

$A = -\log_{10}(I/I_0) = \epsilon lc$; practical calibration $A = mc + b$.

Preparation by the distant participant

Select scan range, standards, blank and replicates; define calibration acceptance checks.

On site preparation

Prepare solutions, document preparation, check bubbles and contamination and load cuvettes.

Experimental procedure

1. Measure blank.
2. Scan representative standard and choose analytical wavelength.
3. Measure standards in documented order.
4. Include replicates and check standard.
5. Measure unknown.
6. Request dilution if outside validated range.
7. Download spectra and settings.

Role of the distant researcher or student

Select wavelength and supported parameters, schedule readings and evaluate calibration. Request technician changes when no sample changer exists.

Analysis and interpretation

Fit calibration and inspect residuals; calculate unknown and dilution factor; assess uncertainty and interference; distinguish repeated readings from independent preparations.

Required submission

Spectra, calibration, unknown concentration and uncertainty.

Station 7 FTIR and Raman spectroscopy

Polymer identification

Purpose

Identify prepared polymers using complementary vibrational spectra.

Apparatus

FTIR with ATR, Raman instrument with enclosed laser, reference polymers, unknown and software.

Theory

Band positions and patterns support identification; FTIR and Raman have complementary responses.

Preparation by the distant participant

Review functional groups, predict diagnostic bands, choose settings and candidate materials.

On site preparation

Load samples, establish ATR contact, focus Raman and prevent sample damage.

Experimental procedure

1. Acquire FTIR background.
2. Record reference spectra.
3. Record unknown FTIR spectrum.
4. Acquire Raman spectra.
5. Repeat weak or questionable measurements within limits.
6. Compare references.
7. Preserve originals and document correction.

Role of the distant researcher or student

Choose permitted resolution, scans and duration; assess signal quality; request additional evidence and explain diagnostic bands.

Analysis and interpretation

Assign bands using appropriate references; compare evidence; discuss fluorescence, overlap and identification uncertainty. Uncalibrated ATR intensity is not direct concentration.

Required submission

Annotated spectra, assignments and justified identification.

Station 8 Automated titration

Potentiometric acid concentration

Purpose

Determine concentration and compare equivalence-point methods.

Apparatus

Titration, calibrated pH electrode, standardized base, acid, stirrer, dispenser and containment.

Theory

For a monoprotic acid and monovalent base: $C_a V_a = C_b V_b$ at equivalence.

Preparation by the distant participant

Balance reaction, estimate equivalence volume, select increments and distinguish endpoint from equivalence.

On site preparation

Prepare reagents, record titrant concentration, calibrate electrode, prime dispenser and load sample.

Experimental procedure

1. Record initial pH.
2. Start approved dosing program.
3. Add controlled increments.
4. Allow readings to stabilize.
5. Use finer additions near equivalence.
6. Continue enough to define post-equivalence curve.
7. Repeat with independent aliquots.

Role of the distant researcher or student

Define and run approved dosing, monitor the curve and request finer additions or repeats. Technician changes samples and handles waste.

Analysis and interpretation

Plot pH–volume and derivatives; compare equivalence estimates; calculate concentration and uncertainty from titrant, dosing and aliquot volume.

Required submission

Curves, derivative plots, concentration and replicate statistics.

Station 9 Digital microscopy

Calibrated microscopic measurements

Purpose

Measure features and assess magnification and image quality.

Apparatus

Microscope, camera, stage micrometer, specimens, supported motorized stage/focus and software.

Theory

Feature length = pixel count $\times$ calibrated micrometres per pixel. Calibration must match optical configuration.

Preparation by the distant participant

Define features, selection rule, fields and number of measurements; distinguish magnification and resolution.

On site preparation

Load slides, check illumination and stage limits.

Experimental procedure

1. Image micrometer at each objective.
2. Calculate scale.
3. Navigate specimen.
4. Adjust supported focus and exposure.
5. Capture representative fields.
6. Measure with matching calibration.
7. Repeat measurements for operator variation.

Role of the distant researcher or student

Navigate available controls, select fields and measure. Direct manual technician movements with coordinates or marked images when needed.

Analysis and interpretation

Compute distributions, mean and standard deviation; assess calibration, boundary choice and sampling bias.

Required submission

Original and annotated images, calibration and measurement statistics.

Station 10 Biological assays

Temperature dependence of enzyme activity

Purpose

Compare initial rates of a validated teaching assay.

Apparatus

Colorimeter or plate reader, enzyme/substrate, temperature holder, dispenser or pipettes and vessels.

Theory

Initial rate follows the early reaction slope; concentration conversion requires a validated assay calibration.

Preparation by the distant participant

Review reaction, controls, temperatures, replicates and initial-rate interval.

On site preparation

Prepare approved non-pathogenic assay, validate controls and manage materials under institutional procedures.

Experimental procedure

1. Record blank.
2. Equilibrate reagents.
3. Initiate and timestamp reaction.
4. Measure absorbance at intervals.
5. Repeat independent mixtures.
6. Compare approved temperatures.
7. Collect controls.

Role of the distant researcher or student

Choose measurement schedule and approved temperatures, examine early linearity and timing. Manual initiation is timestamped on-site; automation requires validated mixing.

Analysis and interpretation

Calculate blank-corrected initial slopes; convert only where justified; compare rates and discuss timing, reagent variability and inactivation.

Required submission

Reaction curves, controls, rates and qualified interpretation.

Station 11 Scanning electron microscopy

Morphology and particle dimensions

Purpose

Compare surfaces and measure representative features.

Apparatus

SEM, stubs, adhesive, preparation/coating facilities where needed, vacuum system and software.

Theory

Image contrast depends on detector and operating conditions; two-dimensional images do not fully specify three-dimensional shape.

Preparation by the distant participant

Submit composition, questions, feature definition and region plan; review charging and beam sensitivity.

On site preparation

Assess compatibility, mount/load specimen and establish appropriate imaging.

Experimental procedure

1. Capture overview.
2. Select representative regions.
3. Adjust approved focus and magnification.
4. Record documented settings.
5. Compare approved detector or beam conditions.
6. Measure multiple fields.
7. Flag charging and damage.

Role of the distant researcher or student

Choose regions and justified settings through supervised access. Technician controls loading, vacuum and restricted operations.

Analysis and interpretation

Define size metric, measure consistently and report distributions and morphology. EDS is an optional extension only if installed and approved.

Required submission

Micrographs, metadata, measurements and morphology analysis.

Station 12 Transmission electron microscopy

Nanoparticle size and crystallinity

Purpose

Measure nanoparticles and examine supported crystallinity evidence.

Apparatus

TEM, compatible grids/holder, camera, vacuum system, supported diffraction mode and software.

Theory

Dimensions require calibrated images; diffraction interpretation requires calibration and suitable reference information.

Preparation by the distant participant

Submit composition, selection rules, regions and questions; review overlap, thickness and beam damage.

On site preparation

Assess grids, prepare/load specimen, align instrument and approve conditions.

Experimental procedure

1. Survey grid.
2. Select suitable thickness.
3. Image separated particles.
4. Sample multiple regions.
5. Acquire diffraction when supported.
6. Request images resolving uncertainty.
7. Save calibration and settings.

Role of the distant researcher or student

Select relevant regions and propose imaging conditions within supervised limits.
Technician handles exchange, alignment and fault recovery.

Analysis and interpretation

Define measured dimension and population; plot distribution; interpret calibrated diffraction cautiously; distinguish crystallinity evidence from definitive phase identification.

Required submission

Images, measurements, distributions and qualified diffraction interpretation.

Station 13 Sensors wireless measurement and DAQ

Calibration and sampling quality

Purpose

Calibrate channels and assess sampling, noise and transmission.

Apparatus

Force/temperature sensors, motion detector, references, DAQ, wireless nodes, microcontroller and controlled motion source.

Theory

Linear response $V = Sx + b$. Sampling and filtering determine whether a waveform can be represented faithfully.

Preparation by the distant participant

Define range, frequencies, reference points, rates and missing-data checks.

On site preparation

Wire and verify channels, apply references and set source limits.

Experimental procedure

1. Measure known inputs.
2. Repeat calibration points.
3. Acquire periodic signal at high rate.
4. Repeat at lower rates.
5. Compare wired/wireless records.
6. Inspect timestamps and missing samples.
7. Repeat to assess drift.

Role of the distant researcher or student

Configure approved channels/rates, acquire data and assess quality; request physical reference loads and wiring changes.

Analysis and interpretation

Fit sensitivity and offset; inspect residuals, repeatability and drift; compare aliasing and filtering; quantify missing samples and timestamp reliability.

Required submission

Calibration, time series, sampling comparisons and quality report.

Common reporting and assessment requirements

Question and prediction

State the research question, hypothesis and expected observations.

Method and division of work

Describe apparatus, sample preparation, settings and actions performed remotely or by the technician.

Raw data and metadata

Provide original measurements, units, timestamps, calibration and instrument configuration. Retain an untouched copy.

Analysis and uncertainty

Show equations, processing, calculations, graphs, uncertainty and justified exclusions. Include analysis code or calculation workbook.

Interpretation and limitations

Answer the question using measurements; explain limitations, unexpected results and alternatives.

Reproducibility

Record software versions where relevant, sample identity, processing choices and conditions needed to repeat the work.

Conclusion

Give a clear result supported by evidence and suggest a justified follow-up measurement.

Assessment should recognize experimental planning, decisions during the session, data quality, uncertainty and interpretation, alongside final numerical results. Researchers should agree on sample handling, data access and publication requirements before measurements begin.