# Remote laboratory experiments

## JOOUST Remote Laboratory Demonstration Centre




**November 2026**

## 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.

## Five-year phase schedule

| Phase | Delivery | Physics | Chemistry | Biology |
|---|---|---|---|---|
| **1** | Years 1-2 | Mechanics, AFM | 0UV-Vis | Digital microscopy |
| **2** | Years 3-4 | Thermal, STM | Titration | Assays, SEM applications |
| **3** | Year 5 | Optics, DAQ applications | FTIR and Raman | TEM, DAQ applications |

SEM and TEM allowances cover defined teaching and research access during Years 3–5 and Year 5 respectively. Written agreements must confirm eligible specimens, rates, booking capacity, live participation, data export and access terms. Partner operators run instruments and may deliver approved recordings and datasets when live participation is unavailable.

## 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 local-station controls or request acquisition through the partner operator. Monitor live results when available, record changes and justify requests for repeat measurements.

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

**Phase 1 | Years 1-2 | Physics**

**Applications across the three disciplines**

Physics - Verify Newton’s second law.

Chemistry - Compare sliding friction of polymer surfaces.

Biology - Analyze forces in a model limb.

**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 $1/M_{total}$; evaluate friction and propagate measurement uncertainty.

**Required submission**

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

## Station 2 Thermal physics

**Phase 2 | Years 3-4 | Physics**

**Applications across the three disciplines**

Physics - Fit a cooling curve.

Chemistry - Compare heat transfer for water and dilute salt solution.

Biology - Use a water phantom to model tissue cooling.

**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**

$T(t) = T_a + (T_0 - T_a)e^{-kt}$ ; thermal time constant τ = 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

**Phase 3 | Year 5 | Physics**

**Applications across the three disciplines**

Physics - Measure laser wavelength by diffraction.

Chemistry - Compare transmission through safe dye standards.

Biology - Measure diffraction through a prepared wing specimen.

## 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

**Phase 1 | Years 1-2 | Physics / materials**

**Applications across the three disciplines**

Physics - Measure thin-film roughness.

Chemistry - Compare surface texture of polymer coatings.

Biology - Measure topography of a prepared cellulose film.

**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**

$R_a = \frac{1}{N}\sum_{i=1}^{N}\left|z_i - \bar{z}\right|, R_q = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(z_i - \bar{z}\right)^2}$. 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

**Phase 2 | Years 3-4 | Physics / materials**

**Applications across the three disciplines**

Physics - Fit tunnelling current versus distance.

Chemistry - Compare graphite before and after a technician-applied surface treatment.

Biology - Analyze graphite data as a conductive biosensor substrate case study.

**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

**Phase 1 | Years 1-2 | Chemistry**

**Applications across the three disciplines**

Physics - Characterize transmission and absorbance.

Chemistry - Determine dye concentration by Beer–Lambert calibration.

Biology - Estimate pigment concentration from a prepared plant extract.

**Beer Lambert calibration**

**Purpose**

Determine unknown solution concentration from absorbance.

**Apparatus**

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

**Theory**

$A = -\log_{10} \left( \frac{I}{I_0} \right) = \log_{10} \left( \frac{I_0}{I} \right) = \varepsilon l c$ ; 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

**Phase 3 | Year 5 | Chemistry**

**Applications across the three disciplines**

Physics - Compare vibrational modes across reference spectra.

Chemistry - Identify a polymer using diagnostic bands.

Biology - Analyze a reference cellulose or chitin spectrum.

## 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

**Phase 2 | Years 3-4 | Chemistry**

**Applications across the three disciplines**
Physics - Characterize electrode response and stabilization.

Chemistry - Find acid concentration by potentiometric titration.

Biology - Compare buffering in a cell-free bicarbonate model.

**Potentiometric acid concentration**

**Purpose**
Determine concentration and compare equivalence-point methods.

**Apparatus**
Titrator, 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

**Phase 1 | Years 1-2 | Biology**

**Applications across the three disciplines**
Physics - Calibrate optical magnification and resolution.

Chemistry - Measure dimensions of a prepared salt crystal sample.

Biology - Compare cell sizes on prepared slides.

**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 × 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

**Phase 2 | Years 3-4 | Biology**

**Applications across the three disciplines**
Physics - Check the stability of a temperature-controlled measurement.

Chemistry - Fit reaction-rate curves from absorbance data.

Biology - Compare enzyme activity at different temperatures.

**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

**Phase 2 | Years 3-4 | Shared / materials**

**Applications across the three disciplines**

Physics - Compare detector contrast and charging in approved data.

Chemistry - Compare morphology of prepared catalyst particles.

Biology - Measure dimensions of prepared pollen or diatom specimens.

Partner facility session. The remote participant selects regions and proposes settings. The partner operator loads specimens, executes instrument controls and exports calibrated files with acquisition metadata. Use approved data for analysis when a live session is unavailable.

## Morphology and particle dimensions

### Purpose

Compare surfaces and measure representative features.

### Apparatus

Partner SEM and supported detectors, sample mounts, preparation or coating facilities as needed, and exported calibrated images with settings and scale.

### 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

The partner operator assesses specimen compatibility, prepares and loads the specimen, and confirms approved imaging conditions.

### 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

Propose regions and settings to the partner operator and interpret the returned data. The operator controls the instrument, sample 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

**Phase 3 | Year 5 | Biology / materials**

**Applications across the three disciplines**

Physics - Interpret calibrated electron diffraction from a suitable standard.

Chemistry - Measure size distributions of prepared nanoparticles.

Biology - Measure features in a fixed teaching specimen or approved archived images.

Partner facility session. The remote participant selects regions and proposes settings. The partner operator loads specimens, executes instrument controls and exports calibrated files with acquisition metadata. Use approved data for analysis when a live session is unavailable.

**Nanoparticle size and crystallinity**

**Purpose**

Measure nanoparticles and examine supported crystallinity evidence.

**Apparatus**

Partner TEM with compatible grids and holder, digital imaging and supported diffraction mode, plus exported calibrated images and metadata.

**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**

The partner operator assesses grids, prepares or loads the specimen, aligns the instrument and approves acquisition 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**

Propose relevant regions and imaging conditions to the partner operator, then analyze calibrated images and diffraction data when available. The operator runs the instrument, handles alignment and resolves faults.

**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

**Phase 3 | Year 5 | Shared**

**Applications across the three disciplines**

Physics - Quantify sensor sampling error and aliasing.

Chemistry - Calibrate a conductivity probe with salt standards.

Biology - Track light and temperature in a plant-growth model.

**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.