**Supplementary Material**

**1: Global scale usage of virtual laboratories**

The Virtual laboratories have been reported to have more than 300,000 registered users as of February 28, 2018, with a steady increase of new users since 2012. In 2012, there were 13438 registered users and as of today (February 28) has 305327 users.

**2. Usage statistics from CAPVL platform (Period from 22nd February, 2012- 28th February, 2018)**

|  |  |
| --- | --- |
| Popular Operating System | |
| Windows | 53% |
| Android | 20% |
| Macintosh | 8% |
| iOS | 6% |
| Linux | 2% |
| BlackBerry | 1% |

Data shows user’s preferences on browsers and operating system for performing virtual lab experiments.

|  |  |
| --- | --- |
| Popular Browser | |
| Chrome | 54% |
| Firefox | 12% |
| Safari | 10% |
| Opera Mini | 7% |
| Internet Explorer | 7% |
| UC Browser | 6% |

3. Virtual Laboratories: Access information

Virtual laboratory experiments are divided among biological sciences, physical sciences, chemical sciences and engineering disciplines. The laboratories are freely accessible at <http://vlab.amrita.edu>

Users may need to register with their Google or institutional email ID for access.

|  |  |  |
| --- | --- | --- |
| Discipline | Subjects Covered | Experiment name |
| **Biotechnology and Biomedical engineering** | Neurophysiology | Brain Slice Preparation |
| Simple Neuron Model - the HH neuron |
| Patch Clamp Technique |
| Current Clamp Technique |
| Voltage Clamp Technique |
| Study of Synaptic Transmission |
| Measuring Field Potentials Using MEA chips |
| Understanding the Passive Properties of a Simple Neuron |
| Effects of Ion Channels in Membrane Biophysics |
| Effect of Noise on Spiking Neurons |
| Neuron Simulation | Modeling resting potentials in Neurons |
| Modeling action potentials |
| Modeling the delayed rectifier Potassium channels |
| Modeling the sodium ion channel and its effects on neural signaling |
| Current Clamp protocol |
| Voltage Clamp Protocol |
| Understanding Frequency-Current relationship |
| Understanding first spike latency - current relationship |
| Voltage-Current (VI) plot |
| Effects of pharmacological blockers on action potential |
| Biochemistry | Qualitative Analysis of Carbohydrates |
| Isoelectric Precipitation of Proteins: Casein from Milk |
| Quantitative Estimation of Amino Acids by Ninhydrin |
| Separation of Amino Acids by Thin Layer Chromatography |
| Estimation of Saponification Value of Fats/Oils |
| Detection of Adulteration in Milk |
| Qualitative Analysis of Amino Acid |
| Estimation of Iodine Value of Fats and Oils |
| Titration Curves of Aminoacids |
| Estimation of blood glucose by Glucose oxidase method |
| Isolation of β -Amylase from Sweet Potato |
| Gelatin Zymography |
| Extraction of Caffeine from Tea |
| Construction of Maltose Standard Curve by DNS Method |
| Isolation of Plant Pigments by Column Chromatography |
| Structural Studies of Phycobiliproteins from Spirulina |
| Construction of Protein Standard Curve using Folin’s Lowry Method |
| Effect of Substrate Concentration on Enzyme Kinetics |
| Effect of temperature on enzyme kinetics |
| Hydrolysis of Ester using orange peel esterase |
| Population Ecology | Population with Continuous and Discrete Growth |
| Spread of a Pest Population - Population Invasion |
| Age Structured Leslie Matrix |
| Stage Structured Leslie Matrix |
| Metapopulation Dynamics -Levins Model |
| Interspecific Competition and Coexistence |
| Effect of Interspecific Competition on Species Border |
| Logistic Population Growth: Continuous and Discrete |
| Parasitoid-Host Dynamics |
| Conserving an Endangered Species |
| Predator - Prey Dynamics - Rats and Snakes (Lotka Volterra Simulation) |
| Effect of Predator Efficiency on Equilibrium Densities & Pop. Stability |
| Effect of Social Behavior Amongst Predator-Prey Populations |
| Effects of Carrying Capacity and Satiation in Predator-Prey Dynamics |
| Harvesting a Prey Population |
| Optimal Foraging with Minimal Time: A Case of Searching Predators |
| Optimal Foraging : Searching Predators that Maximize Energy |
| Optimal Pollinators |
| Optimal Foraging: Sit-and-wait Predators that Maximize Energy |
| Microparasite and Macroparasite - Host Dynamics |
| Immunology | Collection of Serum from Blood |
| Blood Grouping Experiment |
| Latex Agglutination |
| Indirect ELISA |
| Direct ELISA |
| Sandwich Elisa |
| ELISPOT Assay |
| Antibody Labeling with HRP |
| Extraction of IgG Antibodies from Immunized Hen Egg |
| Isolation of lymphocytes from whole blood |
| Ouchterlony Double Diffusion -Titration |
| Ouchterlony Double Diffusion - Patterns |
| Purification of IgG Antibodies with Ammonium Sulphate |
| Removal of Thymus and Spleen from Mice |
| Mouse Anesthesia and Blood Collection |
| Parenteral Injections |
| Purification of IgG Antibodies using Affinity Chromatography |
| Fluorescent Labeling of Antibodies |
| Fragmentation of IgG Using Papain |
| Fragmentation of IgG using pepsin |
| Microbiology | Gram Stain Technique |
| Aseptic Technique and the Transfer of Microorganisms |
| Streak Plate Method |
| Motility Test |
| Catalase and Coagulase Test |
| Selective and Differential Media for Identifying Microorganisms |
| Lecithinase Test |
| Bacterial Growth Curve |
| Carbohydrate Fermentation Test |
| Differential and Cytological Staining Techniques |
| Antibiotic Susceptibility Testing |
| Methylene Blue Reductase Test |
| Voges-Proskauer Test |
| Triple Sugar Iron Agar |
| Urease Test |
| Litmus Milk Test |
| Slide Culture Technique for Fungi |
| Bacteriophage Plaque Assay for Phage Titer |
| Isolation and Identification of Auxotrophic and Drug Resistant Mutants |
| Isolation and Identification of Two Bacterial Unknowns |
| Routes of Viral Inoculation in Embryonated Eggs |
| 16S Ribosomal RNA Sequencing |
| Molecular Biology | Preparation of Buffer stocks (TBE,TE and TAE) |
| Plasmid Isolation (Mini prep) |
| Extraction of DNA from Fish Fins |
| Hot Shot Method of DNA Extraction |
| Agarose Gel Electrophoresis (AGE) |
| Restriction Digestion |
| Maintenance and Storage of DH5alpha E.coli cells |
| Preparation of Competent Cell (Calcium Chloride Treatment) |
| Transformation of the Host Cells |
| Extraction of DNA from Agarose gel |
| Preparation of Equilibrated Phenol |
| Isolation of RNA |
| Polyacrylamide Gel Electrophoresis |
| Ligation ( Using T4 DNA Ligase) |
| Polymerase Chain Reaction (PCR) |
| Electroblotting |
| Plating of the Bacteriophage |
| Plasmid Curing |
| Extraction of Bacteriophage DNA from Large Scale Cultures Using Proteinase K and SDS |
| Preparation of stocks of bacteriophage lambda by plate lysis and elution |
| Cell Biology | Light Microscope |
| Cell Organization and Sub Cellular Structure Studies (Prokaryotic and Eukaryotic) |
| Transmission Electron Microscopy |
| Isolation of Mitochondria |
| Isolation of Chloroplast |
| Isolation of Endoplasmic Reticulum |
| Basics of Plant Tissue Culture |
| Glucose Uptake Assay |
| Transfection |
| Western Blotting |
| Lignin Staining |
| Hemocytometer (Counting of Cells) |
| Maintenance of Mamallian Cell Lines |
| Cell Attachment |
| Cell Migration |
| Actin Assembly |
| Mitosis in Onion Root Tips |
| Cell Proliferation |
| Toxicity studies in Zebrafish |
| Primary Cell Culture |
| Biological Image Analysis | Introduction to Biological Image Analysis |
| Quantification of Lignin in Tissue Sections |
| Analysis of Cell Morphology |
| Counting of Fluorescent Particles |
| Counting of Total Fluorescence in a Cell |
| Analysis on Molecular Gels: A Case Study in Polyacrylamide Gel Electrophoresis |
| Quantification of Stained Liver Cells |
| Quantification of Bacterial Colonies on an Agar Plate |
| Quantification of Amino Acids Present in a Mixture |
| Quantification of Protein Present in a Sample |
| Bioinformatics | Retrieving sequence data from Entrez |
| Locating the chromosome of a Gene |
| Retrieve gene expression data from GEO |
| Retrieving articles using PubMed |
| Finding ORF of a Given Sequence |
| Retrieving structural data of a protein using PDB database |
| Retrieving Motif Information of a Protein Using Prosite |
| Retrieving Gene Information from TAIR database |
| Designing a primer |
| Global alignment of two sequences - Needleman-Wunsch Algorithm |
| Smith-Waterman Algorithm - Local Alignment of Sequences |
| Pairwise Sequence Alignment using BLAST |
| Pairwise sequence alignment using FASTA |
| Aligning Multiple Sequences with CLUSTAL W |
| Construction of Cladogram |
| Phylogenetic Analysis using PHYLIP - Rooted trees |
| Phylogenetic Analysis using PHYLIP - Unrooted trees |
| Genome Annotation and Multiple Sequence Allignment |
| Visualizing the Secondary Structure of a Protein |
| Calculating the Distance between the Ligand and a Particular Amino acid |
| Finding the Active Site Pockets of a given Protein Molecule |
| Primary Structure Analysis of a Protein Using ProtParam |
| Secondary structure analysis of a protein using SOPMA |
| Surface Analysis of a Protein Using CASTp |
| Retrieving details of a drug molecule |
| Converting chemical file formats |
| Homology Modeling using Modeller |
| Protein- Ligand Interaction |
| Systems Biology | Mathematical modeling and simulating of Biochemical network |
| Import and simulate models from different databases |
| To Import and simulate a model from the repository |
| SBML-A markup language for mathematical models in systems biology using cell designer |
| Creating and Visualizing a Simple Network Model |
| Analysis of biological networks for feature detection |
| Integrating Biological Networks and Microarray Expression data |
| Analyzing the network by finding sub modules |
| Computer Aided Drug Design | Constructing computational model of a molecule |
| Introducing Hydrogen atoms to a molecule |
| Dihedral angle calculation of a molecule |
| Energy minimization of a molecule |
| Predict the structure of protein-Homology Modeling |
| Drug-Receptor Interaction |
| Absorption and Distribution Property Prediction in Drug Designing Process |
| Toxicity prediction of a Molecule |
| Ecology | Determination of pH of Waste Water Sample |
| Biological Oxygen Demand |
| Chemical Oxygen Demand of Waste water |
| Nitrogen Cycle |
| A Brief Introduction to Species Interactions in Ecology |
| Bacterial Population Growth |
| Population Invasion - A Threat to Ecosystem |
| Study of Foraging of Organisms in the Ecosystem |
| Case Studies on Ecology |
| Bio-inspired Robotics | Controlling a servo motor in a bio-robotic environment |
| Understanding the kinematics of a robotic upper arm |
| Understanding the kinematics of a robotic upper arm - Interactive |
| Light sensing process in a neural circuit |
| Mechanism behind the movement of a Walker robot with 4 neurons |
| Interaction study with Neuronal Circuits |
| Constructing a six core brain like circuit |
| Pattern recognition in a hardware neural network |
| Biophysics | Using a light microscope |
| Observing an animal cell using a light microscope |
| Study of RC Properties of Cell Membrane |
| Study of Electrically excitable cells |
| Bursting phenomenon in biology via RC models |
| Micrometry |
| Multicompartmental modelling of biophysical behaviour of neurons |
| Understanding Photosynthesis as a Biologically Closed Process |
| **Chemical Sciences** | Physical Chemistry | Spectrophotometry |
| Cryoscopy |
| Ebullioscopy |
| EMF measurement |
| Determination of Viscosity of Organic Solvents |
| Adsorption Isotherm |
| Verification of Tafel Equation |
| Determination of Viscosity Average Molecular Weight of Polymer |
| Calorimetry -Water equivalent Calorimetry |
| Calorimetry -Heat of Neutralization |
| Organic Chemistry | Detection of Functional Groups |
| Detection of Elements: Lassaigne’s Test |
| Separation of Compounds Using Column Chromatography |
| Purification by Fractional distillation/crystallisation |
| Purification by Steam distillation/crystallisation |
| Laser Flash Photometer |
| Organic Preparations - Allylation of Isatin |
| Estimation of Aspirin |
| Estimation Of Glucose |
| Calculation of λmax of Organic Compounds Using Woodward Fieser Rules |
| Inorganic Chemistry | Water analysis-Determination of Physical parameters |
| Water analysis-Determination of Chemical parameters |
| Acid Base Titration |
| Gravimetric Estimation of Barium |
| Gravimetric Estimation of Nickel |
| Crystal Field Theory |
| Group Theory |
| Alloy Analysis (Brass) |
| Soil Analysis-Determination of Specific conductivity of Soil |
| Soil Analysis-Determination of pH of Soil |
| Advanced Analytical Chemistry | Soil Analysis-Determination of Available Organic Carbon content in the Soil |
| Soil Analysis-Determination of Available Nitrogen content in the Soil by Kjeldahl method |
| Soil Analysis-Determination of Available Phosphorus content in the Soil by Bray's method |
| Electrogravimetric Estimation of Metals |
| Estimation of Phosphate Content in Soft Drinks |
| Flame Photometry |
| Polarography - Determination of Unknown Concentration of Cadmium |
| Polarography - Determination of Unknown Concentration of Vitamin C |
| **Physical Sciences** | Electricity & Magnetism | Tangent Galvanometer |
| Magnetic Field Along The Axis of A Circular Coil Carrying Current |
| Deflection Magnetometer |
| Van De Graaff Generator |
| Barkhausen Effect |
| Temperature Coefficient of Resistance |
| Anderson's Bridge |
| Quincke's Method |
| Heat & Thermodynamics | Heat Transfer by Radiation |
| Heat transfer by Conduction |
| Heat Transfer by Natural Convection |
| The Study of Phase Change |
| Black Body Radiation: Determination of Stefan's Constant |
| Newton's Law of Cooling |
| Lee's Disc Apparatus |
| Thermo Couple-Seebeck Effect |
| Harmonic Motion and Waves | Astable multivibrator |
| Melde's String Apparatus |
| Kundt's Tube Apparatus |
| Ultrasonic Interferometer |
| Doppler Effect |
| A.C Sonometer |
| Colpitts Oscillator |
| Hartley Oscillator |
| Modern Physics | Franck-Hertz Experiment |
| Soldering |
| Solar Panel Experiment |
| Photoelectric effect |
| Determination of Planck's Constant |
| Abbe's Refractometer |
| Emission spectra |
| Millikan's oil drop experiment |
| Magnetic Material Characterization via Hystersis |
| Laser Optics | Michelson's Interferometer- Refractive index of glass plate |
| Newton's Rings-Refractive index of liquid |
| Michelson's Interferometer- Wavelength of laser beam |
| Laser beam divergence and spot size |
| Newton's Rings-Wavelength of light |
| Brewsters Angle determination |
| Numerical Aperture of Optical Fiber |
| Mechanics | Torque and angular acceleration of a fly wheel |
| Torsional oscillations in different liquids |
| Moment of Inertia of Flywheel |
| Newton's Second Law of Motion |
| Ballistic Pendulum |
| Collision balls |
| Projectile Motion |
| Elastic and Inelastic Collision |
| Electric Circuits | Parallel RC Circuits |
| Parallel LC Circuits |
| Thevenin’s Theorem |
| Series RL Circuits |
| Norton's theorem |
| Series LCR Circuits |
| Kirchhoff’s Laws |
| Series RC Circuits |
| Series LC Circuits |
| Parallel LCR Circuits |
| Parallel RL Circuits |
| Advanced Mechanics | Rigidity Modulus of The Suspension Wire of A Torsion Pendulum |
| Young's Modulus-NonUniform Bending |
| Compound Pendulum- Symmetric |
| Kater's pendulum |
| Young's Modulus-Uniform Bending |
| Moment of inertia of a Torsion Pendulum |
| Rigidity Modulus -Static Torsion |
| Optics | Resolving power of a prism |
| Angle of the prism using Spectrometer |
| Spectrometer i-i' curve |
| Spectrometer: i-d curve |
| Spectrometer- Determination of Cauchy's constants |
| Spectrometer, Refractive Index of the material of a prism |
| Spectrometer,Dispersive power of a prism |
| Diffraction Grating |
| Solid State Physics | Characteristics of Zener diode |
| Characteristics of Thermistor |
| Resistivity by Four Probe Method |
| B-H Curve |
| Hall effect experiment:- Determination of charge carrier density |
| Cornus Experiment |
| Zener Diode as Voltage Regulator |
| Crystal Structure |
| **Computer Science** | Wireless Sensor Network lab | Introduction to WSN |
| nesC Programming |
| Send and Receive |
| Range & Connectivity vs. Antenna Power |
| Duty Cycle vs. Power Consumption |
| Sensor Data Acquisition |
| Data Collection Frequency and Tx. vs. Power Consumption |
| Wireless Propagation |
| Wireless Sensor Network |
| Wireless Sensor Network Data Acquisition, Transmission, and Aggregation |
| Clustering Algorithms |
| Time Synchronization |
| **Mechanical Engineering** | Wind energy lab | Anemometer |
| Wind Modelling Analysis |
| Wind Tunnel - Pressure |
| Wind Tunnel- Force |
| Wind Tunnel - Angle |
| Wind Tunnel -Pitot |
| Dynamometer |
| Wind Turbine -Power production in Wind Turbine |
| Wind Turbine - Cp Vs λ |
| Solar energy Labs | Solar Energy Measurements - Pyrheliometer |
| Solar Energy Measurements - Pyranometer |
| Solar Energy Measurements |
| Solar PV Tracker |
| External Compound Parabolic Collector(XCPC) - Oil |
| External Compound Parabolic Collector (XCPC) |
| Parabolic Trough - Angle |
| Parabolic Trough -Flow Rate |
| Mechanics of Solids Labs | Beam Theory I |
| Beam Theory II |
| Young's modulus on UTM |
| Poisson's ratio on UTM |
| Saint Venant Principle |
| Stress Distribution around a circular hole |
| Stress Concentration around a Notch using UTM |
| Creep Test |
| Energy Storage Labs | Ultracapacitor |
| DC flywheel battery |
| AC Flywheel battery |
| PbA Battery |
| Ni-Cad Battery |
| Ni-MH Battery |
| Li-ion Battery |
| Li-Po Battery |
| Peukert Law |
| Cyber Security | In development phase | |