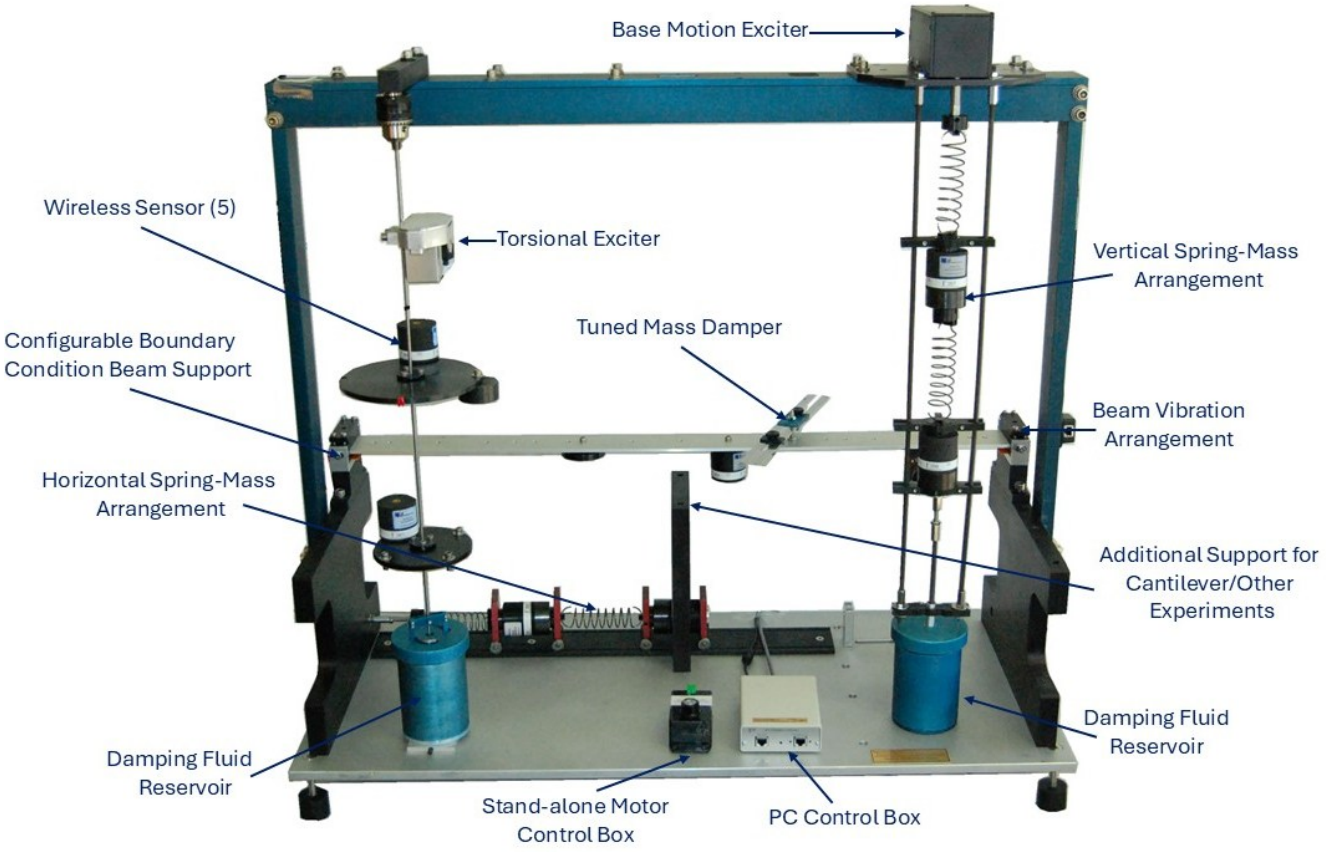
Vibration Fundamentals Training System

VFT



Introducing Wireless Sensors & Exciters for Performing True Damping free "Free and Forced" Vibration Experiments

Innovative Teaching System Combining Virtual Labs with Hands-On Experiments

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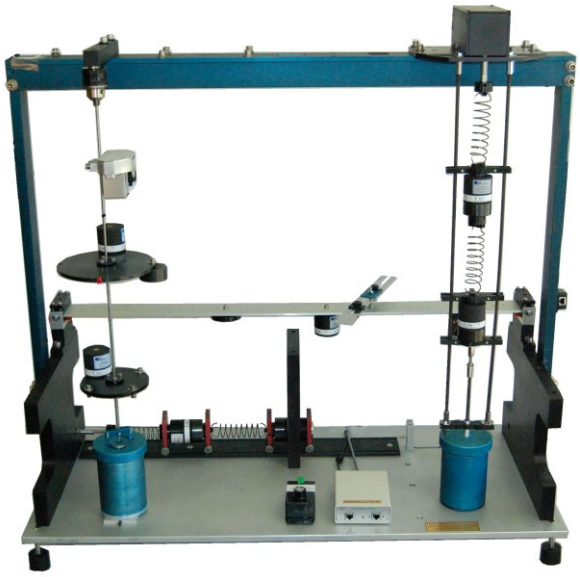
Vibration Fundamentals Training System (VFT)

An Ideal Tool for Optimizing Your Vibration Class Learning Experience



The Vibration Fundamentals Training System (alias VFT) is a turn-key integrated educational package for teaching/learning the fundamental principles of mechanical vibration as well as engineering mechanics. The VFT combines virtual laboratory with hands-on experiments for each exercise taught in a traditional vibration course. It also includes a complete instrumentation package consisting of wireless sensors, for performing laboratory exercises to enhance student understanding of vibration theory.

The VFT clearly brings classical theory to life by providing a convenient mean to validate predictions and to demonstrate the influence of parameter changes on system response visually. Students can perform virtual experiments using the vibration simulation software and then verify the results with actual experiments thereby reinforcing the learning of difficult principles. The VFT provides an ideal tool for damping free vibration experiments using the wireless sensors and exciter without affected by the damping associated with the sensor/exciter cables. It is a perfect tool for teaching mechanical vibration courses both at undergraduate and graduate levels.

With an increase in high speed manufacturing and automation, it has become more important to use the theory of vibration for design and maintenance of machinery. This vibration theory is even more important in the monitoring and diagnosis of machinery malfunctions. Considering the importance and complexity of vibration principles, a course curriculum should include laboratory demonstration and hands-on experiments to help students understand the somewhat abstract concepts of vibration. To this date, most academic institutions include only theoretical lectures without laboratory exercises due a lack of an apparatus combined with an instrumentation setup. With SpectraQuest's VFT, this deficiency has been resolved making hands-on vibration teaching now possible. The modular design of the VFT will enable the current customers to use it to teach automatic controls.

Benefits:

- Clarify difficult concepts of vibration theory by performing hands-on controlled experiments
- Perform both free and forced natural vibration experiments without damping for the first time using SpectraQuest developed wireless sensors.
- Validate theoretical predictions of natural frequencies, mode shapes, and frequency response as a function of frequency, boundary conditions, geometry, and materials
- Validate theoretical concepts by comparing experimental results with the computer simulation of the vibration theory
- Determine the detrimental effects of vibration load transmission to the support structure and component fatigue life
- Learn to control vibration amplitude using tuned mass dampers and damping treatments
- Learn vibration measurement transducers, signal processing, data acquisition & analysis

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Vibration Fundamentals Training System (VFT)

Controlled Experiments Expedite Learning

SpectraQuest's Vibration Fundamentals Training System (VFT) is an innovative tool you can use for teaching the fundamental principles of mechanical vibration. The VFT is professionally researched and designed for immediate implementation for vibration laboratory development. It is can be easily integrated with a typical vibration course taught at most institutions. The VFT provides a comprehensive hands-on experimental device, an instrumentation package, and experimental program with course curriculum for performing laboratory exercises to enhance student understanding of vibration theory. The bench-top apparatus has a spacious modular design featuring versatility, operational simplicity, and robustness. Each component is machined to high tolerances so it can be operated without conflicting vibration in a totally controlled environment. The instrumentation package includes wireless less accelerometers and transducers, precision servomotor for excitation, tachometer, and four channels simultaneously sampled data acquisition hardware, signal conditioners, and time and frequency domain analysis software. Also included are a software simulation of theory and a well-defined experimental program for free and forced vibration experiments ranging from single degree of freedom spring mass to continuous beam with different boundary conditions.

Students can perform both hands-on and virtual experiments to optimize the learning. The VFT is designed to perform both free and forced vibration experiments with and without damping. The basic VFT frame consists of two identical test stations mounted on a portable structure. It features into changeable restraint fixtures, optional force transducers to measure the support reactions, sensors to measure deflection and acceleration, and a variable frequency rotary shaker for forced excitation. It allows for the first time to perform almost damping free vibration experiments to verify the theory using SpectraQuest in-house developed wireless sensor technology.

Features:

- Fully integrated turn-key package consisting of comprehensive experimental device, wireless sensors, data acquisition instrumentation, analysis software, course curriculum, exercise book, and simulation software for virtual experimentation
- Robust, user friendly, modular, and compact bench-top device for performing controlled experiments
- Experimental setup for single and two-degrees of freedom spring-mass system (with and without damping)
- One and two-degrees of freedom torsional vibration (with and without damping)
- Vibration control experiments with viscoelastic damping and tuned-mass-damper
- Full experimental setup for beams with different boundary conditions, material, geometry, and length to understand effects on natural frequency and mode shapes
- User friendly software with pre-defined experiments integrated with data acquisition and data analysis
- Virtual experiment capabilities to learn the effects of parameters for each type of test configuration

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Vibration Fundamentals Training System (VFT)

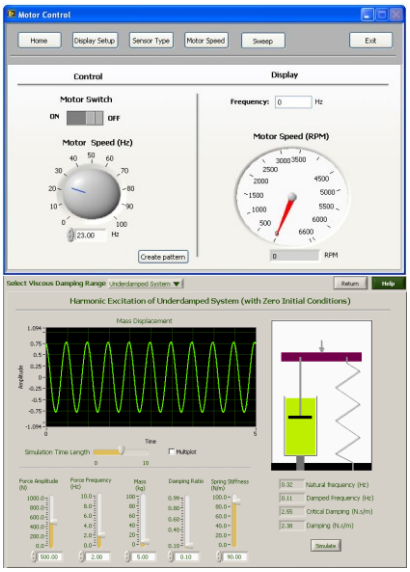
Wireless Sensors Simply Experimentation and Enhance Learning Experience

Cables are often a source of problem due to entanglement and damping associated with them. Cables require special handling during any experimental procedure. They also created hard to characterize unwanted damping. Both issues have been solved by SpectraQuest VFT system. We have developed wireless sensors that eliminated both problems. Our proprietary algorithm enables simultaneous acquisition of data from all sensors, thus making it possible to obtain accurate phase information and the mode shapes.

Data Acquisition and Analysis Instrumentation

The VFT is equipped with wireless transducers, SpectraQuest's proprietary 6 channel simultaneously sampled data acquisition (DAQ) system; data analysis software with automated setup for performing each experiment, simulation software, motor control module, multi-featured display, and mounting hardware/tooling. Transducers are provided for the measurement of acceleration, force, and rotational speed. The DAQ system samples all channel simultaneously enabling accurate calculation of mode shapes. Easy to use software automates steps to conduct each experiment and display the results. Students can perform time and frequency domain analysis, read data to do calculations and compare them with theoretical predictions.

The DAQ hardware/software is fully integrated with the excitation motor operation and control. The user can send speed command to control the excitation frequency or a sine sweep can be applied to obtain the full frequency response information over the frequency range of interest. All experimental and data collection setups are pre-defined so that students can focus on the results. The user-friendly software is a powerful tool for basic signal processing. Simple and intuitive interface allows fast and easy operation. The signal analysis modules include data presentations of time waveform, FFT spectrum, and frequency response function (FRF). Superimposed data comparison of two data sets is also possible.



Vibration Simulation/Animation-A Virtual Lab

Vibration fundamentals simulation software is designed to teach basic concepts using a new interactive and visual simulation technique. The student can perform virtual experiments on various topics by changing the parameters of a vibratory system and see how the system behavior is affected. The effect is displayed dynamically. The vivid visualization enhances the learning and clarification. A spring-mass-damper system is used to animate the vibration response. A multi-plot option can be used to compare their effects on vibration response. Therefore, instead of deriving the equations, the user can go one step further, "play and see" the vibration behavior. The software includes the most common topics of a typical vibration course.

The VFT Configurations

The VFT design is modular and versatile. The smart design makes it easy to use and simple to configure for a variety of experiments. Many option kits are provided to perform different controlled experiments. The user can obtain in any he or she desires depending on the budget and needs. More option kits can be added later to the same platform without purchasing an entirely new device. This feature makes it affordable and upgradeable at the same time. The following summarizes different modules of the VFT.

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Vibration Fundamentals Training System (VFT)

The Basic VFT (VFT2020)

The basic VFT is designed as an introductory system to demonstrate fundamental concepts of vibration theory. We have developed many optional modules to enhance your learning. The following sections provide detailed description about the basic unit as well as each optional module.

Basic VFT Includes:

- Base platform enabling mounting of several vibration training modules
- Integrated training package including data acquisition hardware and analysis software system
- One wireless sensor, Data communication Module, USB Cable to connect to a PC/Laptop
- Simulation software
- Software/manual driven variable speed shaker for excitation with tachometer display
- One degree of freedom spring mass system
- One 1/8" thick aluminum beam with provision for adjusting weight location and one weight block(mass)
- Two user configurable beam supports for cantilever or simply supported configurations (adjustable length)

Vertical Mass-Spring Module (VFT-VSMM)

The Spring-Mass module is a perfect tool for doing classic single and two DOF vibration experiments. Natural frequencies for different mass and spring, with and without viscous damping, can be determined under free oscillations (initial displacement or velocity). Tests can also be done under forced excitation at various frequencies. The forcing function can be applied either at the base or the mass. The system response could be measured at one frequency at a time or over the entire frequency range by selecting the sine sweep excitation. The data can be easily stored and plotted with the software data processing capabilities to obtain the frequency response function. With the multi-plot feature of the analysis software, the system response to controlled variables (*k*, *m*, and *c*) can be easily compared. *Fundamental experiments* include determining the stiffness of the springs by performing static deflection measurements and also by observing the natural period under different loading conditions, determining effective mass of the spring and estimating the gravitational acceleration *g*.

Includes: Three springs of different stiffness, three different weight blocks, low frequency excitation system.

Beam Vibration Module (VFT-BVM)

This module allows to study natural frequencies, mode shapes, and damping in beams of different materials such as steel, aluminum, and plastic. The beam length is fully adjustable and can be configured as simply supported or cantilever (at either of the beam ends) and overhung. This

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adaptable mounting allows creating all the standard *boundary conditions* commonly encountered in academic study and field practice. Provisions to mount rigid masses at different locations and dashpot make beam completely customizable. Custom built force transducers can be mounted to measure the support reaction forces and determine transmissibility factor. External unbalance force of variable frequency may be applied to excite natural frequencies and produce visible mode shapes. The amplitude of deflection during resonance may be measured at any point along the length of the beam. By using a stroboscope on the beam, the user can clearly see the natural mode shapes predicted by classical beam theory, including the second, third, and even higher orders.

The standard beam restraint fixtures accept up to 2" wide x 1/8", 3/16", and ¼" thick bar stocks and offer fixed, sliding, and hinged restraint modes. Point, distributed, and twisting moment loading patterns can be applied. To add interest, customer designed beams or trusses may be installed for design competition and special projects. The VFT can also be used for a simple modal test and vibration control experiments. *Fundamental experiments* include modal tests by using a hammer or shaker, determining the natural frequency and mode shapes using different methods such Dunkerley's method, Rayleigh Ritz method and compare them against the classical differential equation solutions.

Includes: Three different beams (aluminum, steel, and plastic), mode shape animation software and shaker frequency sweep software for excitation of different modes, and three masses.

Vertical Torsional Vibration of Rods Module (VFT-VTVM)

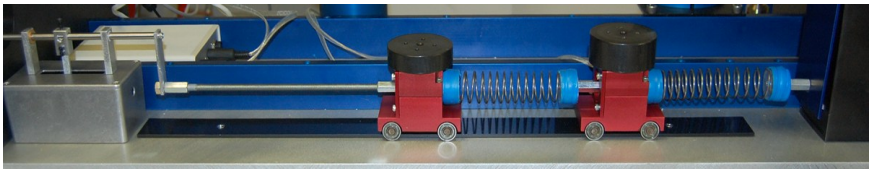
Torsional vibration issues are important in design and diagnostics of turbomachinery, internal combustion engines, and many other applications. The fundamental concept of torsional vibration is similar to the flexural and longitudinal vibration, but students often find difficulty both with calculations and the measurements. The VFT addresses both issues. The torsional vibration module consists of a stainless-steel shaft, several rotors, a torsional viscous damper, and mounting hardware. The unit can be configured as one and two degrees of freedom systems for free and forced vibration experiments. It can also be configured with different rod length, diameter, and material to vary system stiffness, with different disks to vary the mass, and with or without a dashpot.

Includes: Three rods of different diameters and three rotors of different mass moment of inertia, and viscous damper.

Horizontal Spring-Mass Module (VFT-HSMM)

Designed to perform the experiments with spring-mass laid horizontally on a hard plate using ball bearings. This module gives an ability to do both free and forced vibration experiments. Both free and forced experiments can be conducted with and without damping.

Includes: Hardware and mounting brackets for installation of one and two degrees of freedom spring-mass systems, ball bearing system for linear motion of masses, viscous damper system, and three springs with different stiffness and three weights, and sinusoidal excitation system.



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Vibration Control Study Module (VFT-VCM)

The VFT is an ideal platform for not only to understand basic vibration principles, but also to learn passive vibration control. Students can even learn to alter excitation frequency, change resonance frequency by modifying modal mass and/or stiffness, and add damping to bring vibration levels to acceptable values. Students can also design tuned-mass damper to absorb vibration in a spring-mass system or on beam a beam using a leaf spring with sliding masses. The student can then hold the vibrating masses to transfer the vibratory motion back to the original structure. A complete kit is provided for the experimentations. The vibration control study module also provides a constrained layer viscoelastic sandwich beam to study the effect of viscoelastic damping in vibration control. This is a more advanced topic for graduate level. program, but students can use this module to study the relationship between system damping ratio/loss factor and the damping materials, damping layer thickness and damping coverage, etc**.**

Includes: Hardware and software for Tuned-Mass-Damper, one constraint layer and without constraint layer Viscoelastic beams, and two viscous damping setups-one for linear and one for torsional vibration control.

Vibration Transmissibility Module (VFT-VTM)

Conduct tests to measure vibratory force/motion transmitted to the supporting structure at different frequencies of excitations.

Includes: Once force transducer and signal conditioner, transmissibility software.

Experimental Curriculum Book

The experiments book is an integral part of the VFT package. This is professionally designed book includes detailed, step by step instructions for more than 20 experiments. Students can easily follow the instructions and conduct each experiment by themselves. The instructions tell the student how to setup the hardware, connect the transducers, setup the data acquisition system, configure the data collection, and analyze the data. This comprehensive experimental book also comes with exercises, homework, and questions to help students better understand the vibration theory and experiments.

Vibration Measurements

The VFT is an excellent platform for learning basics of transducers, signal conditioning and data acquisitions. Displacement, force, and acceleration are measured to describe vibration and mechanics of structures. The device is useful for learning how to use different types of transducers and associated signal conditioning issues. Applications of tachometers and stroboscope in studies of vibration phenomena can be investigated. Data acquisition and importance of signal processing in proper analysis can be emphasized.

Modal Analysis

The VFT is an excellent platform for learning basics of modal testing and modeling. Having wireless sensors makes it easy to set and do modal surveys and determine modal parameters such natural frequencies, mode shapes and damping in common structures. The data can be transferred to modal analysis software such as ME'Scope. Students can perform modal tests by using hammer or shaker. The results can be modeled to determine structural dynamic properties such as natural

frequencies, mode shapes, and damping. A comparison of measured data with theoretical predictions can also be done.

Specifications

Base VFT (VFT2020)	
Dimensions & Weight	40”w x 45”h x 18”d (100 x 112 x 46 cm) & 100 lb. (45 Kg)
Excitation motor	Software/manual driven variable speed motor with built-in unbalance load, electrodynamic shaker, unbalance exciter, torsional exciter, displacement controlled exciter
Vibration isolation	Four rubber feet
Vertical Spring-Mass Module (VFT-VSMM)	
Spring	Three different stiffness, stackable for 2 DOF
Mass	Three weights, stackable
Beam Vibration Module (VFT-BVM)	
Beam	one thickness steel, one aluminum, one plastic
Mass	Three weight blocks
Supports	User configurable: cantilever or simply supported, adjustable length
Horizontal Spring-Mass Module (VFT-HSMM)	
Spring	Three different stiffness, stackable for 2 DOF
Carts	Two axis aluminum carts with friction-less wheels, one slotted track. Damper with mounting hardware included.
Vibration Control Module (VFT-VCM)	
Tuned mass damper	Hardware for mass-spring absorber and for beam absorber
Beam with damping treatment	One viscoelastic layer and one constrained layer
Torsional Damper	One dashpot and three fluids
Vibration Transmissibility Module (VFT-VTM)	
Vibration Transmissibility Module	Force transducer & signal conditioner, transmissibility software
Data Acquisition	
DAQ specifications	6 channel, 16 bits 4,000 samples/sec. wireless data transmission and Ethernet/USB connection
Software	
DAQ and analysis software	Time waveform, spectrum, FRF, coherence, motor control
Electrical	
Power Source	110 V/220 V 50/60Hz

SpectraQuest: A Valuable Resource for Keeping Companies and Colleges Productive

SpectraQuest offers a wide range of products for vibration technology education and research. To learn more about our products and how it can help you to keep your plant operating profitably, please call or e-mail us at info@spectraquest.com

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