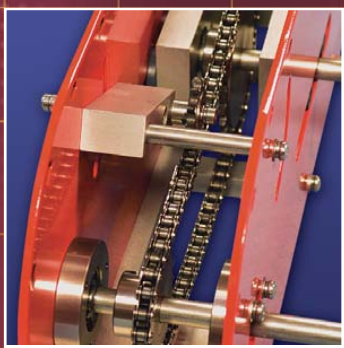
Theory of Machines

Friction 223
Motion 227
Vibration 237



“ I have the pleasure to express my full satisfaction with the smooth functioning of the TecQuipment laboratory educational equipment supplied to IUBAT Departments of Mechanical and Civil Engineering. I particularly appreciate TecQuipment’s local agent Sine Waves Ltd for assisting IUBAT with free installation, commissioning, testing along with comprehensive training. ”

Prof M Alimullah Miyan, International University of Business Agriculture and Technology, Bangladesh

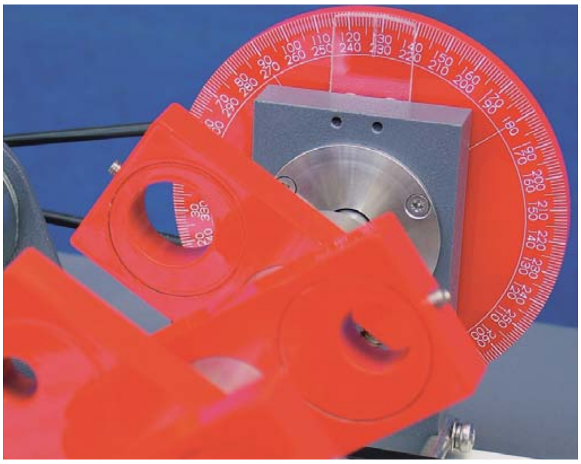
Theory of Machines

Basic and advanced

The Theory of Machines range includes equipment that teaches the basics of machine engineering such as vibration and motion, to more advanced studies of friction in bearings.

Safe yet highly visual

For clarity and understanding, most of the equipment includes fast moving parts. TecQuipment's products always include safety by design, using interlocked guards to prevent accidents, while still allowing students to see what is happening.



Automatic data acquisition

Some of the products in this range work with TecQuipment's unique Versatile Data Acquisition System (VDAS®). See **Section 2** for more details.

Look out for the VDAS® logo: VDAS®

VDAS®	Product	Page
●	**Air Bearing Apparatus** (TE96)	223
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●	**Free Vibrations of a Beam and Spring** (TM167)	245
●	**Free and Forced Vibrations** (TM1016)	247

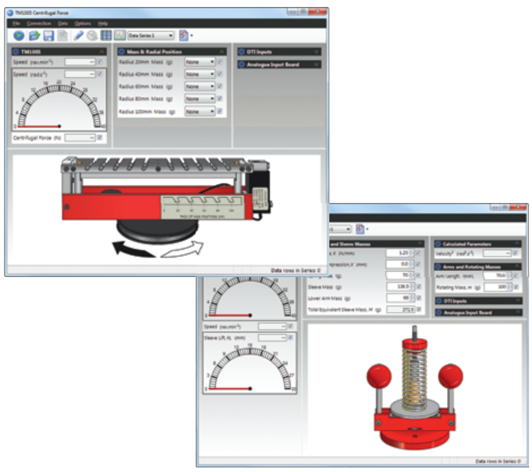
KEY FEATURES AND BENEFITS:

- **Basic to advanced teaching: equipment to suit teaching from fundamental to advanced principles.**
- **Safety by design: some equipment uses highly visual rotating parts, but interlocked guards prevent accidents.**
- **Automatic data acquisition: fast-moving equipment often needs multiple fast measurements, making data acquisition a powerful tool.**

Engineering Science

Our Engineering Science range also includes products that demonstrate some of the fundamental principles of simple machines, such as pulleys and gears.

See **Section 1** for more details.



Air Bearing Apparatus (TE96)

Works with VDAS®

Shows the performance of and pressure distribution around a gas (air) lubricated bearing

- Shows the performance of a self-acting, gas (air) lubricated journal bearing
- Self-contained and bench-mounting – includes all instrumentation needed for tests
- Variable bearing load and speed, for a range of tests
- Includes a multi-channel digital pressure display
- Shows the onset of bearing 'whirl'

Typical screenshot of the optional VDAS® software

EXPERIMENTS:

- **Demonstrate how a vertical load affects the pressure distribution around an air-lubricated journal bearing.**
- **Demonstrate how bearing speed, and therefore compressibility number, affects the pressure distribution in the bearing, and how this compares with theory.**
- **Demonstrate the onset of 'whirl'.**

A self-contained product that shows how a self-acting gas-lubricated journal bearing works. It also shows the onset of 'whirl'.

The main part has a variable-speed motor that turns a belt drive. The belt drive turns a precision bearing shaft. The shaft has a high-quality surface finish and spins inside a vertically loaded bush. A hand-operated load control and load cell allow the user to apply and measure the load on the bearing bush. The bush has pressure tappings equally spaced around its circumference. The tappings connect to a multi-channel digital pressure display unit.

A motor drive module allows the user to vary the bearing speed. A speed sensor and the bearing bush load cell connect to the motor drive module. This module displays the bearing speed and the load measured at the load cell.

Both the motor drive module and the pressure display module fit into an instrument frame that has extra space for the optional frame-mounted VDAS-F. Both modules include sockets to connect to the optional VDAS-F.

For quick and reliable tests, TecQuipment can supply the optional VDAS® (Versatile Data Acquisition System). VDAS® gives accurate real-time data capture, monitoring and display, calculation and charting of all important readings on a computer. The computer is not supplied.

Note: TecQuipment's VDAS® software includes a bar chart display of pressures. This display works with this product to see the pressure distribution around the bearing as a realtime image – ideal for classroom demonstrations.

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Frame-mounted version (VDAS-F)	32

Alternative Products:	Page
• Michell Pad Apparatus (TE99)	225
• Journal Bearing Demonstration (TM25)	226

Hertzian Contact Apparatus (TE98)

Self-contained unit that allows a practical examination of Hertz's theories of contact between materials

- Helps engineers study and predict contact shapes between common machined surfaces and materials
- No electricity or external services needed
- Uses flexible material to produce magnified and easily viewed results
- Easy-to-use, simple design

EXPERIMENTS:

- **The effect of varied pressure with constant angle**
- **The effect of varied angle (different relative curvature) with constant pressure**

The Hertzian Contact Apparatus is a self-contained and easy-to-use unit that shows the nature of contact between two surfaces. It compares experiment results with predictions based on Hertz's original theories. This helps engineers to predict contact areas between common machined surfaces and materials, for example different types of bearings.

The apparatus has two pads with curved contact surfaces. The upper pad (made of a transparent plastic material) has compound radii. The lower pad (made of an opaque flexible material) has a simple radius. A hand-operated hydraulic pump and cylinder force the two pads together. Students may rotate the lower pad and a pointer shows the angle of rotation. This allows the study of the effect of different relative curvatures.

A contact shape (or 'zone') forms between the pads. The contact zone may be circular or elliptical, depending on the relative angular position of the two pads. Supplied is a transparent scale to measure the contact shape and angle.

The hydraulic system includes a pressure-relief valve to prevent damage to the equipment.

Standard features for all our products:

Supplied with comprehensive user guide

Five-year warranty

Manufactured in accordance with the latest European Union directives

Michell Pad Apparatus (TE99)

Shows the pressure distribution across the film of oil in a Michell tilting pad slider bearing. Helps to prove Reynold's equation for pressure gradient in fluid film.

- Proven design, based on a machine created by the Department of Mechanical Engineering, Imperial College, London
- Accurately mimics a Michell tilting pad, fluid-lubricated slider bearing
- Fully adjustable pad (tilt) angle
- Includes oil and a viscometer

EXPERIMENTS:

Study of:

- **Pressure distributions in a tilting pad bearing**
- **Influence of sliding speed and viscosity on the pressure distribution in the bearing and comparison with calculations based on Reynold's equation.**
- **Relationship between pressure and the film thickness at the trailing edge of the pad**

The Department of Mechanical Engineering (Imperial College, London) created the original design for this apparatus. It mimics a tilting pad, fluid-lubricated slider bearing, invented by A G M Michell.

The bench-mounting unit has an aluminium plate (pad) mounted above a continuous-loop flat belt. The belt runs in an oil reservoir to provide a continuous supply of oil under the pad. This creates a pressurised film of oil between the pad and the belt.

A set of 13 graduated tubes shows the oil pressure across and along the film under the pad.

Included is a variable-speed control to control the speed of the motor that turns the belt. Students vary the belt speed to find the relationship between sliding speed, oil viscosity and pressure distribution.

Two eccentric shafts hold the pad so students can adjust the angle of tilt of the pad. This helps students to find the relationship between pressure distribution and film thickness. Micrometers measure the leading and trailing edge positions of the pad.

Included with the apparatus is a container of oil and a viscometer to measure the viscosity of the oil.

Alternative Products:	Page
• Air Bearing Apparatus (TE96)	223
• Journal Bearing Demonstration (TM25)	226

Journal Bearing Demonstration (TM25)

Shows the pressures around a journal bearing at different speeds

- Acrylic bearing allows clear observation of oil film at all times
- Pressure profiles, along and around the bearing, continuously monitored on large manometer panel
- Theoretical pressure profiles (Sommerfeld analysis) may be tested and compared with practical results
- Provides striking demonstration of self-excited vibrations (half-speed whirl)
- Fully adjustable speed, direction and loads

EXPERIMENTS:

Simple demonstrations:

- **Observation of oil wedge (film thickness) and hence eccentricity variations for different speeds and loads**
- **Observation of the pressure profiles at these conditions**
- **Observation of the critical bearing whirl**

Experiments:

- **Measuring pressure profiles for chosen conditions and plotting the cartesian and polar pressure curves**
- **Measuring pressure profiles for chosen conditions and plotting the theoretical Sommerfeld curve**
- **Measuring shaft speed and journal speed at the critical whirl**

All tests may be conducted for either direction of rotation of the shaft.

This floor-standing apparatus allows students to study the performance of a journal bearing during different test conditions.

The apparatus consists of a plain steel shaft encased in a clear acrylic shell and directly driven by an electric motor.

The bearing is freely supported on the motor shaft and sealed with a rubber diaphragm. The clearance is especially large to clearly show the oil in the bearing. Supplied with the equipment is a container of suitable oil.

A control unit adjusts the motor speed, which can run in both directions. A display shows the motor speed.

An adjustable reservoir supplies oil to a low-pressure region at both ends of the bearing.

The bearing contains 12 equi-spaced pressure tappings around its circumference and four additional ones along its top side and on a vertical radial plane. All are connected by light and flexible plastic tubes to the rear manometer panel, to clearly show the pressure head of oil at all 16 points at all times.

Students load the bearing by attaching weights (included) to arms connected to the bearing.

A strong steel frame with a worktop holds the bearing, the motor, the manometer panel and the control unit.

Recommended Ancillary: Page

- Stroboscope (ST1) 299

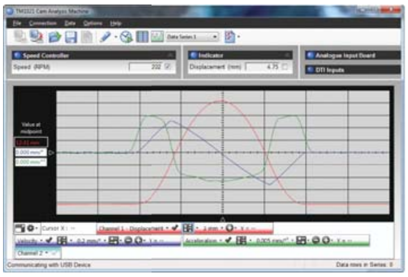
Alternative Products: Page

- Air Bearing Apparatus (TE96) 223
- Michell Pad Apparatus (TE99) 225

Cam Analysis Machine (TM1021) NEW!

Works with VDAS®

Studies the dynamic behaviour of different cams and followers and their 'bounce' speed



Screenshot of the VDAS® mkII software

- Shows cam and follower separation or 'cam bounce' under safe and controlled conditions
- Fully interlocked for safety
- Highly visual and audible – perfect for demonstrations
- Works with TecQuipment's VDAS® mkII to capture data and show live traces (on a computer screen) of the follower movement – even at bounce

Shown connected to VDAS® mkII

EXPERIMENTS:

- **Comparing actual results with theory for profiles of follower displacement, acceleration and velocity**
- **Cam bounce speeds for different cam and follower combinations, and comparison of speeds to those predicted by simplified theory**
- **How spring rate, preload and follower mass affect cam bounce speed**

The TM1021 is a comprehensive machine that allows students to study cams and followers. It shows how they convert rotary to linear motion, and helps students understand their limits of use before the onset of 'bounce'. It also introduces students to key topics of cam terminology such as 'nose', 'flank' and 'dwell'.

The main part of the product has a precision-machined heavy steel base which holds a high-torque, direct-drive, variable-speed motor. The motor shaft connects through a coupling to the main shaft which then passes into the cam test area. Self-aligning, heavy-duty bearings support the shaft which has a substantial flywheel. The flywheel reduces speed variations as the torque demand changes during the cam rotation cycle. The cam under test fits to the end of the main shaft, accurately mounted both axially and radially to ensure repeatability.

Continued on next page

Cam Analysis Machine (TM1021)
Continued from previous page

The follower fits to the bottom of a vertical shaft running in low-friction linear bearings. TecQuipment includes a tool for easy changeover of a choice of two followers. Students may also fit one of a choice of two compression springs and adjust their preload. These add to the mass of the follower and vertical shaft pushing the follower onto the cam face. Students may also add different masses (included) to alter the mass of the follower and thus the force applied to the cam. The selection of springs, followers and cams allow for a wide range of investigations.

Sensors on the main and vertical shafts measure angular position of the cam and vertical position of the follower (displacement or 'cam lift').

A key point of the design of the machine is safety while still allowing easy use. A fixed guard covers the shaft and flywheel. A hinged protective guard with electromechanical interlocks prevents users from touching any moving parts in the cam test area when in use. The guard opens only under safe conditions to allow students to change the cam, spring and follower.

A control and instrumentation unit allows students to vary the cam speed. This unit amplifies and conditions the signals of follower vertical position (displacement) and cam angular position. It also includes a microprocessor-controlled multiline display of cam speed in revolutions per minute, radians per second and rotational frequency in Hertz.

TecQuipment calibrates the conditioned signals of follower displacement and cam position to work with the Versatile Data Acquisition System, VDAS® mkII. The VDAS® hardware and software produce live displays of the follower displacement against cam rotation. Uniquely, it also calculates and displays live plots of the first two derivatives of displacement: velocity and acceleration. The live plots alongside the characteristic 'bounce' sound allow students to find the speed at the point of cam bounce. They can then compare it to that found from simplified theory.

Essential Ancillary:	Page
• Versatile Data Acquisition System – bench-mounted version (VDAS-B mkII)	32

Note: This equipment needs VDAS® mkII and will not work with earlier versions of VDAS®. If unsure, contact TecQuipment or your local agent for advice.

Alternative Product:	Page
• Cam and Crank and Toggle Kit (ES12)	20

Whirling of Shafts (TM1001)

Shows 'whirling' in different horizontal shafts with different fixings (end conditions), loaded and unloaded

- Shows first and second mode whirl speeds and how to predict them
- Extra bearings and weights (included) give a choice of free-free, fixed-free and fixed-fixed end conditions and experiments with loaded shafts and eccentric loading
- Supplied with different shafts to study how length and diameter affects whirling
- Optional stroboscope to 'freeze' the image of the shaft to see its shape clearly

EXPERIMENTS:

- **Basic whirling demonstration**
- **The effect of shaft length and diameter**
- **The effect of end conditions (fixings)**
- **Loaded shaft (one and two masses)**
- **Eccentric loading**

TecQuipment's Whirling of Shafts apparatus (TM1001) shows how shafts vibrate transversely and 'whirl' at a certain rotation frequency. This helps engineers understand possible problems with long shafts and allow for them in their designs.

The equipment is in two parts and fits on a bench or desktop. The main part is a solid alloy frame that holds a variable speed motor which turns the horizontal test shaft. Two bearings hold the shaft, one bearing at the 'driven end' and the other bearing at the 'tail end' of the shaft. The tail end bearing slides in its housing to allow the shaft length to change as it 'whirls'. Similar to a beam on two simple knife-edge supports, both bearings allow free angular shaft movement (free ends condition). Also supplied with the equipment are extra bearings that restrict angular movement when fitted, to give 'fixed ends'.

Two movable nylon bushes help to prevent the shaft whirling amplitude from reaching excessive levels. A movable cord plate allows students to control the shaft in some experiments, to help reach the second mode whirl speed. A sensor at the driven end measures the shaft speed and sends its signal to the Control and Instrumentation Unit display. A removable safety guard with magnetic interlock surrounds the shaft and only allows the motor to work when fitted.

The separate Control and Instrumentation Unit contains the drive for the variable speed motor and a display to show the shaft speed. It also includes a trigger output for the optional stroboscope.

When used in a darkened classroom, the optional stroboscope gives an impressive demonstration of how the shaft shape changes as it reaches its whirling speeds.

Supplied with the apparatus is a set of test shafts of different length and diameter to show how these properties affect whirling and its 'critical speed'. Also supplied is a set of weights to show how concentrated loads affect whirling. One weight has an extra hole to make it an eccentric load. This helps to show the phase difference between the load and the deflection (you need the optional stroboscope to see this clearly).

Recommended Ancillary:	Page
• Stroboscope (ST1)	299

Geared Systems (TM1018) NEW!

A set of products for dynamic and static experiments on geared and other drive systems

Screenshot of the optional VDAS® software

FEATURES:		BENEFITS:
For studies of velocity ratios and efficiencies of various geared systems	→	**Develops student understanding of modern drive systems**
Self-contained, bench-mounted base unit for dynamic performance tests, including a dual-purpose simple and compound gear drive unit as standard	→	Complete experiment 'out of the box' with further experiments available
Choice of optional drive units, including belt drives and a chain drive, for comparative tests of different drive types	→	**Allows qualitative and quantitative comparison of different designs of drive systems**
High stability drive motor and hysteresis effect dynamometer brake for a constant torque at any given speed	→	Increases measurement accuracy and consistency of results
Optional Test Stand (TM1018a) for static efficiency and inertia tests including a flywheel as standard	→	**Increased experimental range at minimal cost**

EXPERIMENTS:

Dynamic:

- **Simple and compound gear trains**
- **Mechanical advantage, velocity ratio and dynamic efficiencies of gear trains**
- **Mechanical advantage, velocity ratio and dynamic efficiencies of optional drive units (chain and belts)**
- **Appreciation of the different characteristics of drive systems**
- **Chain and belt drive tension, including different methods of application**

Acceleration and static:

- **Mechanical advantage, velocity ratio and static efficiencies of gear drives**
- **Mass moment of inertia of a flywheel by experiment and calculation**
- **Mass moment of inertia of geared drive systems by experiment and calculation**

A bench-mounting base unit forms the main part of this set of products. Supplied with a three-shaft gear drive unit as standard, the base unit dynamically tests the gear drive and the other optional drive units (TM1018b, c and d).

The dynamic tests run the input of the different drive units at a given speed using a motor, while measuring the input power. At the same time, a dynamometer loads the output of the drive unit while measuring the output power.

Students use the measurements to find the performance and efficiency of the drive unit.

Students may set the gear unit (supplied) as a simple or compound drive by sliding a gear in or out of mesh on the third shaft.

TecQuipment includes simple tools needed to fit the drive units to the base unit, and to adjust the compound gear drive.

In the base unit's upper level, the student fits their choice of drive unit. A variable-speed, low-voltage motor provides the shaft input turning force (effort) to the drive. A dynamometer provides the output braking force (load) to the drive. The dynamometer uses electromagnetic braking and a hysteresis effect to provide a variable load at a constant torque irrespective of the speed. Sensors on the motor and dynamometer measure their shaft speed, torque and therefore power in and out at the drive. Fans provide air cooling for both the motor and dynamometer.

Flexible couplings with collets connect the drive unit to the motor and dynamometer for quick and accurate alignment.

Axial trunnions with race bearings hold the motor and the dynamometer for free rotation against their load cell sensors to measure torque accurately.

On the base unit's lower level, controls and microprocessor-controlled multiline displays adjust the motor speed and the load while showing measurements of torque, speed and power.

The base unit's upper level includes an interlocked guard with transparent sections to prevent students touching any moving parts, while allowing them to see what is happening.

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

Optional Test Stand (TM1018a)

The Acceleration and Static Test Stand (TM1018a, available separately) gives extra experiments in measuring angular acceleration and static efficiency. You may use clamps to mount the test stand temporarily on the edge of a desk, but TecQuipment recommends a more permanent fixing to a desk or to a wall.

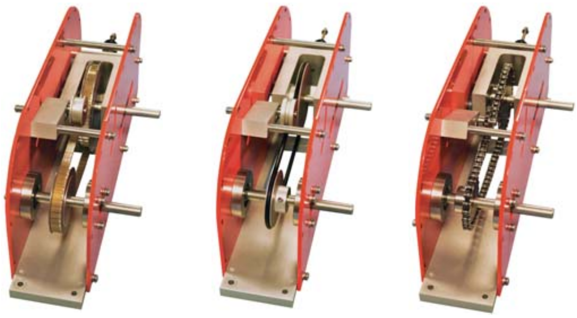
The test stand includes sets of weights to apply turning forces to the shaft of a flywheel (included as standard) or the gear drive from the TM1018. A sensor and a multiline display automatically calculate angular acceleration. Students use this to find inertia by experiment.

The flywheel forms a simplified version of one of the gears in the gear drive, to provide a starting point in understanding inertia calculations of more complex gear drives. The test stand also allows simple static efficiency tests on the gear drive for comparison with those from dynamic tests on the base unit. A slot to the front of the test stand holds a tray (supplied) to store your weights and other loose items.

Note: The test stand and base unit do not connect to each other.

Optional Drive Units:

Toothed Belt Drive (TM1018b)
Round Belt Drive (TM1018c)
Chain Drive (TM1018d)



The optional drive units work with the TM1018 base unit for dynamic tests on performance, allowing comparison with the gear drive. For extended experiments, the optional drives each include three different methods of adjusting their tension to show how this affects performance. The three methods include:

- Distance between drive pulleys
- Fixed tension pulley
- Spring tension pulley

With each drive unit, TecQuipment supplies a tension spring and a spring balance to set the tension of the tension pulley.

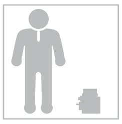
The shafts of all drive units run on maintenance-free, low-friction ball races.

Recommended Ancillaries:	Page
• Acceleration and Static Test Stand (TM1018a)	
• Toothed Belt Drive (TM1018b)	
• Round Belt Drive (TM1018c)	
• Chain Drive (TM1018d)	
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Alternative Products:	Page
• Drive Systems Kit (ES11)	19
• Gear Trains Kit (ES13)	21
• Potential and Kinetic Energy Kit (ES9) (for the optional Test Stand TM1018a)	17

Balance of Reciprocating Masses (TM1022)

A model four-cylinder engine that shows the primary and secondary forces and moments when balancing reciprocating masses



- Includes a control and instrumentation unit to process the force and moment signals – also has an electronic drive control to adjust and display the engine speed accurately
- Simulates one, two and four-cylinder engines
- Variable crank angle settings and additional piston masses – for a range of tests
- Works with an oscilloscope (OS1) to show dynamic force and moment waveforms for popular engine arrangements and compare them with theory

EXPERIMENTS:

- **Primary and secondary forces and moments in popular engine configurations – one, two and four-cylinder**
- **Primary and secondary forces and moments for different crank settings**
- **The effect of adding additional mass to one or more pistons for any chosen crank setting**
- **Comparing calculated forces and moments with actual results**

A bench-mounting model four-cylinder engine that shows primary and secondary forces and moments in reciprocating masses and how to balance them. This product is an excellent follow-on from the Static and Dynamic Balancing equipment (TM1002).

A robust support pillar fixes to a suitable table or bench (not supplied) with a low natural frequency. The pillar holds a cantilever that holds a model four-cylinder engine. The model engine has a crankshaft, connecting rods, bushes (as big-end bearings), pistons and a cylinder block.

A separate control and instrumentation unit (included) controls a motor that turns the engine crankshaft. The crankshaft has adjustable sections. Students can rotate each section relative to the others to change the crank angles. To avoid affecting the experiments, TecQuipment balances the crank sections for all crank angles, even allowing for the connecting rods.

The crankshaft includes a sensor that works with the control and instrumentation unit to measure and display engine speed. It also helps to give a trigger output at top dead centre of the first piston. Each piston includes a tapped hole to allow students to add weights (included) to vary its mass.

The supporting pillar fixes to a workbench, so the engine's centre of mass is on the cantilever axis. Strain gauges on the cantilever detect the bending and torsional strains. The gauges connect to the control and instrumentation unit that calibrates and processes their signals and gives outputs for the oscilloscope (OS1).

Students first find the engine's resonant speeds. They then experiment with different engine arrangements to understand balancing and how to allow for unbalanced reciprocating masses. A removable transparent guard with a safety interlock protects students from the moving crankshaft.

Essential Ancillary:	Page
• Oscilloscope (OS1) – needed to see the dynamic force and moment waveforms and amplitudes	299

Alternative Product:	Page
• Static and Dynamic Balancing (TM1002)	233

Static and Dynamic Balancing (TM1002)

For experiments in balancing a rotating mass system, statically and dynamically

- Demonstrates balancing a horizontal shaft with two, three or four rotating masses
- Independent analysis of static and dynamic balancing
- Includes four removeable rotating masses (balance blocks) with different inserts for a range of moments
- Protractor, horizontal scale and sliding indicator to help accurately position the rotating masses

EXPERIMENTS:

- **Demonstration of simple static and dynamic balancing of two, three and four rotating masses**
- **Dynamic balancing of rotating mass systems by calculation and vector diagrams (triangle and polygon)**

This product allows students to do experiments in balancing a rotating mass system and check their results against accepted theory.

A sturdy base unit holds a test assembly on four flexible mounts. The test assembly includes a balanced steel shaft mounted horizontally on low-friction bearings. The equipment includes a set of four rotating masses (balance blocks). The balance blocks fix in any horizontal position and relative angle on the shaft. Each block contains a different (and removable) circular insert, allowing students to create four blocks of different mass and moment. Without the inserts, the blocks become four identical masses for simple balancing tests.

Students fit an extension shaft and pulley (supplied) to the end of the balance shaft. They then add weights (supplied) to a cord wound round the pulley to measure accurately the moment of each balance block.

The test assembly includes a protractor at the end of the shaft and a linear scale with slider under the shaft. These allow accurate measurement of balance block angles and horizontal positions.

An electric motor and belt turns the shaft to test for dynamic balancing. The flexible mounts allow the assembly to vibrate, showing imbalance during dynamic balancing tests. Students remove the belt to check for static balance (the shaft should remain static at any angular position).

A transparent safety dome covers the whole rotating assembly. An interlock shuts off power to the motor when the dome is not fitted.

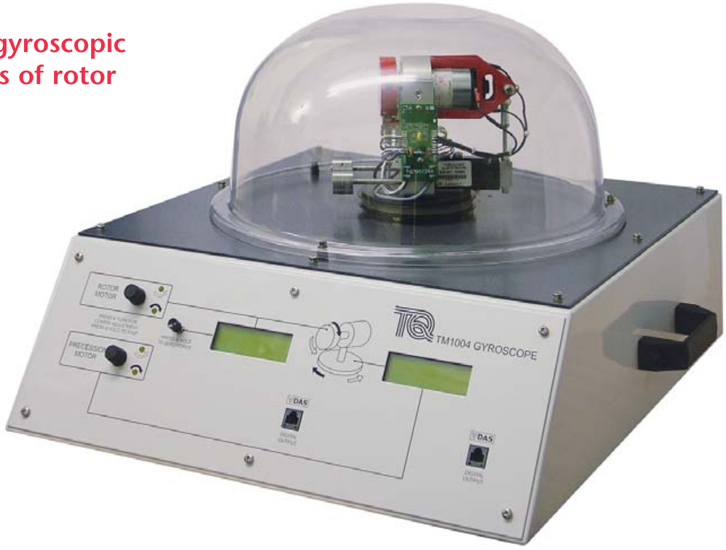
Alternative Product: Page

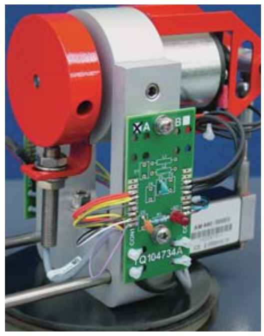
- Balance of Reciprocating Masses (TM1022) 232

Gyroscope (TM1004)

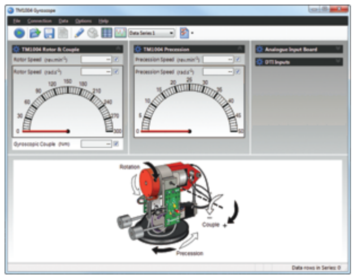
Works with VDAS®

For experiments in gyroscopic couple and velocities of rotor and precession





- Interlocked, transparent dome allows students to see the gyroscope spinning in safety
- Works in both clockwise and anticlockwise directions for a full range of tests
- Unique multifunction controls for coarse and fine adjustment of velocity and direction
- Direct measurement of gyroscopic tilting force, couple and velocities (speeds) shown on digital displays



Screenshot of the optional VDAS® software

EXPERIMENTS:

- **Direction of gyroscopic couple (in relation to precession and rotor spin directions).**
- **Magnitude of gyroscopic couple (in relation to precession and rotor spin velocities).**

A base unit supports a gimbal frame, holding a gyroscope assembly that spins and precesses under a clear dome.

The rotor of an electric motor shares a horizontally supported shaft with a flywheel, forming the gyroscope. A second electric motor turns a belt that turns a turntable under the gyroscope, causing precession about a vertical axis. Both motors work in clockwise and anticlockwise rotation and with variable velocity. Sensors measure the rotational velocity of the rotor and precession.

A sensor measures the gyroscope's up or down tilting force at a known distance from the gyroscope pivot. This allows calculation of the torque or 'gyroscopic couple'.

The clear dome includes an interlock that shuts off power to the motors. This allows students to see the gyroscope and use it in safety while still giving them access to examine the mechanism.

The base unit includes motor controls and multiline displays. The motor controls include unique direction, coarse and fine velocity adjustment and 'press to stop' functions. The displays show rotor and precession velocity (speed) in units of revolutions per minute and radians per second. They also show the magnitude of force and couple.

The equipment works with TecQuipment's Versatile Data Acquisition System (VDAS® available separately). Using VDAS® enables accurate real-time data capture, monitoring and display, calculation and charting of all relevant parameters on a computer (not supplied) making tests quick and reliable.

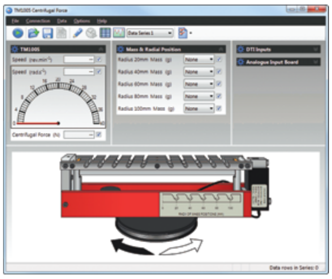
Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Centrifugal Force (TM1005)

Works with **VDAS**®

For experiments in centrifugal force and angular velocity

- Shows the relationship between centrifugal force, mass of a rotating body, its distance from the axis, and its angular velocity
- Balanced arm mechanism for accurate readings
- Interlocked, transparent dome allows students to see the mechanism spinning in safety
- Includes a set of weights for different experiments



Screenshot of the optional VDAS® software

EXPERIMENTS:

Finding the relationship between centrifugal force, the mass of a rotating body, its distance from the axis of rotation (radial position) and the speed of rotation.

A base unit supports a mechanism that rotates under a clear dome. An electric motor turns a belt that turns a turntable under the mechanism. The motor works in clockwise and anticlockwise rotation and with variable velocity. A sensor measures the rotational velocity of the mechanism.

The mechanism has three balance arms. Two (the outside) arms hold any of a selection of masses (supplied) at any of five radial positions. A sensor measures the centrifugal force due to the selected mass as it rotates about the given radii. The other (central) arm holds equal and radially opposite masses to balance the first mass. This prevents unwanted vibrations, which would also affect measurement accuracy.

The clear dome includes an interlock that shuts off power to the motor. This allows students to see the mechanism rotating and use it in safety while still giving them access to change the masses and their positions.

The base unit includes the motor control and a multiline display. The motor control includes unique direction, coarse and fine velocity adjustment and 'press to stop' functions. The display shows velocity (speed) in units of revolutions per minute and radians per second. It also shows centrifugal force.

The equipment works with TecQuipment's Versatile Data Acquisition System (VDAS® available separately). Using VDAS® enables accurate real-time data capture, monitoring and display, calculation and charting of all relevant parameters on a computer (not supplied) making tests quick and reliable.

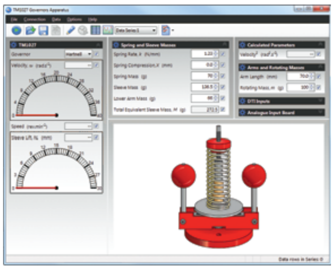
Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Alternative Product:	Page
• Centrifugal Force Kit (ES16)	24

Governors (TM1027)

Works with VDAS®

Shows how different governors work, including Hartnell, Porter and Proell governors



Screenshot of the optional VDAS® software

Includes three different governors (one shown already fitted)

- Includes three easy-to-fit governors: Hartnell, Porter and Proell
- Interlocked, transparent dome allows students to see the governors spinning in safety
- Includes additional weights to change the mass of the Porter and Proell governor sleeves
- Supplied with different springs and rotating masses for the Hartnell governor

EXPERIMENTS:

- **Finding characteristic curves of governor speed against sleeve lift.**
- **Comparison of governor types in terms of sensitivity, stability and effort.**
- **On the Porter and Proell governors, the effects of varying centre sleeve mass.**
- **On the Hartnell governor, the effect of varying:**
  - **– arm length**
  - **– spring rate**
  - **– spring compression**
  - **– rotating mass**
- **Demonstration of the isochronous condition (Hartnell governor).**

A base unit contains a variable-speed motor. The motor turns each of three different governors: Proell, Porter and Hartnell. **Note:** you test one governor at a time.

Each governor uses rotating weights (masses) and levers to raise a ‘sleeve’. The Porter and Proell governors raise the sleeve against the action of gravity. The Hartnell governor raises the sleeve against a compression spring. A sensor measures the position (lift) of each governor sleeve as it rises.

Additional weights (supplied) allow the user to vary the mass of the sleeve of the Porter and Proell governors. Additional springs (supplied) allow the user to vary the spring rate of the Hartnell governor. Users may also adjust the arm length and rotating mass of the Hartnell governor.

The clear dome includes an interlock that shuts off power to the motor. This allows students to see the governors and use them in safety while still giving them access to examine or adjust them.

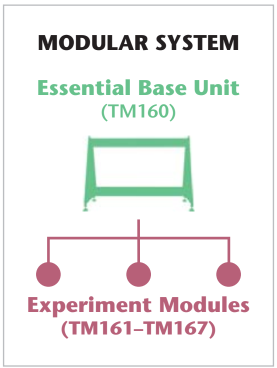
The base unit includes a motor control and a multiline display. The control includes unique direction, coarse and fine velocity adjustment and ‘press to stop’ functions. The display shows governor velocity (speed) in units of revolutions per minute and radians per second. It also shows sleeve lift.

The equipment works with TecQuipment’s Versatile Data Acquisition System (VDAS® available separately). Using VDAS® enables accurate real-time data capture, monitoring and display, calculation and charting of all relevant parameters on a computer (not supplied) making tests quick and reliable.

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Free Vibrations Test Frame (TM160) NEW!

Sturdy frame for use with TecQuipment's Free Vibrations Experiments



FEATURES:		BENEFITS:
Solid and lightweight construction	→	**Ensures repeatability of results and long service life, yet light enough to move around the classroom**
Supplied with all the tools needed for assembly	→	Quick and easy set up time – optimises experiment time during laboratory sessions
Includes a storage tray for safe storage of any tools and smaller parts of your optional experiments	→	**Reduces risk of losing components – greater longevity**

For use with TecQuipment's Free Vibrations Experiments, the test frame fits on any standard desk or bench top.

Students, teachers or lecturers fit the parts of their free vibrations experiments to the test frame to study or demonstrate a free vibrations topic.

The test frame has two extruded alloy horizontal members each with slotted fixing points to all four sides. The two triangular sides each have adjustable levelling feet. A stable, level test frame is essential in vibration experiments to give repeatable and accurate results.

The sturdy construction is necessary for accurate results in vibration experiments, but this also gives the frame a long service life. Despite its sturdy construction, the frame is light enough for two people to move it around the classroom easily.

TecQuipment includes a storage tray and lid with the test frame. This is useful to store tools and smaller parts of your optional experiments, helping prevent accidental loss or damage. The test frame also includes a hexagon tool and a spirit level for easy assembly and levelling.

Available Experiment Modules:	Page
• Simple and Compound Pendulums (TM161)	238
• Filar Pendulums (TM162)	239
• Centre of Percussion (TM163)	240
• Free Vibrations of a Mass-Spring System (TM164)	241
• Free Torsional Vibrations (TM165)	243
• Free Vibrations of a Cantilever (TM166)	244
• Free Vibrations of a Beam and Spring (TM167)	245

Shown with one of the available experiment modules

Simple and Compound Pendulums (TM161) NEW!

Studies simple harmonic motion and the factors that affect the period of oscillation of pendulums

- Back panels with referenced scales and sliding indicators for accurate positioning of pendulum parts
- The simple pendulum has unique quick-change spheres and adjustable cord length – needing no tools
- Includes simple, compound and Kater's pendulums for a range of experiments
- Quick and easy assembly
- Contains all parts needed for the experiments – including a stopwatch and simple tools

EXPERIMENTS:

- **Cord length and period of a simple pendulum**
- **Mass and period of a simple pendulum**
- **Using a simple pendulum to find the acceleration due to gravity**
- **Centre of gravity and period of a compound pendulum**
- **How an adjustable mass affects the period of a compound pendulum**
- **Using a Kater's pendulum to find the acceleration due to gravity**

This product is part of a range that explores free vibrations in simple 'one degree of freedom' systems.

It introduces students to key scientific terms such as:

- Simple harmonic motion (SHM) and period of oscillation
- Mass moment of inertia
- Radius of gyration
- Routh's rule

This product fits to the sturdy Test Frame (TM160) for study or demonstration.

This product includes a simple pendulum and a compound pendulum. Both pendulums swing through small angles, showing the principles and use of simple harmonic motion using the small angle approximation.

The simple pendulum uses a cord which may be considered as 'light' so you can ignore its mass, leaving only the sphere and cord length as the important variables.

The compound or 'physical' pendulum uses a 'heavy' solid rod which has reasonable mass, so you must allow for it in theoretical equations.

Each pendulum has a back panel that fixes separately to the test frame. The back panel of each pendulum has an accurate scale and indicator, referenced to pendulum pivot or centre of mass points. This improves measurement accuracy – essential for good results.

The simple pendulum has a choice of two spheres suspended by a cord. An adjustable indicator also acts as the pendulum pivot point, allowing you to adjust the cord length in seconds. This can also provide a quick visual demonstration of the effect of cord length on period. Each sphere has a different mass for comparison and an internal spring retainer so you can easily swap them between experiments.

The compound pendulum has a solid rod that pivots on a hardened steel knife edge on the upper surface of a steel platform. This pendulum includes an additional spherical mass that fixes at any position along the rod. It also includes an extra pivot and disc-shaped mass so you can convert it for use as a Kater's pendulum.

The Kater's pendulum works as a reversible and adjustable compound pendulum. Students adjust the relative positions of its parts until they have equal time periods in both its standard and reversed arrangements. It then works as an accurate gravimeter.

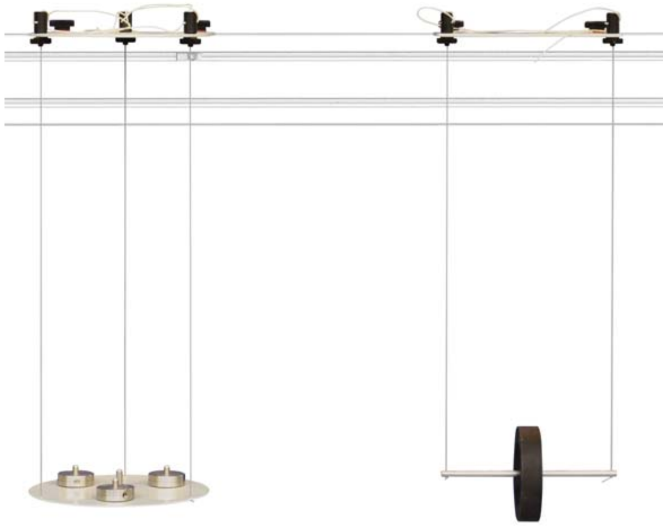
Students test different pendulums to see how different factors, such as mass or pendulum length, affect simple harmonic motion and the period of oscillation. The theory shows how to predict the period of oscillation of a given pendulum for comparison with actual results. It also shows how pendulums can produce an approximate value of the acceleration due to gravity.

Essential Base Unit:	Page
• Free Vibrations Test Frame (TM160)	237

Alternative Product:	Page
• Simple Harmonic Motion Kit (ES7)	15

Filar Pendulums (TM162) NEW!

Studies simple harmonic motion and the factors that affect the period of oscillation of bifilar and trifilar pendulums



- Flexible and modular – fits onto the Test Frame (TM160) for experiments and classroom demonstrations
- Different pendulum designs, lengths, mass and inertia – for a range of experiments
- Quick and easy assembly
- Contains all parts needed for the experiments – including an 'example machine element', stopwatch, steel rule and simple tools

EXPERIMENTS:

- **Cord length and period of bifilar and trifilar pendulums**
- **Cord (support) positions and period of bifilar and trifilar pendulums**
- **Mass and period of bifilar and trifilar pendulums**
- **Position of mass on bifilar and trifilar pendulums**
- **Finding moment of inertia of an 'example machine part' in two different axes**

This product is part of a range that explores free vibrations in simple 'one degree of freedom' systems.

It introduces students to key scientific terms such as:

- Simple harmonic motion (SHM) and period of oscillation
- Mass moment of inertia
- Radius of gyration
- Axis of rotation
- Parallel axis theorem

This product fits to the sturdy Test Frame (TM160) for study or demonstration.

This product includes a rod and a circular plate to show the principles and use of simple harmonic motion theory in bifilar and trifilar pendulums. Two suspension plates fix to the top of the test frame to hold the bifilar and trifilar pendulums.

Bifilar and trifilar – meaning of two (bi) or three (tri) threads or wires.

Students test the two pendulums to see how different factors, such as mass, support position or pendulum length affect the period of oscillation. The theory shows how to predict the period of oscillation of a given pendulum for comparison with actual results. The module includes an 'example machine element' that fits on each pendulum, rotating around two different axes of rotation. It helps to show how you may use a pendulum to predict the moment of inertia of a part rather than use extensive calculation and measurements.

TecQuipment provides a CD-ROM with the equipment. It contains CAD (computer aided design) files of the example machine element used in the experiments. The files are in several formats for use with the most popular CAD software packages. This allows students to compare a software predicted moment of inertia against that found by experiment.

Note: TecQuipment recommend that you have access to a computer with a suitable 3D CAD software package, such as SolidWorks®, which can predict moment of inertia.

Essential Base Unit:	Page
• Free Vibrations Test Frame (TM160)	237

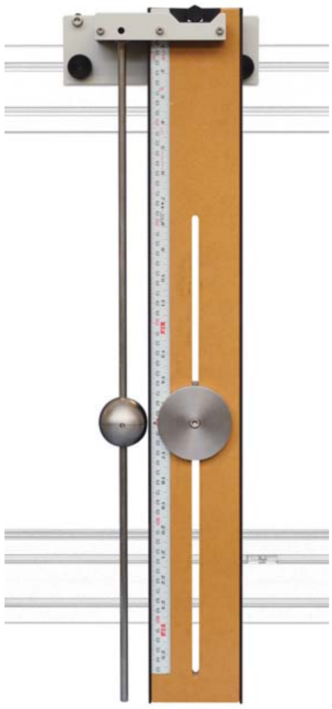
Alternative Product:	Page
• Simple Harmonic Motion Kit (ES7)	15

Shown with the Test Frame (TM160)

Centre of Percussion (TM163) NEW!

Shows how to calculate and find the centre of percussion of a compound pendulum

- Flexible and modular – fits onto the Test Frame (TM160) for experiments and classroom demonstrations
- Realistic scale – for highly visual and accurate experiments in complete safety
- Quick and easy assembly
- Contains all parts needed for the experiments – including a stopwatch and simple tools



EXPERIMENTS:

- **Centre of gravity, period of oscillation and radius of gyration of a compound pendulum**
- **Centre of percussion of a compound pendulum**

This product is part of a range that explores free vibrations in simple 'one degree of freedom' systems.

It introduces students to key scientific terms such as:

- Simple harmonic motion (SHM) and period of oscillation
- Radius of gyration
- Centre of gravity
- Centre of percussion (CoP) and the 'sweet spot'
- Impact reactions

This product fits to the sturdy Test Frame (TM160) for study or demonstration.

Shown with the Test Frame (TM160)

A centre of percussion may also be termed the 'sweet spot' of the impact of a ball against a bat or racquet. It is the impact position which allows no reaction in the hand of the user, which would otherwise create uncomfortable shocks in their arm and wrist.

This product includes a metal pendulum to provide the percussion force (a ball) and a wooden pendulum to absorb the impact. The wooden pendulum forms a suspended mass, similar to a bat held underhand.

A cradle fixes to the top of the test frame. The cradle suspends the fixed metal rod pendulum and heavy sphere beside the wooden pendulum.

Self-aligning bearings hold the metal pendulum to allow rotational movement only.

Hardened steel knife edges rest on a smooth surface on the cradle suspending the wooden pendulum. They allow the wooden pendulum to pivot freely while also allowing some visible horizontal movement, necessary to see any reactions.

Students find the centre of gravity of the wooden (compound) pendulum to calculate its radius of gyration and centre of percussion. They then use the sphere of the metal pendulum to simulate a ball hitting the wooden pendulum at a precise position, confirming the theory. The wooden pendulum has a mass with adjustable position. This allows students to change its centre of gravity position for a range of tests.

TecQuipment has made this product to a realistic scale. This means that it produces highly visual results for demonstrations, yet the masses and inertia are still low enough for safe student use.

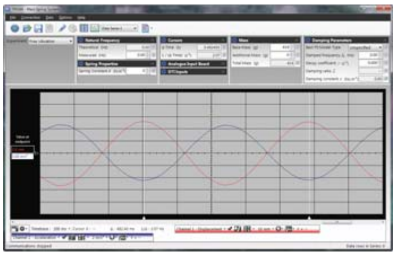
Essential Base Unit:	Page
• Free Vibrations Test Frame (TM160)	237

Free Vibrations of a Mass-Spring System (TM164)

NEW!

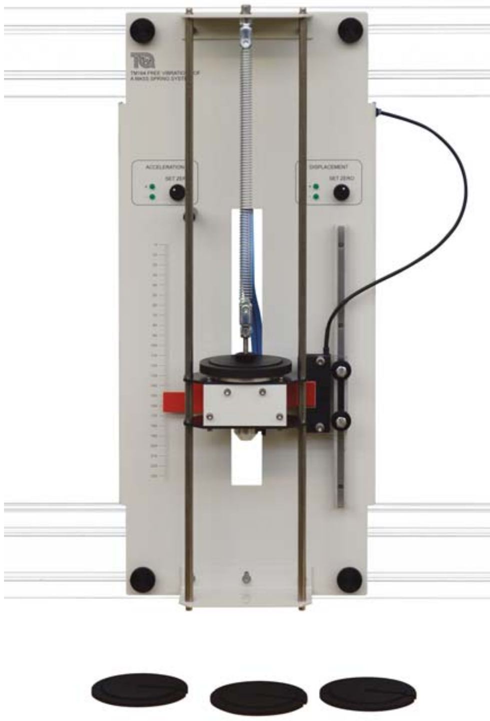
Works with VDAS®

Uses simple harmonic motion theory to show how to calculate the frequency of oscillation in simple mass-spring systems



Screenshot of the VDAS® mkII software

Shown fitted with the optional Damper Kit (TM164a)



- Flexible and modular – fits onto the Test Frame (TM160) for experiments and classroom demonstrations
- Optional dashpot for extra experiments in oscillation damping
- Non-contacting measurement sensors for negligible damping
- Additional acceleration sensor for comparison with software-derived waveform
- Works with TecQuipment's Versatile Data Acquisition System (VDAS® mkII) for real-time display of the mass-spring oscillations

EXPERIMENTS:

- **Spring extension and force (spring constant) and Hooke's law**
- **Frequency of oscillation, spring constant and varying mass**
- **Phase difference between displacement and its derivatives**
- **Comparison of measured and derived acceleration**
- **Oscillation damping and coefficient (needs optional Damper Kit)**

This product is part of a range that explores free vibrations in simple 'one degree of freedom' systems.

It introduces students to key scientific terms such as:

- Simple harmonic motion (SHM) and frequency of oscillation
- Spring constant and Hooke's Law
- Oscillation damping
- Phase difference between displacement and its derivatives

This product fits to the sturdy Test Frame (TM160) for study or demonstration.

The mass-spring system is one of the most easily explainable oscillatory systems. This is because students may already be familiar with Hooke's Law, showing the force exerted by a spring is proportional to the extension. Therefore, students can easily make the link to simple harmonic motion – defined as the oscillatory motion where the restoring force is proportional to the displacement.

A back panel fixes to the test frame. The panel holds two vertical guide rods and a non-contacting displacement sensor. A test spring suspends a balanced mass platform which vibrates (oscillates) vertically in the guide rods.

Students fit additional masses to the platform, and a second spring is provided to test various system combinations.

The displacement sensor measures the vertical oscillations of the platform. An additional sensor (accelerometer) built into the platform measures the acceleration of the platform as it moves up and down. Both sensors measure the motion, yet create negligible damping.

Continued on next page

Free and Forced Vibrations (TM1016)
Continued from previous page

The back panel has a printed scale. Students use it with a cursor on the platform to measure accurately the spring extension, to show Hooke's Law and find the spring constant.

Students pull the platform gently down and release, allowing it to vibrate. They then find the frequency of oscillation and compare it with that predicted from theory.

TecQuipment calibrates the sensors to work with VDAS® mkII for real-time display and data acquisition of system oscillation waveforms. Students use the software to see both the displacement and acceleration waveforms to confirm the phase difference between them and measure frequency. The software calculates and shows the first two derivatives of displacement: velocity and acceleration.

Students can then see and compare both the measured and derived acceleration at the same time, to confirm the relationship.

TecQuipment has specifically designed the TM164 to work with VDAS® mkII. However, the sensor outputs may be connected to your own data acquisition system or oscilloscope, if desired.

Students may fit an optional Damper Kit (TM164a) to test how viscous damping affects the system oscillations. This simple piston disc and cylinder form a dashpot damper that fits to the guide rods under the platform. It works with easily found non-toxic fluids (not supplied) for different damping levels. For example: water and vegetable oil will produce light damping, while castor oil produces heavy damping. Students may try their own fluids (provided they are safe and do not damage the equipment) and their own piston discs for project work.

When using the damper kit, VDAS® can fit its displayed data to underdamped and overdamped viscous damping models.

Note: You may purchase any number of damper kits to make the change between the various fluids more convenient.

Essential Base Unit: Page

- Free Vibrations Test Frame (TM160) 237

Recommended Ancillary:

- Damper Kit (TM164a)

Essential Ancillary: Page

- Versatile Data Acquisition System – bench-mounted version (VDAS-B mkII) 32

Note: This equipment needs the new VDAS® mkII and will not work with earlier versions of VDAS®. Contact TecQuipment or your local agent if unsure.

Alternative Product: Page

- Free and Forced Vibrations (TM1016) 247

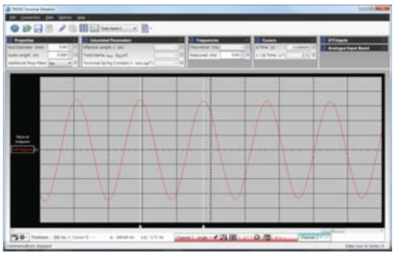
Shown fitted to the Test Frame (TM160) and connected to VDAS® mkII

Free Torsional Vibrations (TM165) NEW!

Works with VDAS®

Shows the oscillatory motion of a disc attached to a slender rod

- Uses the rotational movement of a disc suspended from a circular rod for a highly visual and intuitive display of simple harmonic motion
- Integral scale to save time and improve measurement accuracy
- Includes a selection of specimen rods and an additional inertia ring for a range of experiments
- Non-contacting displacement sensor to see and measure oscillatory motion with negligible damping effect



Screenshot of the VDAS® mkII software

EXPERIMENTS:

- **Rod diameter and frequency of oscillation**
- **Rod length and frequency of oscillation**
- **Inertia and frequency of oscillation**
- **Phase difference between displacement and its derivatives**

This product is part of a range that explores free vibrations in simple 'one degree of freedom' systems.

It introduces students to key scientific terms such as:

- Simple harmonic motion (SHM)
- Frequency of oscillation
- Shear modulus
- Polar moment of area
- Mass moment of inertia
- Phase difference between displacement and its derivatives

This product fits to the sturdy Test Frame (TM160) for study or demonstration.

This product includes a rotating disc or 'rotor' at the end of a slender rod. You can compare this with the mass-spring system, except it replaces mass with the rotor's mass moment of inertia and the spring with the twisting of the rod.

A back panel fixes to the test frame. The panel holds two vertical runners. The runners hold a chuck that securely grips a specimen rod at any position along its length. The bottom of the rod fixes to a rotor that is free to rotate. A bushing ensures the rotation remains along the axis of the rod, and supports the rotor during setup.

A non-contacting sensor next to the rotor disc measures the amplitude of the rotational oscillations. The sensor has no physical contact with the rotor, for negligible damping.

The equipment includes a selection of rods of different diameter and the chuck position may be adjusted. A scale on the back panel referenced to the bottom of the rod gives a direct indication of the rod's 'effective' length. Students can use these to discover how rod diameter and length affect the torsional oscillations.

Students may also fit an additional inertia disc to the rotor to see how the increased inertia affects the torsional oscillations.

Students lower the rotor support when ready and then gently twist and release the rotor to cause free torsional oscillations in the specimen rod. They then find the frequency of oscillation and compare it with that predicted from theory.

TecQuipment calibrate the displacement sensor to work with VDAS® mkII for real-time display and data acquisition of system oscillation waveforms. Students use the software to see the displacement waveform and measure frequency. The software calculates and shows the first two derivatives of displacement: velocity and acceleration.

TecQuipment has specifically designed the TM165 to work with VDAS® mkII. However, the sensor output may be connected to your own data acquisition system or oscilloscope, if desired.

Essential Base Unit:	Page
• Free Vibrations Test Frame (TM160)	237

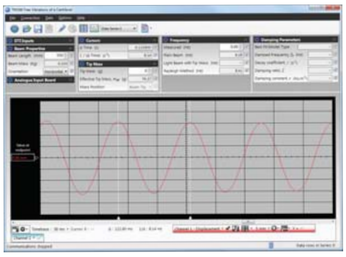
Essential Ancillary:	Page
• Versatile Data Acquisition System – bench-mounted version (VDAS-B mkII)	32

Note: This equipment needs the new VDAS® mkII and will not work with earlier versions of VDAS®. Contact TecQuipment or your local agent if unsure.

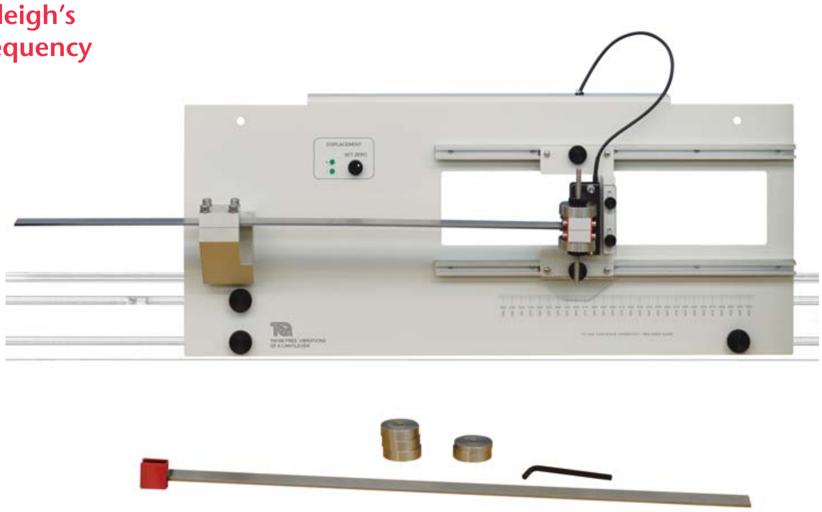
Free Vibrations of a Cantilever (TM166) NEW!

Works with VDAS®

Uses fundamental theory and Rayleigh's approximation to calculate the frequency of oscillation of a cantilever



Screenshot of the VDAS® mkII software



- Quick and easy assembly
- Mounts both vertically and horizontally for alternative analysis
- Includes a plain cantilever and a weighted cantilever with 'tip mass' for a range of experiments
- Non-contacting displacement sensor to see and measure oscillatory motion with negligible damping effect

EXPERIMENTS:

- **Predicting oscillation frequency using Rayleigh's method and the simplified method assuming that the beam is 'light'**
- **Phase difference between displacement and its derivatives**
- **Horizontal cantilever length and frequency of oscillation**
- **Using Dunkerley's method to predict the 'beam only' frequency**
- **Comparison of vertical and horizontal cantilevers**

This product is part of a range that explores free vibrations in simple 'one degree of freedom' systems.

It introduces students to key scientific terms such as:

- Simple harmonic motion (SHM) and frequency of oscillation
- Beam stiffness
- Rayleigh's method
- Dunkerley's method
- Second moment of area
- Phase difference between displacement and its derivatives

This product fits to the sturdy Test Frame (TM160) for study or demonstration.

A beam with the mass at the end works in a similar way to a mass spring system – the stiffness of the beam simply replaces the stiffness of the spring. However, in a mass spring system, we normally assume a 'light' spring compared to the mass. The vibrating cantilever examines what happens if the spring element (the beam in this case) is not light. Additionally, it examines a beam (with no tip mass) as a complete self-contained system, forming the mass and the spring.

The vibrating cantilever forms a simple and highly visual example of oscillations that may occur in real structures such as aircraft wings.

A back panel fixes to the test frame. The panel holds a sturdy clamp and two runners. The clamp holds the beam. Students use the clamp to adjust the oscillating length of the cantilever. The runners hold a non-contacting sensor that measures the oscillations at the end of the cantilever. The sensor has no physical contact with the beam, for negligible damping.

The back panel has a printed scale. Students use it to set the beam length accurately.

The product includes two beams: a plain beam and a beam with tip mass. Students may add extra 'tip mass' to the second beam to test how it affects oscillations.

Students pull the end of the cantilever down and release, allowing it to vibrate. They then find the frequency of oscillation and compare it with that predicted from theory.

Students test the beam with a varying tip mass, changing the ratio of tip mass to beam mass. They discover that for most ratios, the assumption that the beam is 'light' may not give accurate predictions of oscillation frequency. They then learn how Rayleigh's method improves the overall prediction. They also use Dunkerley's method to predict the natural frequency of the beam only, comparing this value with that found by other methods.

The back panel fixes in both horizontal and vertical direction to allow students to test the beams in both positions.

TecQuipment calibrates the displacement sensor to work with VDAS® mkII for real-time display and data acquisition of system oscillation waveforms. Students use the software to see the displacement waveform and measure frequency. The software calculates and shows the first two derivatives of displacement – velocity and acceleration.

TecQuipment has specifically designed the TM166 to work with VDAS® mkII. However, the sensor output may be connected to your own data acquisition system or oscilloscope if desired.

Essential Base Unit:	Page
• Free Vibrations Test Frame (TM160)	237

Essential Ancillary:	Page
• Versatile Data Acquisition System – bench-mounted version (VDAS-B mkII)	32

Note: This equipment needs the new VDAS® mkII and will not work with earlier versions of VDAS®. Contact TecQuipment or your local agent if unsure.

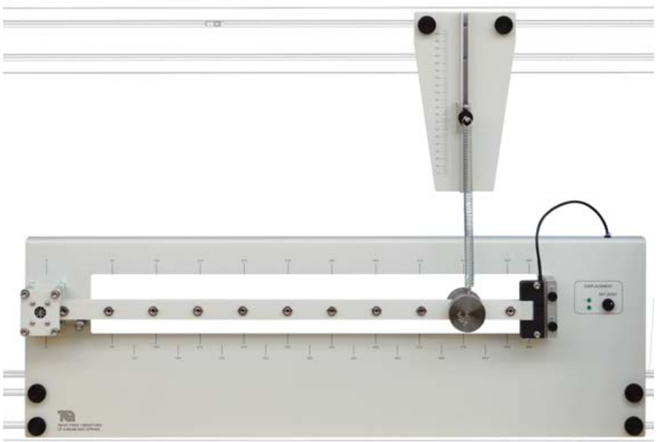
Alternative Product:	Page
• Free and Forced Vibrations (TM1016)	247

Free Vibrations of a Beam and Spring (TM167)

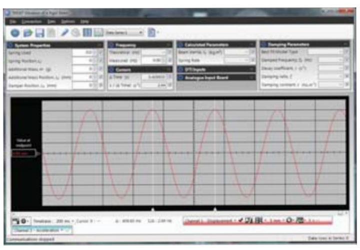
NEW!

Works with VDAS®

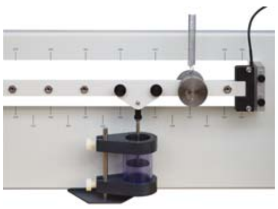
Shows the oscillatory motion of a rigid beam, pivoted at one end and suspended by a spring at the other



- Uses a pivoted beam with spring for a highly visual display of simple harmonic motion
- Integral scales to save time and for convenient use
- Optional Damper Kit (TM167a) for extra experiments in oscillation damping using safe, easily-available fluids
- Non-contacting displacement sensor to see and measure oscillatory motion with negligible damping effect



Screenshot of the VDAS® mkII software



Shown fitted with the optional Damper Kit (TM167a)

EXPERIMENTS:

- Spring extension and force (spring constant), and Hooke's law
- Phase difference between displacement and its derivatives
- Frequency of oscillation and varying mass moment of inertia by varying mass value
- Frequency of oscillation and spring constant
- Frequency of oscillation and varying mass moment of inertia by varying mass position
- Oscillation damping and coefficient (needs optional Damper Kit)

This product is part of a range that explores free vibrations in simple 'one degree of freedom' systems.

It introduces students to key scientific terms such as:

- Simple harmonic motion (SHM) and frequency of oscillation
- Moment of inertia
- Oscillation damping
- Spring constant and Hooke's Law
- Phase difference between displacement and its derivatives

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Free and Forced Vibrations (TM1016)
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This product fits to the sturdy Test Frame (TM160) for study or demonstration.

This product includes a beam pivoted at one end, with the other end suspended by a coiled spring. You can compare this with the mass-spring system, except the mass moment inertia of the beam replaces the simple mass. This common system appears in machines and vehicle suspensions.

A back panel fixes to the Test Frame. The panel holds a pivot and a non-contacting displacement sensor. The pivot contains high-quality self-aligning bearings that hold the left-hand end of a rigid beam, while allowing it freedom to rotate through a small angle. The sensor measures the oscillations at the right-hand end of the beam with negligible damping, while working to guide the movement.

Shown fitted to the Test Frame (TM160) and connected to VDAS® mkII

The beam is of a 'ladder' type construction with equally spaced 'rungs'. The rungs provide convenient mounting positions, while maintaining a uniformly distributed mass along the beam's length. TecQuipment include a set of masses to add to the beam, increasing its inertia. A separate spring bracket above the beam holds a choice of two springs to suspend the beam from any rung along its length. Both the back panel and spring bracket have printed scales. Students use the scale on the back panel to easily position the masses, spring and optional damper along the beam. They use the scale on the spring bracket to show Hooke's Law and find the spring constant.

Students pull the beam gently down and release, allowing it to vibrate. They then find the frequency of oscillation and compare it with that predicted from theory.

The multiple positions along the beam allow students to try their own combinations of experiments, in addition to those suggested. For example, they could try different spring positions or multiple masses.

TecQuipment calibrate the displacement sensor to work with VDAS® mkII for real-time display and data acquisition of system oscillation waveforms. Students use the software to see the displacement waveform and measure frequency. The software calculates and shows the first two derivatives of displacement – velocity and acceleration.

TecQuipment have specifically designed the TM167 to work with VDAS® mkII. However, the sensor output may be connected to your own data acquisition system or oscilloscope if desired.

Students may fit an optional Damper Kit (TM167a) to test how viscous damping affects the beam oscillations. This simple piston disc and cylinder form a dashpot damper that fits to the Test Frame under the beam. It works with easily found non-toxic fluids (not supplied) for different damping levels. For example: water and vegetable oil will produce light damping, while castor oil produces heavy damping. Students may try their own fluids (provided they are safe and do not damage the equipment) and their own piston discs for project work.

When using the Damper Kit, VDAS® can fit its displayed data to underdamped and overdamped viscous damping models.

Note: You may purchase any number of damper kits to make the change between the various fluids more convenient.

Essential Base Unit:	Page
• Free Vibrations Test Frame (TM160)	237

Recommended Ancillary:

- Damper Kit (TM167a)

Essential Ancillary:	Page
• Versatile Data Acquisition System – bench-mounted version (VDAS-B mkII)	32

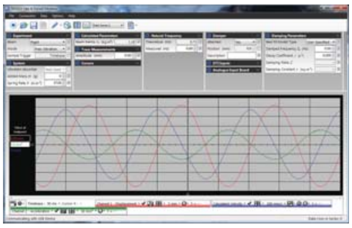
Note: This equipment needs the new VDAS® mkII and will not work with earlier versions of VDAS®. Contact TecQuipment or your local agent if unsure.

Alternative Product:	Page
• Free and Forced Vibrations (TM1016)	247

Free and Forced Vibrations (TM1016) NEW!

Works with VDAS®

Investigates the free and forced vibrations of a rigid beam with a spring, and a simply supported beam



Screenshot of the VDAS® mkII software

FEATURES:	BENEFITS:
Two different vibration systems in one self-contained unit: a 'rigid' beam with a spring and a pinned-pinned (simply supported) 'flexible' beam	**Increased experimental scope with minimal set up time**
Non-contacting displacement sensor	Frictionless measurement of displacement – minimises influence on experiment results
High-quality servomotor 'exciter' – for forced vibrations at a constant speed	**Minimises cyclical variations – enhances accuracy and repeatability**
Offset mass position sensor	Shows the phase relationship between applied force and displacement
Built-in accelerometer for comparison of derived and measured acceleration waveforms	**High level functions deepens students' understanding**
Works with TecQuipment's VDAS® mkII for real-time display of the vibrations	Advanced software eliminates need for additional expensive oscilloscope

EXPERIMENTS:

- Free and forced vibrations of a rigid beam and spring
- Free and forced vibrations of a flexible pinned–pinned (simply supported) beam
- Using Rayleigh's approximation to predict vibration frequency
- Frequency of oscillation and varying mass
- Finding the 'beam only' frequency using Dunkerley's Method
- Phase difference between displacement, its derivatives and measured acceleration
- Damped free and forced oscillations and damping coefficient
- Phase relationship between the applied force and beam position for different damping values
- Demonstration of a 2 degree of freedom (2DOF) system
- Demonstration of an undamped vibration absorber

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Free and Forced Vibrations (TM1016)
Continued from previous page

A bench-top unit to demonstrate free and forced vibrations of two mass-beam systems:

1. A 'rigid' beam with a pivot at one end and a spring at the other – the spring provides the elasticity.
2. A 'flexible' pinned-pinned beam with a pivot at one end and a roller pivot at the other – the beam itself provides the elasticity.

A rigid and heavy steel frame holds the systems. The frame has a low natural frequency, so the vibrations of the systems do not affect it. The frame has two sections: an experiment 'window' to the right and a control panel to the left. The experiment window contains the beam, spring and other parts used in the experiments.

Shown connected to VDAS® mkII

TecQuipment carefully designed the equipment so that all experiments use the same beam. This gives a simple and quick system set up and changeover time. The beam is of high-grade ground steel, and the pivots use high-quality ball races for lowest friction and incidental damping.

Students may vibrate the systems manually. They may also force the vibrations using a high-quality variable-speed servomotor driving a rotating offset mass, forming an 'exciter'. The servomotor has its own encoder and advanced controller for accurate speed regulation. This gives minimal cyclical variation due to inertial load variations.

A non-contacting sensor measures beam displacement. The sensor has no physical contact with the oscillating system, for negligible damping.

An accelerometer built into the exciter assembly works to show the phase relationship between beam displacement and acceleration. It also helps to compare measured acceleration with that derived from the displacement using the software.

The unit includes a variable-area viscous dashpot damper, for use with a non-toxic fluid (supplied) of stable viscosity. This ensures repeatable results over a range of ambient temperatures.

An encoder linked to the rotating exciter mass measures its dynamic position. This helps to measure the relationship between the applied force and the position of the beam, showing phase lag with different damping values.

TecQuipment includes a vibration absorber with the equipment. When fixed to the beam it adds a second degree of freedom to the complete system. This demonstrates the typical behaviour of a 2 degree of freedom (2DOF) system. Students learn how to 'tune' the vibration absorber to eliminate the oscillations of the main beam – a special case of a 2DOF system and an alternative method to damping.

To help store small parts and tools, TecQuipment supplies a storage tray with the equipment.

The control panel houses the servomotor controller and manual controls, alongside a digital display of the motor speed in units of rev.min^{-1}, rad.s^{-1} and frequency in Hz. It also provides outputs of the displacement, acceleration, encoder (offset mass) position, and motor speed. These outputs are calibrated and scaled to work directly with TecQuipment's VDAS® mkII system.

The output signals connect to the VDAS® interface which converts them for connection to a suitable PC (not supplied).

The VDAS® mkII software includes functions to display live plots of first and second derivatives, to show velocity and acceleration waveforms based on the displacement signal. Advanced features of the software allow signal smoothing, reference plots and a tool to help measure the free vibration damping coefficient.

TecQuipment has specifically designed the TM1016 to work with VDAS®. However, the sensor and trigger outputs may be connected to your own data acquisition system or oscilloscope, if desired.

Essential Ancillary:	Page
• Versatile Data Acquisition System – bench-mounted version (VDAS-B mkII)	32

Note: This equipment needs the new VDAS® mkII and will not work with earlier versions of VDAS®. Contact TecQuipment or your local agent if unsure.

Alternative Products:	Page
• Free Vibrations of a Mass-Spring System (TM164)	241
• Free Vibrations of a Cantilever (TM166)	244
• Free Vibrations of a Beam and Spring (TM167)	245