Core topics

15 hours

Essential idea: The basic laws of mechanics have an extension when equivalent principles are applied to rotation. Actual objects have dimensions and they require the expansion of the point particle model to consider the possibility of different points on an object having different states of motion and/or different velocities.

B.1 – Rigid bodies and rotational dynamics

Nature of science:

Modelling: The use of models has different purposes and has allowed scientists to identify, simplify and analyse a problem within a given context to tackle it successfully. The extension of the point particle model to actually consider the dimensions of an object led to many groundbreaking developments in engineering. (1.2)

Understandings:

- Torque
- Moment of inertia
- Rotational and translational equilibrium
- Angular acceleration
- Equations of rotational motion for uniform angular acceleration
- Newton's second law applied to angular motion
- Conservation of angular momentum

Applications and skills:

- Calculating torque for single forces and couples
- Solving problems involving moment of inertia, torque and angular acceleration
- Solving problems in which objects are in both rotational and translational equilibrium

Theory of knowledge:

- Models are always valid within a context and they are modified, expanded or replaced when that context is altered or considered differently. Are there examples of unchanging models in the natural sciences or in any other areas of knowledge?

Utilization:

- Structural design and civil engineering rely on the knowledge of how objects can move in all situations

Aims:

- **Aim 7:** technology has allowed for computer simulations that accurately model the complicated outcomes of actions on bodies

B.1 – Rigid bodies and rotational dynamics	
• Solving problems using rotational quantities analogous to linear quantities • Sketching and interpreting graphs of rotational motion • Solving problems involving rolling without slipping **Guidance:** • Analysis will be limited to basic geometric shapes • The equation for the moment of inertia of a specific shape will be provided when necessary • Graphs will be limited to angular displacement–time, angular velocity–time and torque–time **Data booklet reference:** • $\Gamma = Fr\sin\theta$ • $I = \Sigma mr^2$ • $\Gamma = I\alpha$ • $\omega = 2\pi f$ • $\omega_f = \omega_i + \alpha t$ • $\omega_f^2 = \omega_i^2 + 2\alpha\theta$ • $\theta = \omega_i t + \frac{1}{2}\alpha t^2$ • $L = I\omega$ • $E_{K_{rot}} = \frac{1}{2}I\omega^2$	

Essential idea: The first law of thermodynamics relates the change in internal energy of a system to the energy transferred and the work done. The entropy of the universe tends to a maximum.

<table>
<tr><th colspan="2">B.2 – Thermodynamics</th></tr>
<tr><td colspan="2">Nature of science:
Variety of perspectives: With three alternative and equivalent statements of the second law of thermodynamics, this area of physics demonstrates the collaboration and testing involved in confirming abstract notions such as this. (4.1)</td></tr>
<tr><td>Understandings:
• The first law of thermodynamics
• The second law of thermodynamics
• Entropy
• Cyclic processes and pV diagrams
• Isovolumetric, isobaric, isothermal and adiabatic processes
• Carnot cycle
• Thermal efficiency
Applications and skills:
• Describing the first law of thermodynamics as a statement of conservation of energy
• Explaining sign convention used when stating the first law of thermodynamics a $Q = \Delta U + W$
• Solving problems involving the first law of thermodynamics
• Describing the second law of thermodynamics in Clausius form, Kelvin form and as a consequence of entropy</td><td>International-mindedness:
• The development of this topic was the subject of intense debate between scientists of many countries in the 19th century
Utilization:
• This work leads directly to the concept of the heat engines that play such a large role in modern society
• The possibility of the heat death of the universe is based on ever-increasing entropy
• Chemistry of entropy (see Chemistry sub-topic 15.2)
Aims:
• Aim 5: development of the second law demonstrates the collaboration involved in scientific pursuits
• Aim 10: the relationships and similarities between scientific disciplines are particularly apparent here</td></tr>
</table>

B.2 – Thermodynamics

- Describing examples of processes in terms of entropy change
- Solving problems involving entropy changes
- Sketching and interpreting cyclic processes
- Solving problems for adiabatic processes for monatomic gases using $pV^{\frac{5}{3}} = \text{constant}$
- Solving problems involving thermal efficiency

Guidance:

- If cycles other than the Carnot cycle are used quantitatively, full details will be provided
- Only graphical analysis will be required for determination of work done on a *pV* diagram when pressure is not constant

Data booklet reference:

- $Q = \Delta U + W$
- $U = \frac{3}{2}nRT$
- $\Delta S = \frac{\Delta Q}{T}$
- $pV^{\frac{5}{3}} = \text{constant (for monatomic gases)}$
- $W = p\Delta V$
- $\eta = \frac{\text{useful work done}}{\text{energy input}}$
- $\eta_{\text{Carnot}} = 1 - \frac{T_{\text{cold}}}{T_{\text{hot}}}$

Additional higher level option topics

10 hours

Essential idea: Fluids cannot be modelled as point particles. Their distinguishable response to compression from solids creates a set of characteristics that require an in-depth study.

B.3 – Fluids and fluid dynamics

Nature of science:

Human understandings: Understanding and modelling fluid flow has been important in many technological developments such as designs of turbines, aerodynamics of cars and aircraft, and measurement of blood flow. (1.1)

Understandings:

- Density and pressure
- Buoyancy and Archimedes' principle
- Pascal's principle
- Hydrostatic equilibrium
- The ideal fluid
- Streamlines
- The continuity equation
- The Bernoulli equation and the Bernoulli effect
- Stokes' law and viscosity
- Laminar and turbulent flow and the Reynolds number

Applications and skills:

- Determining buoyancy forces using Archimedes' principle
- Solving problems involving pressure, density and Pascal's principle
- Solving problems using the Bernoulli equation and the continuity equation

International-mindedness:

- Water sources for dams and irrigation rely on the knowledge of fluid flow. These resources can cross national boundaries leading to sharing of water or disputes over ownership and use.

Theory of knowledge:

- The mythology behind the anecdote of Archimedes' "Eureka!" moment of discovery demonstrates one of the many ways scientific knowledge has been transmitted throughout the ages. What role can mythology and anecdotes play in passing on scientific knowledge? What role might they play in passing on scientific knowledge within indigenous knowledge systems?

Utilization:

- Hydroelectric power stations
- Aerodynamic design of aircraft and vehicles
- Fluid mechanics is essential in understanding blood flow in arteries
- Biomechanics (see *Sports, exercise and health science SL* sub-topic *4.3*)

B.3 – Fluids and fluid dynamics

- Explaining situations involving the Bernoulli effect
- Describing the frictional drag force exerted on small spherical objects in laminar fluid flow
- Solving problems involving Stokes' law
- Determining the Reynolds number in simple situations

Guidance:

- Ideal fluids will be taken to mean fluids that are incompressible and non-viscous and have steady flows
- Applications of the Bernoulli equation will involve (but not be limited to) flow out of a container, determining the speed of a plane (pitot tubes), and venturi tubes
- Proof of the Bernoulli equation will not be required for examination purposes
- Laminar and turbulent flow will only be considered in simple situations
- Values of $R < 10^3$ will be taken to represent conditions for laminar flow

Data booklet reference:

- $B = \rho_f V_f g$
- $P = P_0 + \rho_f gd$
- $Av = \text{constant}$
- $\frac{1}{2}\rho v^2 + \rho gz + p = \text{constant}$
- $F_D = 6\pi\eta rv$
- $R = \frac{vr\rho}{\eta}$

Aims:

- **Aim 2:** fluid dynamics is an essential part of any university physics or engineering course
- **Aim 7:** the complexity of fluid dynamics makes it an ideal topic to be visualized through computer software

Essential idea: In the real world, damping occurs in oscillators and has implications that need to be considered.

<table>
<tr><th colspan="2">B.4 – Forced vibrations and resonance</th></tr>
<tr><td colspan="2">Nature of science:

Risk assessment: The ideas of resonance and forced oscillation have application in many areas of engineering ranging from electrical oscillation to the safe design of civil structures. In large-scale civil structures, modelling all possible effects is essential before construction. (4.8)</td></tr>
<tr><td>Understandings:
Natural frequency of vibration
Q factor and damping
Periodic stimulus and the driving frequency
Resonance
Applications and skills:
Qualitatively and quantitatively describing examples of under-, over- and critically-damped oscillations</td><td>International-mindedness:
Communication through radio and television signals is based on resonance of the broadcast signals
Utilization:
Science and technology meet head-on when the real behaviour of damped oscillating systems is modelled</td></tr>
</table>

B.4 – Forced vibrations and resonance

- Graphically describing the variation of the amplitude of vibration with driving frequency of an object close to its natural frequency of vibration
- Describing the phase relationship between driving frequency and forced oscillations
- Solving problems involving *Q* factor
- Describing the useful and destructive effects of resonance

Guidance:

- Only amplitude resonance is required

Data booklet reference:

- $Q = 2\pi \dfrac{\text{energy stored}}{\text{energy dissipated per cycle}}$
- $Q = 2\pi \times \text{resonant frequency} \times \dfrac{\text{energy stored}}{\text{power loss}}$

Aims:

- **Aim 6:** experiments could include (but are not limited to): observation of sand on a vibrating surface of varying frequencies; investigation of the effect of increasing damping on an oscillating system, such as a tuning fork; observing the use of a driving frequency on forced oscillations
- **Aim 7:** to investigate the use of resonance in electrical circuits, atoms/molecules, or with radio/television communications is best achieved through software modelling examples