3.11 Engineering physics (A-level only)

This option offers opportunities for students to reinforce and extend the work of core units by considering applications in areas of engineering and technology. It extends the student's understanding in areas of rotational dynamics and thermodynamics. The emphasis in this option is on an understanding of the concepts and the application of physics. Questions can be set in novel or unfamiliar contexts, but in such cases the scene is set and any relevant required information is given.

3.11.1 Rotational dynamics (A-level only)

3.11.1.1 Concept of moment of inertia (A-level only)

Content

$I = mr^2$ for a point mass. $I = \Sigma mr^2$ for an extended object.

Qualitative knowledge of the factors that affect the moment of inertia of a rotating object.

Expressions for moment of inertia will be given where necessary.

3.11.1.2 Rotational kinetic energy (A-level only)

Content

$E_k = \frac{1}{2}I\omega^2$

Factors affecting the energy storage capacity of a flywheel.

Use of flywheels in machines.

Use of flywheels for smoothing torque and speed, and for storing energy in vehicles, and in machines used for production processes.

3.11.1.3 Rotational motion (A-level only)

Content

Angular displacement, angular speed, angular velocity, angular acceleration, $\omega = \frac{\Delta\theta}{\Delta t}$, $\alpha = \frac{\Delta\omega}{\Delta t}$

Representation by graphical methods of uniform and non-uniform angular acceleration.

Equations for uniform angular acceleration;

$\omega_2 = \omega_1 + \alpha t$, $\theta = \left(\frac{\omega_1 + \omega_2}{2}\right)t$

$\theta = \omega_1 t + \frac{\alpha t^2}{2}$, $\omega_2^2 = \omega_1^2 + 2\alpha\theta$

Students should be aware of the analogy between rotational and translational dynamics.

3.11.1.4 Torque and angular acceleration (A-level only)

Content

$T = Fr$

$T = I\alpha$

3.11.1.5 Angular momentum (A-level only)

Content

$angular\ momentum = I\omega$

Conservation of angular momentum.

Angular impulse = change in angular momentum; $T\Delta t = \Delta(I\omega)$ where T is constant.

Applications may include examples from sport.

3.11.1.6 Work and power (A-level only)

Content

$W = T\theta$; $P = T\omega$

Awareness that frictional torque has to be taken into account in rotating machinery.

3.11.2 Thermodynamics and engines (A-level only)

3.11.2.1 First law of thermodynamics (A-level only)

Content

Quantitative treatment of first law of thermodynamics, $Q = \Delta U + W$

where Q is energy transferred to the system by heating, ΔU is increase in internal energy and W is work done **by** the system.

Applications of first law of thermodynamics.

3.11.2.2 Non-flow processes (A-level only)

Content

Isothermal, adiabatic, constant pressure and constant volume changes.

$pV = nRT$

adiabatic change : $pV^{\gamma} = constant$

isothermal change : $pV = constant$

at constant pressure $W = p\Delta V$

Application of first law of thermodynamics to the above processes.

3.11.2.3 The *p–V* diagram (A-level only)

Content

Representation of processes on p–V diagram.

Estimation of work done in terms of area below the graph.

Extension to cyclic processes: *work done per cycle* = *area of loop*

Expressions for work done are not required except for the constant pressure case, $W = p\Delta V$

3.11.2.4 Engine cycles (A-level only)

Content

Understanding of a four-stroke petrol engine cycle and a diesel engine cycle, and of the corresponding indicator diagrams.

Comparison with the theoretical diagrams for these cycles; use of indicator diagrams for predicting and measuring power and efficiency

$input\ power = calorific\ value \times fuel\ flow\ rate$

Indicated power as $(area\ of\ p - V\ loop) \times (no.\ of\ cycles\ per\ second) \times (no.\ of\ cylinders)$

Output or brake power, $P = T\omega$

$friction\ power = indicated\ power - brake\ power$

Engine efficiency; overall, thermal and mechanical efficiencies.

$Overall\ efficiency = \frac{brake\ power}{input\ power}$

$Thermal\ efficiency = \frac{indicated\ power}{input\ power}$

$Mechanical\ efficiency = \frac{brake\ power}{indicated\ power}$

A knowledge of engine constructional details is not required.

Questions may be set on other cycles, but they will be interpretative and all essential information will be given.

3.11.2.5 Second Law and engines (A-level only)

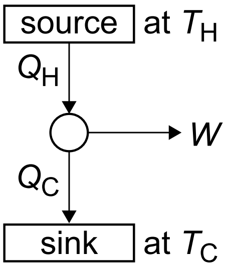
Content

Impossibility of an engine working only by the First Law.

Second Law of Thermodynamics expressed as the need for a heat engine to operate between a source and a sink.

efficiency = $\frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$

maximum theoretical efficiency = $\frac{T_H - T_C}{T_H}$



Reasons for the lower efficiencies of practical engines.

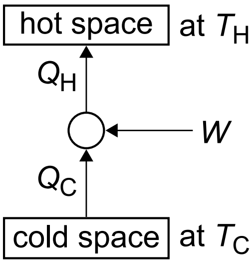
Maximising use of W and Q_H for example in combined heat and power schemes.

3.11.2.6 Reversed heat engines (A-level only)

Content

Basic principles and uses of heat pumps and refrigerators.

A knowledge of practical heat pumps or refrigerator cycles and devices is not required.



Coefficients of performance:

refrigerator: $COP_{\text{ref}} = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C} = \frac{T_C}{T_H - T_C}$

heat pump: $COP_{\text{hp}} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C} = \frac{T_H}{T_H - T_C}$