Physics, Grade 12

College Preparation SPH4C

This course develops students' understanding of the basic concepts of physics. Students will explore these concepts with respect to motion; mechanical, electrical, electromagnetic, energy transformation, hydraulic, and pneumatic systems; and the operation of commonly used tools and machines. They will develop their scientific investigation skills as they test laws of physics and solve both assigned problems and those emerging from their investigations. Students will also consider the impact of technological applications of physics on society and the environment.

Prerequisite: Science, Grade 10, Academic or Applied

Big Ideas

Motion and Its Applications

- All motion involves a change in the position of an object over time.
- Motion can be described using mathematical relationships.
- Many technologies that utilize the principles of motion have societal and environmental implications.

Mechanical Systems

- Mechanical systems use force to do work.
- The operation of mechanical systems can be described using mathematical relationships.
- Friction is a force that influences the design, use, and effectiveness of mechanical systems.
- Mechanical systems can be used to address social and environmental challenges.

Electricity and Magnetism

- Relationships between electricity and magnetism are predictable.
- Electricity and magnetism have many technological applications.
- Technological applications that use electricity and magnetism can affect society and the environment in positive and negative ways.

Energy Transformations

- Energy can be transformed from one type to another.
- Systems that involve energy transformations are never 100% efficient.
- Although technological applications that involve energy transformations can affect society and the environment in positive ways, they can also have negative effects, and therefore must be used responsibly.

Hydraulic and Pneumatic Systems

- Fluids under pressure can be used to do work.
- Fluids under pressure have predictable properties and many technological applications.
- The uses of hydraulic and pneumatic systems can have social and economic consequences.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Motion and Its Applications	Mechanical Systems	Electricity and Magnetism	Energy Transformations	Hydraulic and Pneumatic Systems
Matter			✓		✓
Energy	✓	✓	✓	✓	
Systems and Interactions	✓	✓	✓	✓	✓
Structure and Function	✓	✓	✓	✓	✓
Sustainability and Stewardship		✓		✓	✓
Change and Continuity			✓	✓	✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., electronic probes, pendulums, cylinders) and materials (e.g., motion carts, magnets, simple machines), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection (e.g., personal protective equipment when carrying out fluids experiments)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems using quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., free-body diagrams, algebraic equations)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., alternative energy advocate, sustainable energy technician, electrician, mechanic) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Elijah McCoy, Jaisel Vadgama, Gerald Vincent Bull, Elizabeth Cannon, Richard Marceau, Normand C. Beaulieu), to the fields under study

B. MOTION AND ITS APPLICATIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse selected technologies that are used to move objects or track their motion, and evaluate their impact on society and the environment, including their contribution to scientific knowledge;

B2. investigate, in qualitative and quantitative terms, the linear uniform and non-uniform motion of objects, and solve related problems;

B3. demonstrate an understanding of different kinds of motion and the relationships between speed, acceleration, displacement, and distance.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse the design and uses of a transportation technology (e.g., snowmobiles, automobiles, motorized personal water craft), and evaluate its social and environmental impact, including the impact on risk behaviour and accident rates [AI, C]

Sample issue: All-terrain vehicles (ATVs), designed to be driven off-road, are used in occupations requiring access to remote areas and for recreational purposes. However, ATVs can lack stability on uneven surfaces, which can result in serious accidents, particularly for inexperienced drivers. The vehicles can also cause damage when they are driven in environmentally sensitive areas.

Sample questions: What design aspects of the snowmobile make it particularly useful for travel over ice or snow? What impact does the altering of a vehicle's centre of gravity have on the functioning of the vehicle? Why is it important to take training courses before operating a motorized vehicle? Why are there special licences and training for different kinds of motor vehicles?

B1.2 analyse how technologies are used to track the motion of objects, and outline various kinds of scientific knowledge gained through the use of such technologies (e.g., data on animal populations and migrations, on changes in ocean currents related to global warming, on the behaviour of celestial objects) [AI, C]

Sample issue: In order to bill drivers for road use, a toll highway in southern Ontario uses motion cameras and transponders to track where vehicles enter and exit the highway. The information provided can also be used to analyse traffic flow and to determine when existing roads are unable to handle the volume of traffic.

Sample questions: How are motion-related technologies used to monitor wildlife populations? What type of information do these technologies provide, and how is it used? How are satellites used to track weather systems? What are the uses of the information gathered?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to motion, including, but not limited to: *distance, displacement, position, speed, acceleration, instantaneous, force,* and *net force* [C]

B2.2 plan and conduct investigations to measure distance and speed for objects moving in one dimension in uniform motion [IP, PR]

B2.3 plan and conduct investigations to measure constant acceleration for objects moving in one dimension [IP, PR]

B2.4 draw distance–time graphs, and use the graphs to calculate average speed and instantaneous speed of objects moving in one dimension [PR, AI, C]

B2.5 draw speed–time graphs, and use the graphs to calculate average acceleration and distance of objects moving in one dimension [PR, AI, C]

B2.6 solve simple problems involving one-dimensional average speed (v_{av}), distance (Δd), and elapsed time (Δt), using the algebraic equation $v_{av} = \Delta d / \Delta t$ [AI]

B2.7 solve simple problems involving one-dimensional average acceleration (a_{av}), change in speed (Δv), and elapsed time (Δt) using the algebraic equation $a_{av} = \Delta v / \Delta t$ [AI]

B2.8 plan and conduct an inquiry to determine the relationship between the net force acting on an object and its acceleration in one dimension [IP, PR, AI]

B2.9 analyse, in quantitative terms, the forces acting on an object, and use free-body diagrams to determine net force and acceleration of the object in one dimension [AI, C]

B2.10 conduct an inquiry to measure gravitational acceleration, and calculate the percentage error of the experimental value [PR, AI, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 distinguish between constant, instantaneous, and average speed, and give examples of each involving uniform and non-uniform motion

B3.2 describe the relationship between one-dimensional average speed (v_{av}), distance (Δd), and elapsed time (Δt)

B3.3 describe, in quantitative terms, the relationship between one-dimensional average acceleration (a_{av}), change in speed (Δv), and elapsed time (Δt)

B3.4 state Newton's laws, and apply them qualitatively and quantitatively to explain the motion of an object in one dimension

B3.5 explain the relationship between the acceleration of an object and the net unbalanced force acting on that object

C. MECHANICAL SYSTEMS

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse common mechanical systems that use friction and applied forces, and evaluate their effectiveness in meeting social or environmental challenges;

C2. investigate forces, torque, work, coefficients of friction, simple machines, and mechanical advantage, and interpret related data;

C3. demonstrate an understanding of concepts related to forces and mechanical advantage in relation to mechanical systems.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse advantages and disadvantages of friction within mechanical systems in real-world situations, as well as methods used to increase or reduce friction in these systems (e.g., advantages of, and methods for increasing, friction on the surface of car tires and the soles of hiking boots; disadvantages of, and methods for reducing, friction between moving parts of artificial joints) [AI, C]

Sample issue: Hip replacement has become an increasingly common surgical procedure. Artificial hips consist of separate pieces, made of low-friction materials, that are designed to mimic the movement of the ball and socket hip joint. As the artificial joint ages, however, wear debris can cause increasing friction and restrict movement in the joint.

Sample questions: What changes to the design of the bobsled have resulted in faster speeds in competition and improved steering and manoeuvrability? How and why does an under- or over-inflated tire affect the performance of a motor vehicle? Why do the soles of athletic shoes differ depending on the purpose of the shoe? Why do race car tires have no treads?

C1.2 evaluate, on the basis of research, the effectiveness of a common mechanical system in addressing a social or environmental challenge (e.g., prosthetic devices, bathtub lifts, high-efficiency heating and cooling systems) [IP, PR, AI, C]

Sample issue: In the nineteenth century, lift locks were built in Ontario to give boats access to unnavigable sections of waterways such as the Great Lakes and the Trent-Severn waterway. Although the locks were mechanically simple, they were also highly effective, and some continue to be used to the present day.

Sample questions: Why were crumple zones and airbags added to cars? How have integrated mechanical systems such as programmable thermostats improved energy efficiency in homes?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to mechanical systems, including, but not limited to: *coefficients of friction, torque, mechanical advantage, work input*, and *work output* [C]

C2.2 analyse, in qualitative and quantitative terms, the forces (e.g., gravitational, frictional, and normal forces; tension) acting on an object in one dimension, and describe the resulting motion of the object [AI, C]

C2.3 use an inquiry process to determine the factors affecting static and kinetic friction, and to determine the corresponding coefficient of friction between an everyday object and the surface with which it is in contact [PR, AI]

C2.4 use an inquiry process to determine the relationships between force, distance, and torque for the load arm and effort arm of levers [IP, PR, AI]

C2.5 solve problems involving torque, force, load-arm length, and effort-arm length as they relate to the three classes of levers [AI]

C2.6 investigate, in quantitative terms, common machines (e.g., a bicycle, a can opener, a piano) with respect to input and output forces and mechanical advantage [PR]

C2.7 construct a simple or compound machine, and determine its mechanical advantage (e.g., a pulley, a mobile, a can crusher, a trebuchet) [PR, AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 identify and describe, in quantitative and qualitative terms, applications of various types of simple machines (e.g., wedges, screws, levers, pulleys, gears, wheels and axles)

C3.2 explain the operation and mechanical advantage of compound machines and biomechanical systems (e.g., block-and-tackle, winch, chain-and-sprocket systems; the human leg, arm)

C3.3 explain, with reference to force and displacement, the conditions necessary for work to be done

C3.4 explain the concept of mechanical advantage

D. ELECTRICITY AND MAGNETISM

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse the development of selected electrical and electromagnetic technologies, and evaluate their impact on society and the environment;

D2. investigate real and simulated mixed direct current circuits and the nature of magnetism and electromagnetism, and analyse related data;

D3. demonstrate an understanding of the basic principles of electricity and magnetism.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 evaluate, on the basis of research, the impact on society and the environment of the evolution of an electrical technology (e.g., electric cars or buses, electric appliances) [IP, PR, AI, C]

Sample issue: Prior to the development of the electric light bulb, people used candles, gaslight, and oil lamps. After the tungsten filament was developed, incandescent light bulbs changed the way society used light, and resulted in increased demands for electrical power. Today, inefficient incandescent bulbs are increasingly being replaced by compact fluorescent bulbs.

Sample questions: What impact has the development and evolution of refrigeration technologies had on society and the environment? Are trains powered by electricity an improvement over trains powered by steam or diesel engines? Why or why not? What impact does the use of electric buses, streetcars, and subway trains by the Toronto Transit Commission have on local residents and the environment?

D1.2 assess the impact of an electromagnetic technology that is used for the benefit of society or the environment (e.g., devices for diagnosing and treating diseases, technologies for treating seeds to increase the rate of germination) [AI, C]

Sample issue: Globally, landmines cause thousands of deaths and injuries each year. Although many countries, including Canada, have signed an agreement banning the use of landmines, old mines continue to be a hazard. Specially trained personnel use electromagnetic technologies to detect and clear mines.

Sample questions: What impact has electromagnetic technology had on the usefulness and security of credit cards? What are some of the uses of electromagnetic technologies in health care? What are the benefits of using electromagnetic sensors to detect metal concentrations in brown-field developments? What are the advantages of maglev trains over conventional transportation technologies?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to electricity and magnetism, including, but not limited to: *direct current*, *alternating current*, *electrical potential difference*, *resistance*, *power*, *energy*, *permanent magnet*, *electromagnet*, *magnetic field*, *motor principle*, and *electric motor* [C]

D2.2 construct real and simulated mixed direct current (DC) circuits (i.e., parallel, series, and mixed circuits), and analyse them in quantitative terms to test Kirchhoff's laws [PR, AI]

D2.3 analyse, in quantitative terms, real or simulated DC circuits and circuit diagrams, using Ohm's law and Kirchhoff's laws [AI]

D2.4 conduct an inquiry to determine the magnetic fields produced by a permanent magnet, a straight current-carrying conductor, and a solenoid, and illustrate their findings [PR, AI, C]

D2.5 conduct an inquiry to determine the direction of the magnetic field of a straight current-carrying conductor or solenoid [PR, AI]

D2.6 conduct an inquiry to determine the direction of the forces on a straight current-carrying conductor that is placed in a uniform magnetic field [PR, AI]

D2.7 construct, or deconstruct and explain the components of, a basic electric device (e.g., a DC motor, a water-level detector) [PR, C]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 compare and contrast the behaviour and functions of series, parallel, and mixed DC circuits

D3.2 state Kirchhoff's laws and Ohm's law, and use them to explain, in quantitative terms, direct current, potential difference, and resistance in mixed circuit diagrams

D3.3 identify and explain safety precautions related to electrical circuits in the school, home, and workplace (e.g., the importance of turning off the current before performing electrical repairs; the reasons for grounding circuits; how to safely replace spent fuses; the use of double insulated tools and appliance circuit breakers)

D3.4 describe, with the aid of an illustration, the magnetic field produced by permanent magnets (bar and U-shaped) and electromagnets (straight conductor and solenoid)

D3.5 explain the law of magnetic poles

D3.6 distinguish between conventional current and electron flow

D3.7 state Oersted's principle, and apply the right-hand rule to explain the direction of the magnetic field produced when electric current flows through a long, straight conductor and through a solenoid

D3.8 state the motor principle, and use the right-hand rule to explain the direction of the force experienced by a conductor

D3.9 explain, using diagrams, the components and operation of a DC electric motor

D3.10 compare and contrast direct current and alternating current (AC) in qualitative terms (e.g., the difference between DC and AC motors), and describe situations in which each is used

E. ENERGY TRANSFORMATIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. evaluate the impact on society and the environment of energy-transformation technologies, and propose ways to improve the sustainability of one such technology;

E2. investigate energy transformations and the law of conservation of energy, and solve related problems;

E3. demonstrate an understanding of diverse forms of energy, energy transformations, and efficiency.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse an energy-transformation technology (e.g., wind turbines, refrigerators, telephones, steam engines, coal-fired electrical plants), and evaluate its impact on society and the environment [AI, C]

Sample issue: Fax machines allow documents to be transmitted quickly and securely. Most fax machines use ink cartridges, which can end up in landfill sites. By contrast, thermal fax machines use heat resistors to convert electricity into usable heat. They then apply this heat through a print head onto chemically treated paper to print a document.

Sample questions: What types of energy transformations take place in an air conditioner? What impact does the widespread use of air conditioners have on society and the environment? What types of energy transformations occur in incandescent and fluorescent light bulbs? What impact does the difference in energy transformations in these two types of bulbs have on the environment?

E1.2 propose a course of practical action to improve the sustainability of an energy-transformation technology (e.g., solar panels, internal combustion engines, fuel cells, air conditioners) [PR, AI, C]

Sample issue: Although wind is a renewable source of energy, many windmills are needed to generate a useful amount of energy, and large wind farms can have a negative impact on wildlife and local residents. Researchers are experimenting with modifications to the blades to increase the efficiency of each windmill.

Sample questions: Why are ice-cooling systems more energy efficient than traditional air conditioners? How could solar panels be modified to enable them to capture solar energy on a cloudy day? How could a speaker system be improved to maximize its energy use? What modifications could be made to an internal combustion engine so that it used less gasoline?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to energy and energy transformations, including, but not limited to: *work, gravitational potential energy, kinetic energy, chemical energy, energy transformations,* and *efficiency* [C]

E2.2 use the law of conservation of energy to solve problems involving gravitational potential energy, kinetic energy, and thermal energy [AI]

E2.3 construct a simple device that makes use of energy transformations (e.g., a pendulum, a roller coaster), and use it to investigate transformations between gravitational potential energy and kinetic energy [PR]

E2.4 design and construct a complex device that integrates energy transformations (e.g., a mousetrap vehicle, an “egg-drop” container, a wind turbine), and analyse its operation in qualitative and quantitative terms [IP, PR, AI]

E2.5 investigate a simple energy transformation (e.g., the use of an elastic band to propel a miniature car), explain the power and output, and calculate the energy [PR, AI, C]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe and compare various types of energy and energy transformations (e.g., transformations related to kinetic, sound, electric, chemical, potential, mechanical, nuclear, and thermal energy)

E3.2 explain the energy transformations in a system (e.g., a toy, an amusement park ride, a skydiver suspended from a parachute), using principles related to kinetic energy, gravitational potential energy, conservation of energy, and efficiency

E3.3 describe, with the aid of diagrams, the operation of selected energy-transformation technologies (e.g., wind turbines, photoelectric cells, heat engines)

E3.4 compare the efficiency of various systems that produce electricity (e.g., wind farms, hydroelectric generators, solar panels), using the law of conservation of energy, and outlining the transformations, transmissions, and energy losses involved

E3.5 describe a variety of renewable and non-renewable sources of energy (e.g., solar energy, fossil fuels, hydroelectric energy, energy generated from biomass), and identify the strengths and weaknesses of each

F. HYDRAULIC AND PNEUMATIC SYSTEMS

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse the development of technological applications related to hydraulic and pneumatic systems, and assess some of the social and environmental effects of these systems;

F2. investigate fluid statics, fluid dynamics, and simple hydraulic and pneumatic systems;

F3. demonstrate an understanding of the scientific principles related to fluid statics, fluid dynamics, and hydraulic and pneumatic systems.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 research the historical development of a pneumatic or hydraulic system used in a specific technology (e.g., the hydraulic system in aircraft or other vehicles or in precision machining; the pneumatic system in an air motor or robotics), analyse the original design, and determine why the technology was developed and how it has been improved [IP, PR, AI, C]

Sample questions: How have hydraulic systems in aircraft improved over the past 50 years? In what ways have pneumatic systems been used to improve the ergonomics of workplace equipment? In what ways have the uses of hydraulic systems for irrigation purposes evolved over time?

F1.2 analyse some of the social and economic consequences of the use of robotic systems for different kinds of operations (e.g., in the manufacturing of computers, for lifting and manoeuvring heavy objects on assembly lines, for handling hazardous materials, for activities under water and in space) [AI, C]

Sample issue: The use of robotic systems on assembly lines in automotive plants speeds up production, cuts labour costs, reduces the need for workers to perform small repetitive tasks, and reduces workplace injuries. But the use of such systems has eliminated some jobs.

Sample questions: What impact could remote surgery using robotics have on the health of people living in remote areas? What types of jobs are made safer through the use of robotics? How can simulations using robotics reduce the social and economic costs associated with natural disasters?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to hydraulic and pneumatic systems, including, but not limited to: *density, atmospheric pressure, absolute pressure, laminar flow, turbulent flow, static pressure, pressure, volume,* and *flow rate* [C]

F2.2 draw simple hydraulic or pneumatic circuits [C]

F2.3 use an inquiry process to determine factors that affect the static pressure head in fluids, compare theoretical and empirical values, and account for discrepancies [IP, PR, AI]

F2.4 conduct a laboratory inquiry or computer simulation to demonstrate Pascal's principle [PR]

F2.5 use an inquiry process to determine the relationships between force, area, pressure, volume, and time in a hydraulic or pneumatic system (e.g., a hydraulic bottle rocket, a two-cylinder circuit using small plastic syringes filled with air or water) [IP, PR, AI]

F2.6 solve problems related to the relationships between force, area, pressure, volume, and time in hydraulic and pneumatic systems (e.g., the force exerted on the wheel of a motor vehicle by the hydraulically operated brake pad; the time required for a robotic system to complete one cycle of operation) [AI]

F2.7 design and construct a hydraulic or pneumatic system (e.g., a braking system for a car, a clamping device, a model of a crane), solving problems as they arise, and evaluate the system with respect to mechanical advantage and efficiency [IP, PR, AI]

F2.8 conduct an inquiry to demonstrate Bernoulli's principle (e.g., using a wind tunnel or Venturi tube, suspending a table tennis ball in an air current, blowing between pieces of paper) [PR]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 identify factors affecting static pressure head (e.g., variations in Earth's atmosphere), analyse static pressure head in quantitative terms, and explain its effects in liquids and gases

F3.2 state Pascal's principle, and explain its applications in the transmission of forces in fluid systems

F3.3 describe common components used in hydraulic and pneumatic systems (e.g., cylinders, valves, motors, fluids, hoses, connectors, pumps, reservoirs), and explain their function

F3.4 describe factors affecting laminar flow, and explain how the design of an item or organism (e.g., cars, boats, planes, turbine blades, propellers, golf balls, swimsuits, sharks) responds to these factors

F3.5 state Bernoulli's principle, and explain some of its applications (e.g., spray atomizers, propellers, spoilers on racing cars, turbine blades in jet engines)