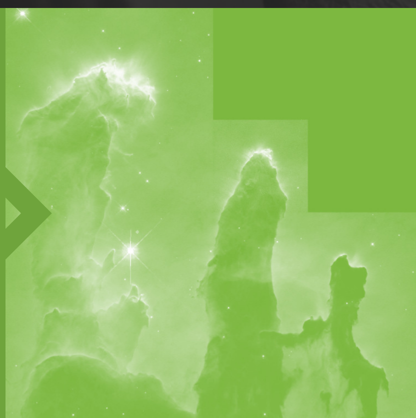
YEAR 12 PHYSICS NOTES

Modules 5 - 8

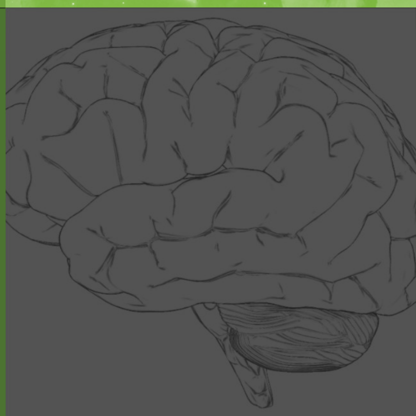
"In all things of nature, there is something of the marvellous."

Aristotle



THE ABSENCE OF EVIDENCE IS NOT THE EVIDENCE OF ABSENCE.

Carl Sagan



5-8

SCIENCE IS ONLY A LATIN WORD FOR KNOWLEDGE.

Module 5: Advanced Mechanics

Outcomes

A student:

- › selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4
- › analyses and evaluates primary and secondary data and information PH11/12-5
- › solves scientific problems using primary and secondary data, critical thinking skills and scientific processes PH11/12-6
- › communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7
- › describes and analyses qualitatively and quantitatively circular motion and motion in a gravitational field, in particular, the projectile motion of particles PH12-12

Content Focus

Motion in one dimension at constant velocity or constant acceleration can be explained and analysed relatively simply. However, motion is frequently more complicated because objects move in two or three dimensions, causing the net force to vary in size or direction.

Students develop an understanding that all forms of complex motion can be understood by analysing the forces acting on a system, including the energy transformations taking place within and around the system. By applying new mathematical techniques, students model and predict the motion of objects within systems. They examine two-dimensional motion, including projectile motion and uniform circular motion, along with the orbital motion of planets and satellites, which are modelled as an approximation to uniform circular motion.

Working Scientifically

In this module, students focus on gathering, analysing and evaluating data to solve problems and communicate ideas about advanced mechanics. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Projectile Motion

Inquiry question: How can models that are used to explain projectile motion be used to analyse and make predictions?

Students:

- analyse the motion of projectiles by resolving the motion into horizontal and vertical components, making the following assumptions:
  - a constant vertical acceleration due to gravity
  - zero air resistance

Students:

- apply the modelling of projectile motion to quantitatively derive the relationships between the following variables:
  - initial velocity
  - launch angle
  - maximum height
  - time of flight
  - final velocity
  - launch height
  - horizontal range of the projectile (ACSPH099)

Students:

- conduct a practical investigation to collect primary data in order to validate the relationships derived above.

Students:

- solve problems, create models and make quantitative predictions by applying the equations of motion relationships for uniformly accelerated and constant rectilinear motion

Circular Motion

Inquiry question: Why do objects move in circles?

Students:

- conduct investigations to explain and evaluate, for objects executing uniform circular motion, the relationships that exist between:
  - centripetal force
  - mass
  - speed
  - radius

Students:

- analyse the forces acting on an object executing uniform circular motion in a variety of situations, for example:
  - cars moving around horizontal circular bends
  - a mass on a string
  - objects on banked tracks (ACSPH100)

Students:

- solve problems, model and make quantitative predictions about objects executing uniform circular motion in a variety of situations, using the following relationships:
  - $\vec{a} = \frac{|\vec{v}|^2}{\vec{r}}$
  - $\Sigma\vec{F} = \frac{m|\vec{v}|^2}{\vec{r}}$
  - $\omega = \frac{\Delta\theta}{t}$

Students:

- investigate the relationship between the total energy and work done on an object executing uniform circular motion

Students:

- investigate the relationship between the rotation of mechanical systems and the applied torque $(\tau = \vec{r}\vec{F}_{\perp} = |\vec{r}||\vec{F}|sin\theta)$

Motion in Gravitational Fields

Inquiry question: How does the force of gravity determine the motion of planets and satellites?

Students:

- apply qualitatively and quantitatively Newton's Law of Universal Gravitation to:
  - determine the force of gravity between two objects $(\vec{F} = -\frac{GMm}{\vec{r}^2})$
  - investigate the factors that affect the gravitational field strength $(\vec{g} = \frac{GM}{\vec{r}^2})$
  - predict the gravitational field strength at any point in a gravitational field, including at the surface of a planet (ACSPH094, ACSPH095, ACSPH097)

Students:

- investigate the orbital motion of planets and artificial satellites when applying the relationships between the following quantities:
  - gravitational force
  - centripetal force
  - centripetal acceleration
  - mass
  - orbital radius
  - orbital velocity
  - orbital period

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Students:

- predict quantitatively the orbital properties of planets and satellites in a variety of situations, including near the Earth and geostationary orbits, and relate these to their uses (ACSPH101)

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Students:

- investigate the relationship of Kepler's Laws of Planetary Motion to the forces acting on, and the total energy of, planets in circular and non-circular orbits using: (ACSPH101)
  - $v_o = \frac{2\pi r}{T}$
  - $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$

Students:

- derive quantitatively and apply the concepts of gravitational force and gravitational potential energy in radial gravitational fields to a variety of situations, including but not limited to:
  - the concept of escape velocity ($v_{esc} = \sqrt{\frac{2GM}{r}}$)
  - total potential energy of a planet or satellite in its orbit ($U = -\frac{GMm}{r}$)
  - total energy of a planet or satellite in its orbit ($E = -\frac{GMm}{2r}$)
  - energy changes that occur when satellites move between orbits (ACSPH096)
  - Kepler's Laws of Planetary Motion (ACSPH101)

Module 6: Electromagnetism

Outcomes

A student:

- develops and evaluates questions and hypotheses for scientific investigation PH11/12-1
- designs and evaluates investigations in order to obtain primary and secondary data and information PH11/12-2
- conducts investigations to collect valid and reliable primary and secondary data and information PH11/12-3
- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4
- analyses and evaluates primary and secondary data and information PH11/12-5
- explains and analyses the electric and magnetic interactions due to charged particles and currents and evaluates their effect both qualitatively and quantitatively PH12-13

Content Focus

Discoveries about the interactions that take place between charged particles and electric and magnetic fields not only produced significant advances in physics, but also led to significant technological developments. These developments include the generation and distribution of electricity, and the invention of numerous devices that convert electrical energy into other forms of energy.

Understanding the similarities and differences in the interactions of single charges in electric and magnetic fields provides students with a conceptual foundation for this module. Phenomena that include the force produced on a current-carrying wire in a magnetic field, the force between current-carrying wires, Faraday's Law of Electromagnetic Induction, the principles of transformers and the workings of motors and generators can all be understood as instances of forces acting on moving charged particles in magnetic fields.

The law of conservation of energy underpins all of these interactions. The conversion of energy into forms other than the intended form is a problem that constantly drives engineers to improve designs of electromagnetic devices.

Working Scientifically

In this module, students focus on: developing and evaluating questions and hypotheses when designing and conducting investigations; and obtaining data and information to solve problems about electromagnetism. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Charged Particles, Conductors and Electric and Magnetic Fields

Inquiry question: What happens to stationary and moving charged particles when they interact with an electric or magnetic field?

Students:

- investigate and quantitatively derive and analyse the interaction between charged particles and uniform electric fields, including: (ACSPH083)
  - electric field between parallel charged plates ($|E| = -\frac{V}{d}$)
  - acceleration of charged particles by the electric field ($F = ma, F = qE$)
  - work done on the charge ($W = qV, W = qEd, K = \frac{1}{2}mv^2$)

Students:

- model qualitatively and quantitatively the trajectories of charged particles in electric fields and compare them with the trajectories of projectiles in a gravitational field

Students:

- analyse the interaction between charged particles and uniform magnetic fields, including: (ACSPH083)
  - acceleration, perpendicular to the field, of charged particles
  - the force on the charge ($F = qvB sin\theta$)

Students:

- compare the interaction of charged particles moving in magnetic fields to:
  - the interaction of charged particles with electric fields
  - other examples of uniform circular motion (ACSPH108)

The Motor Effect

Inquiry question: Under what circumstances is a force produced on a current-carrying conductor in a magnetic field?

Students:

- investigate qualitatively and quantitatively the interaction between a current-carrying conductor and a uniform magnetic field ($F = BIlsin\theta$) to establish: (ACSPH080, ACSPH081)
  - conditions under which the maximum force is produced
  - the relationship between the directions of the force, magnetic field strength and current
  - conditions under which no force is produced on the conductor

Students:

- conduct a quantitative investigation to demonstrate the interaction between two parallel current-carrying wires

Students:

- analyse the interaction between two parallel current-carrying wires $\left(\frac{F}{l} = \frac{\mu_0}{2\pi} \times \frac{I_1 I_2}{r}\right)$ and determine the relationship between the International System of Units (SI) definition of an ampere and Newton's Third Law of Motion (ACSPH081, ACSPH106)

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Electromagnetic Induction

Inquiry question: How are electric and magnetic fields related?

Students:

- describe how magnetic flux can change, with reference to the relationship $\Phi = BA$ (ACSPH083, ACSPH107, ACSPH109)

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Students:

- analyse qualitatively and quantitatively, with reference to energy transfers and transformations, examples of Faraday's Law and Lenz's Law $\left(\varepsilon = -\frac{\Delta\Phi}{\Delta t}\right)$, including but not limited to: (ACSPH081, ACSPH110)
  - the generation of an electromotive force (emf) and evidence for Lenz's Law produced by the relative movement between a magnet, straight conductors, metal plates and solenoids
  - the generation of an emf produced by the relative movement or changes in current in one solenoid in the vicinity of another solenoid

Students:

- analyse quantitatively the operation of ideal transformers through the application of: (ACSPH110)
  - $\frac{V_P}{V_S} = \frac{N_P}{N_S}$
  - $V_p I_p = V_s I_s$

Students:

- evaluate qualitatively the limitations of the ideal transformer model and the strategies used to improve transformer efficiency, including but not limited to:
  - incomplete flux linkage
  - resistive heat production and eddy currents

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Students:

- analyse applications of step-up and step-down transformers, including but not limited to:
  - the distribution of energy using high-voltage transmission lines

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Applications of the Motor Effect

Inquiry question: How has knowledge about the Motor Effect been applied to technological advances?

Students:

- investigate the operation of a simple DC motor to analyse:
  - the functions of its components
  - production of a torque ($\tau = nBAcos\theta$)
  - effects of back emf (ACSPH108)

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Students:

- analyse the operation of simple DC and AC generators and AC induction motors (ACSPH110)

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Students:

- relate Lenz's Law to the law of conservation of energy and apply the law of conservation of energy to:
  - DC motors and
  - magnetic braking

Module 7: The Nature of Light

Outcomes

A student:
- develops and evaluates questions and hypotheses for scientific investigation PH11/12-1
- designs and evaluates investigations in order to obtain primary and secondary data and information PH11/12-2
- conducts investigations to collect valid and reliable primary and secondary data and information PH11/12-3
- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7
- describes and analyses evidence for the properties of light and evaluates the implications of this evidence for modern theories of physics in the contemporary world PH12-14

Content Focus

Prior to the 20th century, physicists, including Newton and Maxwell, developed theories and models about mechanics, electricity and magnetism and the nature of matter. These theories and models had great explanatory power and produced useful predictions. However, the 20th century saw major developments in physics as existing theories and models were challenged by new observations that could not be explained. These observations led to the development of quantum theory and the theory of relativity. Technologies arising from these theories have shaped the modern world. For example, the independence of the speed of light on the frame of observation or the motion of the source and observer had significant consequences for the measurement, and concepts about the nature, of time and space.

Throughout this module, students explore the evidence supporting these physical theories, along with the power of scientific theories to make useful predictions.

Working Scientifically

In this module, students focus on: developing and evaluating questions and hypotheses when designing and conducting investigations; evaluating the data obtained from investigations; and communicating ideas about the nature of light. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Electromagnetic Spectrum

Inquiry question: What is light?

Students:

- investigate Maxwell's contribution to the classical theory of electromagnetism, including:
  - unification of electricity and magnetism
  - prediction of electromagnetic waves
  - prediction of velocity (ACSPH113)

Students:

- describe the production and propagation of electromagnetic waves and relate these processes qualitatively to the predictions made by Maxwell's electromagnetic theory (ACSPH112, ACSPH113)

Students:

- conduct investigations of historical and contemporary methods used to determine the speed of light and its current relationship to the measurement of time and distance (ACSPH082)

Students:

- conduct an investigation to examine a variety of spectra produced by discharge tubes, reflected sunlight or incandescent filaments

Students:

- investigate how spectroscopy can be used to provide information about:
  - the identification of elements

Students:

- investigate how the spectra of stars can provide information on:
  - surface temperature
  - rotational and translational velocity
  - density
  - chemical composition

Light: Wave Model

Inquiry question: What evidence supports the classical wave model of light and what predictions can be made using this model?

Students:

- conduct investigations to analyse qualitatively the diffraction of light (ACSPH048, ACSPH076)

Students:

- conduct investigations to analyse quantitatively the interference of light using double slit apparatus and diffraction gratings ($d sin\theta = m\lambda$) (ACSPH116, ACSPH117, ACSPH140)

Students:

- analyse the experimental evidence that supported the models of light that were proposed by Newton and Huygens (ACSPH050, ACSPH118, ACSPH123)

Students:

- conduct investigations quantitatively using the relationship of Malus's Law ($I = I_{max} cos^2\theta$) for plane polarisation of light, to evaluate the significance of polarisation in developing a model for light (ACSPH050, ACSPH076, ACSPH120)

Light: Quantum Model

Inquiry question: What evidence supports the particle model of light and what are the implications of this evidence for the development of the quantum model of light?

Students:

- analyse the experimental evidence gathered about black body radiation, including Wein's Law $\left(\lambda_{max} = \frac{b}{T}\right)$ related to Planck's contribution to a changed model of light (ACSPH137)

Students:

- investigate the evidence from photoelectric effect investigations that demonstrated inconsistency with the wave model for light (ACSPH087, ACSPH123, ACSPH137)

Students:

- analyse the photoelectric effect ($E_k = hf - \Phi$) as it occurs in metallic elements by applying the law of conservation of energy and the (ACSPH119)

Light and special relativity

Inquiry question: How does the behaviour of light affect concepts of time, space and matter?

Students:

- analyse and evaluate the evidence confirming or denying Einstein's two postulates:
  - the speed of light in a vacuum is an absolute constant
  - all inertial frames of reference are equivalent (ACSPH131)

Students:

- investigate the evidence, from Einstein's thought experiments and subsequent experimental validation, for time dilation $\left(t = \frac{t_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}\right)$ and length contraction $\left(l = l_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}\right)$, and analyse quantitatively situations in which these are observed, for example:
  - observations of cosmic-origin muons at the Earth's surface
  - atomic clocks (Hafele–Keating experiment)
  - evidence from particle accelerators
  - evidence from cosmological studies

Students:

- describe the consequences and applications of relativistic momentum with reference to:
  - $p_v = \frac{mv}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$
  - the limitation on the maximum velocity of a particle imposed by special relativity (ACSPH133)

Students:

- Use Einstein's mass–energy equivalence relationship ($E = mc^2$) to calculate the energy released by processes in which mass is converted to energy, for example: (ACSPH134)
  - production of energy by the sun
  - particle–antiparticle interactions, eg positron–electron annihilation
  - combustion of conventional fuel

Module 8: From the Universe to the Atom

Outcomes

A student:

- analyses and evaluates primary and secondary data and information PH11/12-5
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes PH11/12-6
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7
- explains and analyses the evidence supporting the relationship between astronomical events and the nucleosynthesis of atoms and relates these to the development of the current model of the atom PH12-15

Content Focus

Humans have always been fascinated with the finite or infinite state of the Universe and whether there ever was a beginning to time. Where does all the matter that makes up the Universe come from? Ideas and theories about the beginnings of the Universe, based on sound scientific evidence, have come and gone. Current theories such as, the Big Bang theory and claims of an expanding Universe are based on scientific evidence available today through investigations that use modern technologies. Evidence gathered on the nucleosynthesis reactions in stars allows scientists to understand how elements are made in the nuclear furnace of stars. On scales as large as the Universe to those as small as an atom, humans look to the sky for answers through astronomical observations of stars and galaxies.

Beginning in the late 19th and early 20th centuries, experimental discoveries revolutionised the accepted understanding of the nature of matter on an atomic scale. Observations of the properties of matter and light inspired the development of better models of matter, which in turn have been modified or abandoned in the light of further experimental investigations.

By studying the development of the atomic models through the work of Thomson and Rutherford, who established the nuclear model of the atom – a positive nucleus surrounded by electrons – students further their understanding of the limitations of theories and models. The work of Bohr, de Broglie and, later, Schrödinger demonstrated that the quantum mechanical nature of matter was a better way to understand the structure of the atom. Experimental investigations of the nucleus have led to an understanding of radioactive decay, the ability to extract energy from nuclear fission and fusion, and a deeper understanding of the atomic model.

Particle accelerators have revealed that protons themselves are not fundamental, and have continued to provide evidence in support of the Standard Model of matter. In studying this module, students can appreciate that the fundamental particle model is forever being updated and that our understanding of the nature of matter remains incomplete.

Working Scientifically

In this module, students focus on analysing and evaluating data to solve problems and communicate scientific understanding about the development of the atomic model and the origins of the Universe. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Origins of the Elements

Inquiry question: What evidence is there for the origins of the elements?

Students:

- investigate the processes that led to the transformation of radiation into matter that followed the 'Big Bang'

Students:

- investigate the evidence that led to the discovery of the expansion of the Universe by Hubble (ACSPH138)

Students:

- analyse and apply Einstein's description of the equivalence of energy and mass and relate this to the nuclear reactions that occur in stars (ACSPH031)

Students:

- account for the production of emission and absorption spectra and compare these with a continuous black body spectrum (ACSPH137)

Students:

- investigate the key features of stellar spectra and describe how these are used to classify stars

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Students:

- investigate the Hertzsprung–Russell diagram and how it can be used to determine the following about a star:
  - characteristics and evolutionary stage
  - surface temperature
  - colour
  - luminosity

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Students:

- investigate the types of nucleosynthesis reactions involved in Main Sequence and Post-Main Sequence stars, including but not limited to:
  - proton–proton chain
  - CNO (carbon-nitrogen-oxygen) cycle

Structure of the Atom

Inquiry question: How is it known that atoms are made up of protons, neutrons and electrons?

Students:

- investigate, assess and model the experimental evidence supporting the existence and properties of the electron, including:
  - early experiments examining the nature of cathode rays
  - Thomson's charge-to-mass experiment
  - Millikan's oil drop experiment (ACSPH026)

Students:

- investigate, assess and model the experimental evidence supporting the nuclear model of the atom, including:
  - the Geiger–Marsden experiment
  - Rutherford's atomic model
  - Chadwick's discovery of the neutron (ACSPH026)

Quantum Mechanical Nature of the Atom

Inquiry question: How is it known that classical physics cannot explain the properties of the atom?

Students:

- assess the limitations of the Rutherford and Bohr atomic models

Students:

- investigate the line emission spectra to examine the Balmer series in hydrogen (ACSPH138)

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Students:

- relate qualitatively and quantitatively the quantised energy levels of the hydrogen atom and the law of conservation of energy to the line emission spectrum of hydrogen using:
  - $E = hf$
  - $E = \frac{hc}{\lambda}$
  - $\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$ (ACSPH136)

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Students:

- investigate de Broglie's matter waves, and the experimental evidence that developed the following formula:
  - $\lambda = \frac{h}{mv}$ (ACSPH140)

Students:

- analyse the contribution of Schrödinger to the current model of the atom

Properties of the Nucleus

Inquiry question: How can the energy of the atomic nucleus be harnessed?

Students:

- analyse the spontaneous decay of unstable nuclei, and the properties of the alpha, beta and gamma radiation emitted (ACSPH028, ACSPH030)

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Students:

- examine the model of half-life in radioactive decay and make quantitative predictions about the activity or amount of a radioactive sample using the following relationships:
  - $N_t = N_o e^{-\lambda t}$
  - $\lambda = \frac{ln\,(2)}{t_{1/2}}$

  where N_t = number of particles at time t, N_0 = number of particles present at $t = 0$, $\lambda =$ decay constant, $t_{1/2}$ = time for half the radioactive amount to decay (ACSPH029)

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Students:

- model and explain the process of nuclear fission, including the concepts of controlled and uncontrolled chain reactions, and account for the release of energy in the process (ACSPH033, ACSPH034)

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Students:

- analyse relationships that represent conservation of mass-energy in spontaneous and artificial nuclear transmutations, including alpha decay, beta decay, nuclear fission and nuclear fusion (ACSPH032)

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Students:

- account for the release of energy in the process of nuclear fusion (ACSPH035, ACSPH036)

Students:

- predict quantitatively the energy released in nuclear decays or transmutations, including nuclear fission and nuclear fusion, by applying: (ACSPH031, ACSPH035, ACSPH036)
  - the law of conservation of energy
  - mass defect
  - binding energy
  - Einstein's mass–energy equivalence relationship ($E = mc^2$)

Deep inside the Atom

Inquiry question: How is it known that human understanding of matter is still incomplete?

Students:

- analyse the evidence that suggests:
  - that protons and neutrons are not fundamental particles
  - the existence of subatomic particles other than protons, neutrons and electrons

Students:

- investigate the standard model of matter, including:
  - quarks, and the quark composition hadrons
  - leptons
  - fundamental forces (ACSPH141, ACSPH142)

Students:

- investigate the operation and role of particle accelerators in obtaining evidence that tests and/or validates aspects of theories, including the Standard Model of matter (ACSPH120, ACSPH121, ACSPH122, ACSPH146)