3.9 Astrophysics (A-level only)

Fundamental physical principles are applied to the study and interpretation of the Universe. Students gain deeper insight into the behaviour of objects at great distances from Earth and discover the ways in which information from these objects can be gathered. The underlying physical principles of the devices used are covered and some indication is given of the new information gained by the use of radio astronomy. The discovery of exoplanets is an example of the way in which new information is gained by astronomers.

3.9.1 Telescopes (A-level only)

3.9.1.1 Astronomical telescope consisting of two converging lenses (A-level only)

Content
Ray diagram to show the image formation in normal adjustment.   Angular magnification in normal adjustment. $M = \frac{\textit{angle subtended by image at eye}}{\textit{angle subtended by object at unaided eye}}$ Focal lengths of the lenses. $M = \frac{f_o}{f_e}$

3.9.1.2 Reflecting telescopes (A-level only)

Content
Cassegrain arrangement using a parabolic concave primary mirror and convex secondary mirror.   Ray diagram to show path of rays through the telescope up to the eyepiece.   Relative merits of reflectors and refractors including a qualitative treatment of spherical and chromatic aberration.

3.9.1.3 Single dish radio telescopes, I-R, U-V and X-ray telescopes (A-level only)

Content
Similarities and differences of radio telescopes compared to optical telescopes. Discussion should include structure, positioning and use, together with comparisons of resolving and collecting powers.

3.9.1.4 Advantages of large diameter telescopes (A-level only)

Content
Minimum angular resolution of telescope.   Rayleigh criterion, $\theta \approx \frac{\lambda}{D}$ Collecting power is proportional to *diameter*^{2}.   Students should be familiar with the rad as the unit of angle.   Comparison of the eye and CCD as detectors in terms of quantum efficiency, resolution, and convenience of use.   No knowledge of the structure of the CCD is required.

3.9.2 Classification of stars (A-level only)

3.9.2.1 Classification by luminosity (A-level only)

Content
Apparent magnitude, m. The Hipparcos scale. Dimmest visible stars have a magnitude of 6. Relation between brightness and apparent magnitude. Difference of 1 on magnitude scale is equal to an intensity ratio of 2.51. Brightness is a subjective scale of measurement.

3.9.2.2 Absolute magnitude, *M* (A-level only)

Content
Parsec and light year. Definition of M, relation to m: $m - M = 5 \log \frac{d}{10}$

3.9.2.3 Classification by temperature, black-body radiation (A-level only)

Content
Stefan's law and Wien's displacement law. General shape of black-body curves, use of Wien's displacement law to estimate black-body temperature of sources. Experimental verification is not required. $\lambda_{max} T = constant = 2.9 \times 10^{-3}$ m K Assumption that a star is a black body. Inverse square law, assumptions in its application. Use of Stefan's law to compare the power output, temperature and size of stars $P = \sigma A T^4$

3.9.2.4 Principles of the use of stellar spectral classes (A-level only)

Description of the main classes:

Spectral class	Intrinsic colour	Temperature / K	Prominent absorption lines
O	blue	25 000 – 50 000	He^+, He, H
B	blue	11 000 – 25 000	He, H
A	blue-white	7 500 – 11 000	H (strongest) ionized metals
F	white	6 000 – 7 500	ionized metals
G	yellow-white	5 000 – 6 000	ionized & neutral metals
K	orange	3 500 – 5 000	neutral metals
M	red	< 3 500	neutral atoms, TiO

Temperature related to absorption spectra limited to Hydrogen Balmer absorption lines: requirement for atoms in an n = 2 state.

3.9.2.5 The Hertzsprung-Russell (HR) diagram (A-level only)

Content
General shape: main sequence, dwarfs and giants. Axis scales range from –10 to +15 (absolute magnitude) and 50 000 K to 2 500 K (temperature) or OBAFGKM (spectral class). Students should be familiar with the position of the Sun on the HR diagram. Stellar evolution: path of a star similar to our Sun on the HR diagram from formation to white dwarf.

3.9.2.6 Supernovae, neutron stars and black holes (A-level only)

Content
Defining properties: rapid increase in absolute magnitude of supernovae; composition and density of neutron stars; escape velocity > c for black holes. Gamma ray bursts due to the collapse of supergiant stars to form neutron stars or black holes. Comparison of energy output with total energy output of the Sun. Use of type 1a supernovae as standard candles to determine distances. Controversy concerning accelerating Universe and dark energy. Students should be familiar with the light curve of typical type 1a supernovae. Supermassive black holes at the centre of galaxies. Calculation of the radius of the event horizon for a black hole, Schwarzschild radius (R_s), $R_s \approx \frac{2GM}{c^2}$

3.9.3 Cosmology (A-level only)

3.9.3.1 Doppler effect (A-level only)

Content
$\frac{\Delta f}{f} = \frac{v}{c}$ and $z = \frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$ for $v \ll c$ applied to optical and radio frequencies.
Calculations on binary stars viewed in the plane of orbit.
Galaxies and quasars.

3.9.3.2 Hubble's law (A-level only)

Content
Red shift $v = Hd$
Simple interpretation as expansion of universe; estimation of age of universe, assuming H is constant.
Qualitative treatment of Big Bang theory including evidence from cosmological microwave background radiation, and relative abundance of hydrogen and helium.

3.9.3.3 Quasars (A-level only)

Content
Quasars as the most distant measurable objects.
Discovery of quasars as bright radio sources.
Quasars show large optical red shifts; estimation involving distance and power output.
Formation of quasars from active supermassive black holes.

3.9.3.4 Detection of exoplanets (A-level only)

Content
Difficulties in the direct detection of exoplanets.
Detection techniques will be limited to variation in Doppler shift (radial velocity method) and the transit method.
Typical light curve.