1. Physics and Physical Measurement

1.1 the realm of physics: time: Planck time 10^{-23} s to Bismuth-209 half-life 10^{24} s
mass: electron 10^{-31} kg; length: Planck length 10^{-35} m to universe 10^{52} kg, 10^{24} m

1.2 measurement and uncertainties: derived unit: all other units, in SI form: $[\mathrm{s}^{-1}]$
base units: kilogram kg, metre m, second s, ampere A, kelvin K, candela Cd, mole
scientific notation: $1.66 \times 10^{-27}\mathrm{kg} = 1.66\ \mathrm{yg}$; errors can be random or systematic
precision is how close values are to measured mean; random errors lose precision
accuracy is how close measured mean is to actual; systematic errors lose accuracy
significant figures: add to smallest common digit, multiply to fewest significant digits
uncertainty: max(high - mean, mean - low), absolute 3 ± 1, fraction $1/3$, percent 33%

1.3 vectors and scalars: $|\mathbf{u}| = \sqrt{\mathbf{u}_1^2 + \mathbf{u}_2^2}$, $\mathbf{u} \cdot \mathbf{v} = |\mathbf{u}||\mathbf{v}| \cos\theta$, $\mathbf{u} \times \mathbf{v} = |\mathbf{u}||\mathbf{v}| \sin\theta$
scalars have magnitude, vectors have direction; can multiply vectors by scalars
right-hand rule: if $\mathbf{u} \times \mathbf{v} = \mathbf{w}$, then index is $\mathbf{u}$, middle is $\mathbf{v}$, and thumb is $\mathbf{w}$

2. Mechanics

2.1 kinematics: distance d scalar trip length, displacement $\mathbf{d}$ vector from start to end
speed $v \equiv d/t$ scalar, velocity $\mathbf{v} \equiv \mathbf{d}/t$ vector, acceleration $\mathbf{a} \equiv \mathbf{v}/t$ vector
instantaneous $v, \mathbf{v}, \mathbf{a}$ measured at one instant; average $v, \mathbf{v}, \mathbf{a} = (\mathbf{v}_f - \mathbf{v}_i)/\Delta t$
slope of $\mathbf{d}$ vs. $t = \mathbf{v}$, slope of $\mathbf{v}$ vs. $t = \mathbf{a}$; area under $\mathbf{v}$ vs. $t = \mathbf{d}$, under $\mathbf{a}$ vs. $t = \Delta\mathbf{v}$
air resistance: objects have terminal speed; relative velocity $\mathbf{v}_{AC} = \mathbf{v}_{AB} + \mathbf{v}_{BC}$
near earth $a = g$; data book $s = \mathbf{d}$, $u = \mathbf{v}_i$, $\boldsymbol{v} = \mathbf{v}_f$, uniform acceleration equations

2.2 forces and dynamics: weight $\equiv mg$, net force $\mathbf{F}$ $[\mathrm{N}]$ $\equiv$ sum of all external forces
free body diagrams isolate a system as a point, only has external forces, draw vectors
Newton's First Law: if $\mathbf{F} = 0, \mathbf{a} = 0$; equilibrium when no net force, no net torque
Second Law: $\mathbf{F} \equiv \Delta\mathbf{p}/\Delta t = m\mathbf{a}$, momentum $\mathbf{p} \equiv m\mathbf{v}$, impulse $\Delta\mathbf{p} = \mathbf{F}\Delta t = m\Delta\mathbf{v}$
Third Law: $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$, area under $\mathbf{F}$ vs. $t = \Delta\mathbf{p}$, momentum conserved if $\mathbf{F} = 0$

2.3 work, energy, and power: work W $[\mathrm{N\ m}] \equiv \mathbf{F} \cdot \mathbf{d}$, area under $\mathbf{F}$ vs. $d = W$
kinetic energy E_k $[\mathrm{J}]$: energy of motion, work done to accelerate object to its speed
change in gravitational potential energy ΔE_P: work done to move object to its height
conservation of energy: cannot be created or destroyed, but can be transferred:
kinetic, gravitational, elastic, radiant, electromagnetic, chemical, thermal, nuclear
elastic collisions: kinetic energy conserved; inelastic collisions: heat, sound released
power $[\mathrm{W}] \equiv W/t = \mathbf{F} \cdot \mathbf{v}$, efficiency: useful work output over energy input

2.4 uniform circular motion: centripetal acceleration $\mathbf{a}_\mathrm{c}$ towards centre if no $\Delta\alpha$
centripetal forces: gravity of the earth, friction of a banked road, tension of a string
angular position θ $[\mathrm{rad}]$, velocity $\omega \equiv \theta/t = vr$, acceleration $\alpha \equiv \omega/t = ar$

3. Thermal Physics

3.1 thermal concepts: internal energy U: potential + random kinetic energy in a body
thermal energy: non-mechanical energy transfer between system and surroundings
heat: flow of thermal energy, based on temperature (hot to cold), until equilibrium
temperature T: average thermal energy; Celsius + 273.15 = kelvin, 0 at absolute zero
Avogadro's constant N_A $[\mathrm{mol}^{-1}]$ ≡ number of stuff (atoms, soot, ducks) in a mole
molar mass: mass divided by number $[\mathrm{kg\ mol}^{-1}]$, constant for each type of stuff

3.2 thermal properties of matter: thermal capacity: heat added to raise temperature
specific heat capacity c $[\mathrm{J\ K}^{-1}]$: heat needed to raise a kilogram of stuff by a kelvin
gas: moves freely, fills volume; liquid: slides freely, fills bucket; solid: vibrates, no fill
phase change: at some pressure, temperature; adds potential energy to break bonds
gas condenses to liquid melts to solid; solid freezes to liquid boils/vaporizes to gas
gas deposits to solid sublimates to gas; latent heat L: heat needed to change phase
evaporation: below boiling point, fast particles escape; $\mathbf{F} = \mathbf{A} \cdot P$ $[\mathrm{Pa}]$ pressure

10. Thermodynamics

10.1 thermodynamics: absolute zero: lowest entropy, enthalpy, energy (zero-point)
ideal gas criteria: point molecules, random straight-line motion, elastic collisions,
no intermolecular forces, collisions between molecules and walls makes pressure,
average kinetic energy makes temperature, changing volume increases collisions
ideal gases wrong if low temperature (gases condense), high pressure (has volume)

10.2 processes: First Law: energy conservation, internal energy = heat in + work in
isochoric: same volume; isobaric: same pressure; isothermal: same temperature
adiabatic: no heat transfer, happens during rapid expansion or compression
adiabat is always steeper than isotherm, area under P vs. $V = W$ work done

10.3 second law of thermodynamics and entropy: Second Law: heat goes hot to cold,
no work out when system cooled more than surroundings, entropy always increases
entropy: measures disorder, ΔS $[\mathrm{J\ K}^{-1}] \equiv \Delta Q/T = k_B \ln\Omega$ number of microstates
state properties describe system, path-independent: $P\ V\ T\ U\ S$, unlike work, heat

8. Energy, Power and Climate Change

8.1 energy degradation and power generation: thermal energy can all become work
in single process, but continuous conversion needs cycle, must heat surroundings too
degraded energy: energy lost to surroundings cannot do useful work (Second Law)
Sankey diagrams: arrow width proportional to flow, shows where energy is degraded

8.2 world energy sources: energy from Sun (solar, oil, wind) save geothermal, nuclear
energy density $[\mathrm{J\ kg}^{-1}]$: amount of useful energy in a kilogram of fuel, more is better
40% oil, 15% natural gas, 10% coal, 18% electricity, 12% biofuels, 4% renewables

8. Energy, Power and Climate Change

8.3 fossil fuel power production:
8.4 non-fossil fuel power production:
8.5 greenhouse effect:
8.6 global warming:

6. Fields and Forces

6.1 gravitational force and field: Newton's universal law of gravitation: point masses
gravitational field strength g $[\mathrm{m\ s^{-1}}]$: force per unit mass, acceleration from gravity

6.2 electric force and field: two types of charge; total charge in a system conserved
Coulomb's law: point charges; field strength $\mathbf{E}$ $[\mathrm{N\ C^{-1}}] \equiv$ force per unit test charge
find on Google Images the electric field lines of a point charge, a charged sphere, two point charges, and oppositely charged parallel plates, which has the edge effect

6.3 magnetic force and field: state that moving charges give rise to magnetic fields
find on Google the magnetic field lines of a straight wire, a flat coil, and a solenoid
force on a current-carrying conductor $\mathbf{F} = I\mathbf{L} \times \mathbf{B}$, on a moving charge $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$
$\mathbf{F} = \mathbf{I} \times L\mathbf{B}$ defines magnetic flux density $\mathbf{B}$ $[\mathrm{T}]$, in direction of force on a north pole

9. Motion in Fields

9.1 projectile motion: vertical and horizontal components of velocity independent
ballistic motion parabolic; $\mathbf{d}_\mathrm{y} = \mathbf{v}_y^2/2g$, $\mathbf{d}_\mathrm{x} = \mathbf{v}_x t$, $t = 2|\mathbf{v}_y|/g$, $R = |\mathbf{v}|^2 \sin 2\theta\, /g$
air resistance makes parabola shorter overall and steeper towards the end

9.2 gravitational field, potential and energy: potential V $[\mathrm{J\ kg^{-1}}] \equiv E_p$ per unit mass
path-independent scalar, if absolute potential $V \equiv -Gm/r$ then $V = 0$ when $r = \infty$
no change in potential on equipotential surface, always perpendicular to field lines
find on Google Images the equipotential surfaces due to one and two point masses
9.3 electric field, potential and energy: same as gravity but potential per unit charge

9.4 orbital motion: object escapes when $E_k + V = 0$, escape speed $v = \sqrt{2GM/r}$
gravity centripetal force $F = mv^2/r = GMm/r^2$ so $v = \sqrt{GM/r}$, $E_k = GMm/2r$,
$E_p = -GMm/r$, satellite total energy $E = -GMm/2r$; Kepler's Third Law $T^2 \propto r^3$

5. Electric Currents

5.1 electric potential difference, current and resistance: voltage ΔV $[\mathrm{V}] \equiv \Delta V$
current I $[\mathrm{A}] \equiv 1\ A$ makes $2 \times 10^{-7}\ N/m$ force between two conductors $1\ m$ apart
resistance R $[\Omega] \equiv V/I$; cross-sectional area A, length L, resistivity ρ $[\Omega\ \mathrm{m}] \equiv RA/L$

5.2 electric circuits: electromotive force ϵ $[\mathrm{V}] \equiv$ voltage over a battery in a circuit
Thévenin's theorem: a linear network is just its voltage and its internal resistance r
resistors in series, voltages in parallel, capacitors in parallel $R = R_1 + R_2 + \cdots$
resistors in parallel, voltages in series, capacitors in series $1/R = 1/R_1 + 1/R_2 + \cdots$
tangent galvanometer in ammeters and voltmeters: current twists compass needle
ideal ammeter in series no resistance; ideal voltmeter in parallel infinite resistance
potential divider has resistances in series, splits voltage; sensors that decrease resistance (light-dependent resistors, strain gauges, thermistors) increase current

12. Electromagnetic Induction

12.1 induced electromotive force: Faraday's law: move in magnetic field, induces emf
right-hand rule: curve fingers with current, thumb points with induced magnetic field
electron in rod feels force $e\mathbf{v} \times \mathbf{B} = e\mathbf{E}$ in equilibrium with produced electric field
$\mathbf{E} = V/\mathbf{L}$ in length $\mathbf{L}$ rod so $V = L\mathbf{v} \times \mathbf{B}$; Lenz's law: ϵ opposes change that made it
magnetic flux Φ $[\mathrm{Wb}] \equiv \mathbf{B} \cdot \mathbf{A}$ on surface with vector area $\mathbf{A}$, number of field lines
flux linkage λ $[\mathrm{Wb}] \equiv \epsilon \Delta t = N\mathbf{B} \cdot \mathbf{A}$ for N turns of wire, flux through some surface

12.2 alternating current: ϵ is dot product so sinusoidal if coil rotation constant speed
root mean squared value V_{rms} = amplitude $A/\sqrt{2}$ = rating, can then use $P = V_{rms}I$
no losses in ideal transformer: number of turns $N_S/N_P = V_S/V_P = I_P/I_S = a$, where step-up $a > 1$, down $a < 1$; doubling frequency doubles amplitude, halves period

12.3 transmission of electrical power: higher voltage lowers losses: use transformers
real transformer losses: resistance in winding, eddy currents, hysteresis, flux leakage
power lines make low-frequency electric fields but do not harm genetic material

14. Digital Technology

14.1 analogue and digital signals: $10.1_2 = 1 \times 2^1 + 0 \times 2^0 + 1 \times 2^{-1} = 2.5_{10}$
MSB sign, LSB parity; storage media: LPs, tapes, floppy disks, hard disks, CDs, DVDs
interference at edge of CD pit; advantages: quality, reproducibility, speed, portability

14.2 data capture; digital imaging using charge-coupled devices: capacitance:
charge stored over voltage, C $[\mathrm{F}] \equiv q/V$ so energy stored is work done $W = CV^2/2$
CCD: silicon chip divided into pixels, incident light builds charge in pixel capacitors, find its voltage; quantum efficiency: photoelectrons emitted over photons incident
magnification: image length over object length; resolvable if at least two pixels apart
more efficiency, magnification, resolution better quality; CCDs in cameras, telescopes

4. Oscillations and Waves

4.1 kinematics of simple harmonic motion: SHM defining equation $a = -\omega^2 x$
displacement $x = x_0 \sin(\omega t + \varphi)$ for amplitude x_0 and phase difference φ
frequency f $[\mathrm{Hz}]$: cycles per unit time; period T $[\mathrm{s}] \equiv 1/f = 2\pi/\omega$ in SHM

4.2 energy changes during simple harmonic motion: total $E_T = E_k + E_p$ constant
$v = 0$: no kinetic energy, all potential energy; $x = 0, a = 0$: no potential, all kinetic

4.3 forced oscillations and resonance: damping force: dissipative, opposes velocity
light underdamping amplitude decreases (pendulum air drag), heavy overdamping slow, no oscillation (mattress), critical damping to equilibrium fastest (door closer)
resonance: force in phase with natural frequency velocity has maximum power input

4.4 wave characteristics: longitudinal parallel (sound) transverse perpendicular (light)
wavefront: all same phase points; opposites: crest/trough, compression/rarefaction
wave speed v: speed of wavefront, wavelength λ $[\mathrm{m}]$: length of wave, crest to crest
$v \equiv d/t = \lambda/T = \lambda f$; light speed: c; intensity I $[\mathrm{W\ m^{-2}}] \equiv$ power over area, $I \propto x_0^2$
electromagnetic spectrum wavelength: 1 pm gamma rays, 1 nm x-rays, 100 nm UV, 400 nm violet, 700 nm red, 1 μm infrared, 1 cm microwaves, 100 m radio waves

4.5 wave properties: incident wave at boundary makes reflected/transmitted waves
Snell's law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$ from normal, refractive index $n = c/v$ of medium
diffraction: flat wavefronts through hole become circular, more if narrow, large λ
interference: constructive if more displacement, most if in-phase, difference $= n\lambda$, most destructive if difference $= (n + 1/2\,)\lambda$; superposition: add wave displacement

11. Wave Phenomena

11.1 standing waves: if wave hits free end/softer surface, reflected wave in phase
but if wave hits fixed end/harder surface (harder to travel), reflection out of phase
if ongoing reflection out of phase: no energy transfer, nodes stay, antinodes move
mode: standing waves on string or in pipe; fundamental (first harmonic): lowest f
string/open pipe both antinodes, $L = n\lambda/2$; closed pipe has node, $L = (2n-1)\lambda/4$

11.2 Doppler effect: frequency changes if moving; if $v \ll c$, for light $\Delta f = vf/c$
where speed of observer is v; but for sound speed is u_s, u_o, speed of sound is v

11.3 diffraction: positions y of single-slit minima $y/L = n\lambda/b$ for width b, length L

11.4 resolution: Rayleigh criterion: $\theta = \lambda/b$ if slit, $\theta = 1.22\lambda/b$ if circular aperture;
two images just resolved if centre of one overlaps diffracted first minimum of other

11.5 polarization: when light vibrates in same direction, reflected light polarized, at
Brewster's angle: completely polarized, incident angle $\phi = \tan^{-1} n$ refractive index
polarizer: polarises, analyser: second polarizer behind first, repolarizes polarized light
Malus's law: intensity of polarized light through analyzer $I = I_0 \cos^2\theta$ angle between
optically active substances rotate plane of polarization; light can find concentration
some substances optically active under stress, can find stress; LCDs rotate light too!

7. Atomic and Nuclear Physics

7.1 the atom: small nucleus orbited by electrostatically attracted electrons
Geiger–Marsden experiment: alpha particles sometimes bounce backwards off gold
nuclide: only look at nucleus; nucleons: protons and neutrons; isotopes: same atom, different neutron number N, same proton number Z; nucleon number $A = N + Z$
atom ${}^{A}_{Z}Z$; in nucleus, protons feel Coulomb interaction, nucleons feel strong force

7.2 radioactive decay: too many protons or too many neutrons make nuclei unstable
alpha decay: heavy atoms release alpha particle $\alpha = {}^{4}_{2}He$, blocked by piece of paper
beta-minus decay: neutron into proton, ${}^{1}_{0}n \to {}^{1}_{1}p + e^- + \bar{\nu}_e$ electron antineutrino
positron emission: ${}^{1}_{1}p \to {}^{1}_{0}n + \nu_e + e^+$ positron; beta $\beta = e^-$ or e^+, blocked by skin
gamma decay: excited atoms release gamma ray photon γ, blocked by lots of lead
gamma rays ionize: make ions, kills tissue, releases free radicals; ingested α most
radioactive decay: random, spontaneous; half-life $T_{1/2}$: makes half the stuff decay

7.3 nuclear reactions, fission and fusion: binding energy: needed to split nucleus
mass defect: $E = mc^2$ so binding energy takes away nucleons' mass in a nucleus
nuclear fission: nucleus splits; nuclear fusion: nucleus combines, gives Sun energy

13. Quantum Physics and Nuclear Physics

13.1 quantum physics: photoelectric effect: metals emit electrons if exposed to light
Einstein model: light is discrete particles, knock electrons off if work function $\phi < E$
Millikan: found stopping potential ϕ; Davisson–Germer: electrons off Ni diffracted
de Broglie hypothesis: all matter is waves, wave-particle duality, even light $p = h/\lambda$
atomic energy levels: emission, absorption spectra only at certain wavelengths, energy differences between allowed electron energy states is quantized, $E = hf$
electron in a box: length L, standing matter waves, $\lambda = 2L/n$ so $E_k = n^2h^2/8m_eL^2$
Schrödinger model: wavefunction ψ, probability of electron at position $x = |\psi(x)|^2$
Heisenberg uncertainty principle: non-commutative $\Delta x \Delta p$ and $\Delta E \Delta t \geq h/4\pi$

13.2 nuclear physics: find nuclei radii from closest distance of charged particles
Bainbridge mass spectrometer: magnetic force pulls charged particles in a circle
nuclear energy levels: alpha particles discrete energies, gamma ray discrete spectra
but beta decay spectra continuous, so neutrino was postulated to account for this
decay constant λ: chance of decay per unit time, N nuclei, total decays A $[\mathrm{Bq}] = \lambda N$

G. Electromagnetic Waves

G.1 the nature of EM waves and light sources: electromagnetic waves transverse
oscillating charge makes varying electric and induced perpendicular magnetic fields
electromagnetic spectrum wavelength: 1 pm gamma rays, 1 nm x-rays, 100 nm UV, 400 nm violet, 700 nm red, 1 μm infrared, 1 cm microwaves, 100 m radio waves
dispersion: refractive index depends on wavelength so white light in prism rainbow
transmission: permit through; absorption: take in energy; scattering: bounce off
atmosphere scatters more blue: sky away from sun blue; sunset thicker, no blue
monochromatic: same wavelength; coherent: same frequency, constant phase shift
population inversion: more excited than stable atoms; photons make excited atoms emit same photons between mirrors, all coherent in laser: medicine, barcodes, CDs

G.2 optical instruments: convex lenses converge parallel light rays on focal point on principal axis at focal length f away from optical centre, power P $[\mathrm{m}^{-1}]$ in dioptres
positive: focal length convex, object distance left, image distance right, real, upright
negative: focal length concave, image distance left, virtual, magnification inverted
ray diagram: 1 pass centre, 2 parallel, then pass focus, 3 pass focus, then parallel
near/far point: nearest/farthest distance the eye can focus an image, 25 cm/infinite
linear magnification: larger height; angular magnification: larger subtended angle
real can be projected, virtual rays do not meet; image at near point +1 magnification
telescope image at infinity, large focal lengths; large objective lens, small eyepiece
microscope image at near point, small focal lengths, no overlap; small objective lens
spherical aberration: spherical lenses cannot focus light perfectly; use stopper
chromatic aberration: dispersion, cannot focus all colours; use achromatic doublet

G.3 two-source interference of waves: if no diffraction, $d\sin\theta = n\lambda$, $\tan\theta = s/D$, for $d =$ slit width, $n =$ some integer, $s =$ distance on screen, $D =$ distance from slit

G.4 diffraction grating: small slits: more spread out peaks; more slits: sharper peaks with many many tiny tiny slits, diffraction grating: measure angle to find wavelength

G.5 x-rays: Coolidge tube: thermionic electrons accelerated by voltage collide with metal target, exciting target electrons and emitting photons; hardness: more energy
x-ray spectrum: continuous up to maximum frequency at minimum wavelength λ_{min}
characteristic peaks: discrete frequencies of metal target, independent of voltage
x-ray diffraction: constructive interference in crystal planes, Bragg: $2d\sin\theta = n\lambda$, for distance between planes d, angle from surface θ, integer n, wavelength λ

G.6 thin-film interference: air wedge: two glass planes make regularly spaced fringes spacing is λ/θ, can find height of object; rough object bends fringes on optical flat
parallel film: one wavelength constructively interferes for a given thickness, so that
wedge films: thickness varies, forms coloured fringes when white light reflected
used in military stealth planes, oil slick thickness, non-reflecting lenses, solar cells

H. Relativity

H.1 introduction to relativity: frame of reference: has coordinates, measures stuff
Galilean transformations: absolute spacetime, Newtonian, $x' = x - vt$ and $t' = t$

H.2 concepts and postulates of special relativity: inertial frame: no acceleration
postulates: laws of physics same in all inertial frames and speed of light always c
two simultaneous events in different places are only simultaneous for one observer

H.3 relativistic kinematics: light clock: light ray between two mirrors measures time
proper time interval t_0 [s]: change in proper time, time if clock in frame considered
moving light clock makes triangle with sides vt, ct_0, and ct so $t^2 = t_0^2/(1 - v^2/c^2)$
Lorentz factor γ: adds relativistic effects, grows with velocity, asymptote at $v = c$
proper length L_0 [m]: length of ruler in frame considered, $L = L_0/\gamma$, contraction
Lorentz transformations: relative spacetime, $x' = \gamma(x - vt)$ and $t' = \gamma(t - vx/c^2)$

H.4 some consequences of special relativity: twin paradox: twin in rocket accelerates
Hafele–Keating experiment: four cesium-beam atomic clocks on planes, time dilated
velocity addition: since $v \ngtr c$ so addition is not linear, $u' = (u - v)/(1 - uv/c^2)$
mass–energy equivalence: $E = \gamma m_0 c^2$ for rest mass m_0 [kg] or $[\mathrm{MeV\ c^{-2}}]$: invariant
rest energy E_0 [J]: energy because of mass, $E_0 = m_0 c^2$; if all energy is rest or kinetic then kinetic energy $E_K = E - E_0$; since $E_K \to \infty$ as $v \to c$, cannot reach light speed

H.5 evidence to support special relativity: muon decay: short half-life but still survive
Michelson–Morley experiment: coherent light-source aimed at half-silvered mirror, hit other mirrors; if light speed different, would recombine to have large fringe shift
got null result, small fringe shift so ether does not exist and speed of light constant
experiment indicates that speed of light is independent of its source. pion-decay

H.6 relativistic momentum and energy: momentum p $[\mathrm{MeV\ c^{-1}}] = \gamma m_0 u$ at speed u
convert between total energy and relativistic momentum with $E^2 = p^2c^2 + m_0^2c^4$

H.7 general relativity: gravitational mass $g = Gm/r^2$, inertial mass $F = ma$; same
principle of equivalence: accelerating reference frame same as gravity on a planet, predicts that light bends, time slows down, spacetime warps in gravitational field
spacetime: space and time, moving objects follow shortest path in spacetime
black holes: region of spacetime with extreme curvatures due to presence of a mass
Schwarzschild radius R_s: radius of event horizon from which escape velocity $v_e > c$
gravitational redshift: frequency lower if light goes away from mass, $\Delta f/f = g\Delta h/c^2$
gravitational time dilation: accelerated, not special relativity, $\Delta t = \Delta t_0/\sqrt{1 - R_s/r}$

H.8 evidence to support general relativity: Eddington 1919 solar eclipse saw star;
Pound–Rebka experiment: moved photon emitter so redshift and Doppler cancelled
Shapiro time delay: radar signals slower near sun; Mercury: precession of perihelion