PHYSICS
ATAR COURSE YEAR 12
FORMULAE AND DATA BOOKLET
2019
Note: the variable \( t \) refers to the 'time taken', sometimes referred to as the 'change in time' or \( \Delta t \).

**Gravity and motion**

**Average velocity**
\[
v_{av} = \frac{s}{t}
\]

**Equations of motion**
\[
v = u + at \quad s = ut + \frac{1}{2} at^2 \quad v^2 = u^2 + 2as
\]
\[
p = mv
\]

**Force**
\[
F_{net} = ma
\]

**Weight force**
\[
F = mg
\]

**Kinetic energy**
\[
E_k = \frac{1}{2} mv^2
\]

**Gravitational potential energy**
\[
E_p = mg \Delta h
\]

**Work done**
\[
W = Fs = \Delta E
\]

**Equations of circular motion**
\[
v = \frac{2\pi r}{T} \quad a_c = \frac{v^2}{r} \quad F_c = ma_c = \frac{mv^2}{r}
\]

**Newton’s law of universal gravitation**
\[
F = G \frac{m_1 m_2}{r^2}
\]

**Kepler’s 3rd law**
\[
T^2 = \frac{4\pi^2}{GM} r^3
\]

**Gravitational field strength**
\[
g = G \frac{M}{r^2}
\]

**Moment of a force** (force at angle \( \theta \) to lever arm)
\[
\tau = r F \sin \theta
\]

**Wave particle duality and the quantum theory**

**Wave period**
\[
T = \frac{1}{f}
\]

**Wave equation**
\[
c = f\lambda
\]

**Energy of photon**
\[
E = hf
\]

**Energy transitions**
\[
\Delta E = E_2 - E_1 = hf
\]

**Photoelectric effect**
\[
E_k = hf - W
\]

**De Broglie wavelength**
\[
\lambda = \frac{h}{p}
\]
**Electromagnetism**

Coulomb's law
\[ F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \]

Electric field strength
\[ E = \frac{F}{q} = \frac{V}{d} \]

Magnetic field strength
\[ B = \frac{\mu_0 I}{2\pi r} \]

Magnetic force on a charged particle
\[ F = q \, v \, B \text{ where } v \perp B \]

Magnetic force on a current-carrying conductor
\[ F = I \, \ell \, B \text{ where } \ell \perp B \]

Particle motion in a magnetic field
\[ r = \frac{m}{q} \, \frac{v}{B} \]

Torque on a coil
\[ \tau = r \, F \]

Magnetic flux
\[ \Phi = B \, A \perp \]

Electromagnetic induction
induced emf: \( \varepsilon = \ell \, v \, B \) where \( v \perp B \)
induced emf: \( \varepsilon = -N \frac{\Delta (\Phi_2 - \Phi_1)}{t} = -N \frac{\Delta \Phi}{t} = -N \frac{\Delta (BA_\perp)}{t} \)

AC generator emf
\[ \varepsilon_{\text{max}} = 2N\ell v B = 2\pi NBA_\perp f \]
\[ \varepsilon_{\text{rms}} = \frac{\varepsilon_{\text{max}}}{\sqrt{2}} \]

Ohm's law
\[ V = IR \]

Electric current
\[ I = \frac{q}{t} \]

Work and energy
\[ W = Vq \]

Ideal transformer turns ratio
\[ \frac{V_p}{V_s} = \frac{N_p}{N_s} \]

Power
\[ P = VI \]

**Special relativity**

Relativistic effects
\[ \ell = \ell_0 \sqrt{1 - \frac{v^2}{c^2}} \]
\[ t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \]
\[ u = \frac{v + u'}{1 + \frac{uu'}{c^2}} \]
\[ u' = \frac{u - v}{1 - \frac{uu'}{c^2}} \]

Relativistic momentum
\[ p = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}} \]

Mass-energy equivalence
\[ E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} \]

Rest energy
\[ E = mc^2 \]

See next page
The Standard Model

Elementary particles

<table>
<thead>
<tr>
<th>Mass</th>
<th>Charge</th>
<th>Lepton number</th>
</tr>
</thead>
<tbody>
<tr>
<td>~2.3 MeV/c^2</td>
<td>2/3</td>
<td>1/3</td>
</tr>
<tr>
<td>~1.275 GeV/c^2</td>
<td>2/3</td>
<td>1/3</td>
</tr>
<tr>
<td>~173.07 GeV/c^2</td>
<td>2/3</td>
<td>1/3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>~126 GeV/c^2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Quarks

<table>
<thead>
<tr>
<th>Mass</th>
<th>Charge</th>
<th>Lepton number</th>
</tr>
</thead>
<tbody>
<tr>
<td>~4.8 MeV/c^2</td>
<td>1/3</td>
<td>-1/3</td>
</tr>
<tr>
<td>~95 MeV/c^2</td>
<td>1/3</td>
<td>-1/3</td>
</tr>
<tr>
<td>~4.18 GeV/c^2</td>
<td>1/3</td>
<td>-1/3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Leptons

<table>
<thead>
<tr>
<th>Mass</th>
<th>Charge</th>
<th>Lepton number</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2.2 eV/c^2</td>
<td>0</td>
<td>+1</td>
</tr>
<tr>
<td>&lt;0.17 MeV/c^2</td>
<td>0</td>
<td>+1</td>
</tr>
<tr>
<td>&lt;15.5 MeV/c^2</td>
<td>0</td>
<td>+1</td>
</tr>
</tbody>
</table>

Gauge bosons

<table>
<thead>
<tr>
<th>Mass</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>105.7 MeV/c^2</td>
<td>-1</td>
</tr>
<tr>
<td>1.777 GeV/c^2</td>
<td>+1</td>
</tr>
<tr>
<td>91.2 GeV/c^2</td>
<td>0</td>
</tr>
<tr>
<td>80.4 GeV/c^2</td>
<td>±1</td>
</tr>
</tbody>
</table>

Electromagnetic spectrum

<table>
<thead>
<tr>
<th>λ(m)</th>
<th>10^-2</th>
<th>10^-1</th>
<th>10^-2</th>
<th>10^-3</th>
<th>10^-4</th>
<th>10^-5</th>
<th>10^-6</th>
<th>10^-7</th>
<th>10^-8</th>
<th>10^-9</th>
<th>10^-10</th>
<th>10^-11</th>
<th>10^-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of spectrum</td>
<td>radio frequencies</td>
<td>microwaves</td>
<td>infrared radiation</td>
<td>visible</td>
<td>ultraviolet radiation</td>
<td>X-rays</td>
<td>gamma rays</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>f(Hz)</th>
<th>10^6</th>
<th>10^7</th>
<th>10^8</th>
<th>10^9</th>
<th>10^10</th>
<th>10^11</th>
<th>10^12</th>
<th>10^13</th>
<th>10^14</th>
<th>10^15</th>
<th>10^16</th>
<th>10^17</th>
<th>10^18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: shaded areas represent regions of overlap.
Physical data

Mean acceleration due to gravity on the Earth: \( g = 9.80 \text{ m s}^{-2} \)

Mean acceleration due to gravity on the Moon: \( g_M = 1.62 \text{ m s}^{-2} \)

Mean radius of the Earth: \( R_E = 6.37 \times 10^6 \text{ m} \)

Mass of the Earth: \( M_E = 5.97 \times 10^{24} \text{ kg} \)

Mean radius of the Sun: \( R_S = 6.96 \times 10^8 \text{ m} \)

Mass of the Sun: \( M_S = 1.99 \times 10^{30} \text{ kg} \)

Mean radius of the Moon: \( R_M = 1.74 \times 10^6 \text{ m} \)

Mass of the Moon: \( M_M = 7.35 \times 10^{22} \text{ kg} \)

Mean Earth-Moon distance: \( = 3.84 \times 10^8 \text{ m} \)

Mean Earth-Sun distance: \( = 1.50 \times 10^{11} \text{ m} \)

Mass (at rest) of electron: \( m_e = 9.11 \times 10^{-31} \text{ kg} \)

Mass (at rest) of proton: \( m_p = 1.67 \times 10^{-27} \text{ kg} \)

Tonne: \( 1 \text{ t} = 10^3 \text{ kg} \)

Physical constants

Speed of light in vacuum or air: \( c = 3.00 \times 10^8 \text{ m s}^{-1} \)

Electron charge: \( e = -1.60 \times 10^{-19} \text{ C} \)

Planck constant: \( \hbar = 6.63 \times 10^{-34} \text{ J s} \)

Newtonian constant of gravitation: \( G = 6.67 \times 10^{-11} \text{ N m}^2 \text{kg}^{-2} \)

Electric constant: \( \varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1} \)

Magnetic constant: \( \mu_0 = 4\pi \times 10^{-7} \text{ N A}^{-2} = 1.26 \times 10^{-6} \text{ N A}^{-2} \)

Conversions

Electron volt: \( 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \)

Light year: \( 1 \text{ ly} = 9.46 \times 10^{12} \text{ km} \)

Megaparsec: \( 1 \text{ Mpc} = 3.09 \times 10^{19} \text{ km} = 3.26 \times 10^6 \text{ ly} \)
Prefixes of the metric system

<table>
<thead>
<tr>
<th>Factor</th>
<th>Prefix</th>
<th>Symbol</th>
<th>Factor</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{12}$</td>
<td>tera</td>
<td>T</td>
<td>$10^{-3}$</td>
<td>milli</td>
<td>m</td>
</tr>
<tr>
<td>$10^9$</td>
<td>giga</td>
<td>G</td>
<td>$10^{-6}$</td>
<td>micro</td>
<td>µ</td>
</tr>
<tr>
<td>$10^6$</td>
<td>mega</td>
<td>M</td>
<td>$10^{-9}$</td>
<td>nano</td>
<td>n</td>
</tr>
<tr>
<td>$10^3$</td>
<td>kilo</td>
<td>k</td>
<td>$10^{-12}$</td>
<td>pico</td>
<td>p</td>
</tr>
</tbody>
</table>

Mathematical expressions

Quadratic equations

Given $ax^2 + bx + c = 0$, $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Triangles

The following expressions apply to the triangle ABC as shown:

\[
\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}
\]

\[
a = \sqrt{b^2 + c^2 - 2bc \cos A}
\]
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ACKNOWLEDGEMENTS

Elementary particles


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