**Starting equations from this class** **Equations with an asterisk were not prominently featured in homework, and are key formulas for understanding course content, but will not required for the exam.*

| | | |
|---|---|---|
| $\Delta U = Q + W$ | **First Law (energy flow diagrams)** | (1) |
| $\Delta S_{\text{system}} + \Delta S_{\text{surroundings}} \geq 0$ | Second Law | (2) |
| $W = -\int p dV$ | work from a $pV$ diagram | (3) |
| $\Delta S = \frac{Q}{T}$ | if temperature is held constant | (4) |
| $\frac{1}{T} = \frac{dS}{dU}$ | definition of temperature* | (5) |
| $S = k_B \ln \Omega$ | entropy from number of microstates* | (6) |
| $pV = N k_B T$ | ideal gas only! | (7) |
| $\frac{W_{\text{net}}}{Q_{\text{in}}} \leq 1 - \frac{T_C}{T_H}$ | efficiency of heat engines | (8) |
| $C_V = \frac{dU}{dT}$ | heat capacity | (9) |
| energy per degree of freedom $= \frac{1}{2} k_B T$ | equipartition | (10) |
| if $\frac{1}{2} k_B T \ll \Delta E$ | can ignore that degree of freedom | (11) |
| if $\frac{1}{2} k_B T \gg \Delta E$ | can use equipartition | (12) |
| $E_{\text{photon}} = \hbar\omega = \Delta E_{\text{system}}$ | quantum spectra | (13) |
| $p = \frac{h}{\lambda} = \frac{2\pi\hbar}{\lambda}$ | momentum and wavelength | (14) |
| $E_{\text{light}} = p_{\text{light}} c$ | momentum of light | (15) |
| energy/time/area | intensity of light | (16) |
| $I = \sigma T^4$ | Stefan-Boltzmann Law | (17) |
| spectral intensity $S_\lambda$ | the intensity per wavelength | (18) |
| $\lambda_{\text{peak}} = \frac{b}{T}$ | Wien's displacement law* | (19) |

**Course content that will be provided if required**

- Boundary conditions for pipes etc.
- Energy level formulas for quantum systems
- An equation for spectral intensity

**Course content that will not be on the exam** *These topics were discussed in class, but did not appear on homework, and therefore will not appear on the exam.*

- Differential equations for waves
- Optical depth and cross section

### Starting equations from previous classes

$$K.E. = \frac{1}{2}mv^2 \tag{20}$$

$$U = mgh \quad \text{for gravity near the surface of Earth} \tag{21}$$

$$U = k_C\frac{q_1 q_2}{r_{12}} \quad \text{for two point charges} \tag{22}$$

$$p = mv \quad \text{nonrelativistic particle} \tag{23}$$

$$v = \lambda f \quad \text{for a wave} \tag{24}$$

$$\omega = 2\pi f \quad \text{angular versus normal frequency} \tag{25}$$

$$\text{density} = \frac{m}{V} \tag{26}$$

$$\text{number density} = \frac{N}{V} \tag{27}$$

$$Q = mc\Delta T \quad \text{specific heat capacity} \tag{28}$$

### Useful constants

$$k_B \approx 1.4 \times 10^{-23} \quad \text{Boltzmann's constant} \tag{29}$$

$$k_C \approx 9 \times 10^{9} \text{ J m/C}^2 \quad \text{Coulomb constant} \tag{30}$$

$$e \approx 1.6 \times 10^{-19} \text{ C} \quad \text{charge of electron} \tag{31}$$

$$\text{eV} \approx 1.6 \times 10^{-19} \text{ J} \quad \text{an electron volt} \tag{32}$$

$$\hbar \approx 10^{-34} \text{ J s} \quad \text{Plank's constant} \tag{33}$$

$$c \approx 3 \times 10^{8} \text{ m/s} \quad \text{speed of light} \tag{34}$$

$$m_e \approx 10^{-30} \text{ kg} \quad \text{mass of electron} \tag{35}$$

$$m_e c^2 \approx 0.5 \text{ MeV} \quad \text{mass of electron (relativistic version)} \tag{36}$$

$$\text{u} \approx 1.7 \times 10^{-27} \text{ kg} \quad \text{atomic mass unit} \tag{37}$$

$$hc \approx 1240 \text{ nm eV} \quad \text{a convenient combination} \tag{38}$$

$$N_A \approx 6 \times 10^{23} \text{ things/mol} \quad \text{Avogadro's number} \tag{39}$$

$$\sigma \approx 6 \times 10^{-8} \frac{\text{J}}{\text{s} \cdot \text{m}^2 \cdot \text{K}^4} \quad \text{Stefan-Boltzmann constant} \tag{40}$$