HW1:

1. a) $F = m_e \frac{dv}{dt} = -e(E + v \times B)$, b) $\hbar\dot{k} = -eE$, velocity from gradient of band structure. Effective mass enables application of these semiclassical equations for electrons in lattice, since the interaction with lattice is incorporated to the effmass.
2. a,b) Due to the symmetry of the band structure, for each state with velocity v, there is a state with velocity –v, which cancel. c) Shift of states in k-space leads to asymmetric distribution of states. Net current from the "uncancelled" electrons.
3. All states constantly shift in the k-space, from one Brillouin zone to the next (also leads to oscillations in real-space). Scattering restores the system towards equilibrium situation, effectively leading to small shift of the states under steady-state.
4. T-dep straightforward. Elastic vs inelastic scattering. Ineffectiveness of electron-electron scattering.

HW2:

1. At least relaxation-time approximation, linearization of the Boltzmann transport equation, approximating df/dE by delta-function.
2. Estimate Fermi-velocity e.g. from typical Fermi-energy, Fermi-wavevector, electron density. Largely independent of T.
3. Dominated by the scattering processes and their T-dep.
4. T-gradient leads to imbalance of carriers and counteracting electric field. a,b) Describe the "devices". Both require two different metals.

HW3:

1. k/E straightforward. k very small compared to Brillouin zone. Direct-gap for efficient light emission, wide band gap needed to cover the whole spectral range of visible light.
2. Curvature of band => density of states (DOS). #carriers in band is DOS times occupation from Fermi-dirac distribution. #electrons=#holes since they come from thermal excitations, which necessitates that if DOS in the two bands are different, then the center of the Fermi-Dirac distribution must be shifted accordingly. Approaches middle of the gap as T->0. For extrinsic, describe freeze-out, saturation, intrinsic regimes.
3. Describe T-dependence of carrier density in the three regimes and the dome-like T-dep of mobility. Conductivity is carrier density times mobility, and thus its T-dep also arises from both.

HW4:

1. Draw band diagrams. Charge transfer from higher Fermi-level to lower Fermi-level after contacting. Leads to space charge regions with electric potential (electric field) that opposes further charge transfer => band bending. Size of space charge regions depends on the density of dopants (in semiconductors). Screening also affects the potential. The case of two different semiconductors is mainly to highlight what are band offsets. There may or may not be band bending, but that is separate effect.
2. Describe the devices. a) Voltage-controlled formation of conductive channel at interface. b) Pushing majority carriers to other side of the p-n junction by forward bias leads to strong recombination, since there are lots of electrons and holes in same region.

HW5:

1. Give some examples. Eg. a) vacancy, b) dislocation, c) stacking fault.
2. E.g. doping in semiconductors, mechanical strength, electron-defect scattering, color…

3. Formation energy cost overcome by entropy gain. Extended defects arise from the growth/processing etc. Energy barrier for getting rid of them can be very large.
4. E.g. vacancy, interstitial mechanism. Migration barrier, attempt frequency, lattice constant.