Ex. 1:

Consider the (generalized) experts problem, and suppose the time horizon $T$ is not known in advance. Give an algorithm whose performance is asymptotically as good as the Multiplicative Weights algorithm shown in class, up to an additive and/or multiplicative constant (which is independent of $T$ and $n$). Prove your claim.

Ex. 2:

In this exercise we prove a tight lower bound on the regret of any algorithm for Online Convex Optimization.

In a sequence of $T$ fair coin tosses, let $N_h$ be the number of head outcomes and $N_t$ be the number of tails.

(1) Show that $E[|N_h - N_t|] \leq \sqrt{T}$.

(2) Show that $E[|N_h - N_t|] = \Theta(\sqrt{T})$.

**Hint:** You may need Stirling’s approximation, $n! \sim \sqrt{2\pi n}(n/e)^n$.

(3) Consider the general OCO setting over a convex set $\mathcal{K}$. Design a setting (i.e., specify a decision set $\mathcal{K}$ and cost functions $f_t$) in which the cost functions have gradients whose norm is bounded by $G$, and obtain a lower bound on the regret as a function of $G$, the diameter of $\mathcal{K}$, and the number of game iterations $T$. 
Ex. 3-5:
The following questions are taken from the book draft on online convex optimization (reading material number 5).

(1) problem 4 in chapter 2.
(2) problem 7 in chapter 2.
(3) problem 2 in chapter 3.