EEE337/348: Tutorial 3

1) Consider a Si pin photodiode with an absorption region of 10 μm.
   i) What is the photocurrent density produced when a GaAs laser with an optical power of 1 W/cm^2 is focused on the Si photodiode?
   ii) Estimate the transit time limited bandwidth if the electron and hole are assume to travel at a saturated velocity of $7x10^4$ ms^{-1}.

2) An extremely fast photodiode can be designed to achieve bandwidth approaching THz. Recommend a possible design to achieve a bandwidth 100 GHz. Discuss the design trade-off in your design.

3) In metal manufacturing, the temperature measurement is an important approach to maintain the quality. This is typically done by detecting the infrared radiation from the hot metal. If the temperature of the iron is 1000 °C, suggest a suitable photodetector technology that can be used to monitor the temperature uniformity of a 30x30 cm^2 iron plate. Explain your choice. (Assume the steel plate is a perfect blackbody and you may use the Planck's Law to estimate its radiation)

4) Consider a Si avalanche photodiode (APD) with a breakdown voltage V_b = 150 V, series resistance of 1 Ω and n_m = 2. When biased at 90% of its breakdown voltage the dark current is 10 nA.
   i) Calculate the gain produced by this APD when biased at 90% of its breakdown voltage.
   ii) The APD is expected to produce a photocurrent of 2 nA, under unity gain condition. If the incident optical power is 5 nW and the wavelength is 633 nm, what is the required quantum efficiency?

5) In a high speed optical communication, it is a common practice to amplify the signal from an APD with a low noise amplifier. Consider an example, where the APD in part (1) is connected to a low noise transimpedance amplifier with a bandwidth of 1 GHz and a noise current of 4 $pA/Hz^{1/2}$.
   i) Calculate the minimum gain required so that the APD can raise the signal above the noise floor of the amplifier.
   ii) What is the bias voltage required?

6) Conventional APDs used in high speed optical communication have InGaAs absorption region and an InP avalanche region. Explain the advantages offered by this combination over an InGaAs pin diode.

7) Due to increasing internet traffic, very high speed photodetectors are required. Recommend the best option at 2.5 Gb/s and at 100 Gb/s. Provide supporting statements for your recommendations.

8) Discuss how the gain-bandwidth of an APD can be increased. What are the constraints that limit the gain-bandwidth products in conventional telecom APDs.