1. Imagine that you are a network planner for a major carrier that is interested in deploying a 20 Gb/s link. You must choose between the following options:

   (a) An SDM approach using eight fiber-pairs, each operating at 2.5 Gb/s.

   (b) A TDM approach using two 10 Gb/s transmission systems over two fiber pairs.

   (c) A WDM approach using eight wavelengths over a fiber-pair.

   Do an economic analysis to determine the costs of installing each type of system for a link length (a) 1200 km, (b) 240 km, and (c) 40 km. Use spreadsheet or a computer program so that you can vary the parameters and see how they affect your system choice.

   Assume the following costs:

Equipment	**Cost ($)**
2.5 Gb/s terminal	100.000
10 Gb/s terminal	300.000
8-WDM terminal equipment	100.000
Optical amplifier pair	100.000
2.5 Gb/s regenerator pair	100.000
10 Gb/s regenerator pair	150.000

   The WDM terminal equipment includes only the multiplexing and demultiplexing equipment and any amplifiers needed, but does not include the 2.5 Gb/s terminal equipment that must be paid for seperately.

   Assume that the chromatic dispersion limit is 600 km at 2.5 Gb/s and 120 km at 10 km, and that the PMD limit at 10 Gb/s is 600 km. Regeneration is required beyond these limits. An optical amplifier is required every 120 km, unless the link is terminated at that point, and the same type of amplifier can be used in all the systems. Instead of an amplifier, you can optionally use a regenerator, but one is required every 80 km. Assume that standard single-mode fibers are already installed and available for free.

   What do you conclude from your study? How would your conclusions change if the cost of the 10 Gb/s terminal equipment drops 25%, the 2.5 Gb/s 40%, and the WDM terminal equipment by 25%?

2. a) Consider a static broadcast star network consisting of 5 NAS's and using TDM/T-WDMA in FT-TR mode. Find a channel allocation schedule that realizes full point-to-point logical connectivity between the 5 stations using 5 wavelengths.

   b) Assume then that the broadcast star operates in TT-FR mode. Find again a channel allocation schedule that realizes full point-to-point logical connectivity between the 5 stations using 5 wavelengths.

3. Consider a static network connecting four stations with the following normalized traffic matrix:

$$T = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 3 \\ 2 & 2 & 0 & 1 \\ 2 & 1 & 1 & 0 \end{pmatrix}.$$

   The network is realized as a TDM/T-WDMA system operating on a 4×4 broadcast star with 3 λ-channels. Assume further that there is one transmitter and one receiver in each station.

a) Find an optimal channel allocation schedule for the system operating in FT-TR mode.

b) Find an optimal channel allocation schedule for the system operating in TT-FR mode.

4. a) Realize the full connectivity between 3 end systems by interconnecting 3 2×2 wavelength selective cross-connects (see slide 37 of lecture 8) into a unidirectional ring and using wavelength routing to provide the optical connections needed. Solve the routing and channel assignment problem. How many wavelengths are needed (at minimum)? How many optical transceivers are needed in each NAS? Show the connection states of all permutation switches in WSXC1.

   b) Assume then that the 3 WSXC's are connected into a bidirectional ring. Make a similar study as above.

5. a) Consider the mesh WRN consisting of 5 WSXC's and 5 elementary NAS's depicted in slide 22 of lecture 9. Solve the routing and channel assignment problem that realizes the full logical/optical connectivity between the 5 stations using 4 wavelengths.

   b) Assume then that the NAS's are nonblocking (as in slide 23 of lecture 9). Solve the same routing and channel assignment problem as above using only 2 wavelengths. Why is it impossible to solve the problem using only a single wavelength?