Instructions:

I. You must submit your homework electronically only in .pdf format. All word processed, no handwriting.
II. Submit your homework via Blackboard no later than **11:59 pm Oct 24, 2022**.
III. Late homework is subject to 10% penalty for each day past the due date, and before the solutions are posted. No homework will be accepted after the solutions are posted.
IV. Students can discuss problems and share their ideas among themselves but MUST work out the homework problems individually. Any deviation from this policy may result in an" F" grade for the course.
V. You must start working on these problems immediately. Otherwise, you may not have enough time to submit them on time.

1. To provide more reliability than a single parity bit can give, an error-detecting coding scheme uses one parity bit for checking all the odd-numbered bits and a second parity bit for all the even-numbered bits. What is the Hamming distance of this code?

   Hint: How many bits have to be in error to make another valid code. Think about errors in odd/even places.

2. Sixteen-bit messages are transmitted using a Hamming code. How many check bits are needed to ensure that the receiver can detect and correct single-bit errors? Show the bit pattern transmitted for the message 1101001100110101. Assume that even parity is used in the Hamming code.

3. A channel has a bit rate of 4 kbps and a propagation delay of 20 msec. For what range of frame sizes does stop-and-wait give an efficiency of at least 50%? Hint: One approach is to use $E = \frac{1}{1+2\alpha}$, where $\alpha = T_P/T_f$
   and calculate the frame size.

4. Using Hamming code, assume the sender want to send a message of 4 bits, 1111.
   (a) What is actually being transmitted
   (b) Assume during transmission the parity bit p_1 is inverted by an error (noise)
      i. How does the receiver detect the error?
      ii. How does the receiver correct the error?

   Show your work by calculating parity bits and syndrome bits.

5. (a) The distance from earth to a distant planet is approximately 9×10^{10} m. What is the channel utilization if a stop-and-wait protocol is used for frame transmission on a 64 Mbps point-to-point link? Assume that the frame size is 32 KB and the speed of light is 3×10^8 m/s. Hint: $E = \frac{1}{1+2\alpha}$, where $\alpha = T_P/T_f$.

   (b) Now, suppose a sliding window protocol is used instead. For what send window size will the link utilization be 100%? You may ignore the protocol processing times at the sender and the receiver. Hint: $E = \frac{w}{1+2\alpha}$ where $\alpha = T_P/T_f$, and w is the window size.