CS 372 Introduction to Computer Networks
Self-Check Exercises: Lecture 30 **Solutions**

1) What is the purpose of IP fragmentation?
   It is possible for a datagram to encounter a link-layer technology which is incapable of encapsulating the entirety of the datagram into the link-layer frame, due to sizing constraints. If this happens, the datagram must be subdivided such that it will fit – this is fragmentation – or else be dropped from the network.

2) What is an MTU? What is a *path MTU*?
   An MTU is the maximum transmission unit, in terms of bytes of data, for a specific piece of networking hardware. A *path* MTU is the *minimum* MTU on the entire path from source to destination. If a datagram is smaller than the path MTU, there will be **no** fragmentation.

3) Is the header of the original IP datagram included in the *payload* of fragmented datagrams?
   No. Each fragmented IP datagram has its own header (which is almost identical to the original IP datagram header), but the original header is not included in the *payload*.

4) If it is a TCP segment which has been fragmented (with header length = 20 bytes), where does the TCP header go?
   The TCP header was originally the first 20 bytes of the un-fragmented IP datagram. IP doesn't care about the TCP header, and just sees it as IP-layer payload. As a result, it becomes the first 20 bytes of the first fragmented IP datagram. It does not, however, reappear in subsequent datagram fragments.

5) How does the ID field of the IP datagram change from Fragment #1 to Fragment #N?
   It doesn't. All fragments of the same original datagram have the same ID field value.

6) Where does reassembly of fragmented datagrams take place?
   Fragment re-assembly is handled at the destination host.

7) What happens if an IP datagram is fragmented into N datagrams, but the destination only receives the first 1 … N-1 fragmented datagrams?
   When the fragment timer expires, the destination router drops all of the fragmented datagrams.

8) Can a fragmented IP datagram be re-fragmented?
   Yes. This occurs if the fragment encounters a link with an even smaller MTU.

9) A 2400-byte datagram (with ID #422) encounters a router with an MTU of 700 bytes. The *don't-fragment* flag is set to 0

a. How many fragments are generated? 4 fragments.

The amount in the payload of the IP datagram = 2400 – 20 = 2380. (Length – IP header)
The maximum size of data field in each fragment = 700 – 20 = 680 (MTU – IP header).
Thus the number of required fragments $\left\lceil \frac{2400-20}{700-20} \right\rceil = 4$ (Note: the 2380 bytes of data includes a TCP or UDP header, but that doesn't matter, since IP just sees it as "payload".)

b. For each fragment, show the values in the following header fields:

- *Length* Each fragment except the last one will be of size 700 bytes (including IP header). The last datagram will be of size 360 bytes (including IP header).
  Excluding headers, 680 + 680 + 680 + 340 = 2380

- *ID#* Each fragment will have Identification number 422

- *more-fragments* flag Each of the first 3 fragments will have *more-fragments* = 1; the last fragment will have *more-fragments* = 0

- *offset* The offsets of the 4 fragments will be 0, 85, 170, 255.
  NOTE: the destination host will multiply the fragment offset values by 8 to get the byte number.)