1. Calculate time to read 256 KB (512 sectors) for a Barracuda 180 disk using advertised performance parameters (Lecture 13). Assuming no queueing delay.

Disk latency = average seek time + average rotational delay + transfer time + controller overhead
= 7.4 ms + 0.5 * 1/(7200 RPM) + 256 KB / (64 MB/s) + 0.1 ms
= 7.4 ms + 0.5 /(7200 RPM/(60000ms/M)) + 256 KB / (64 KB/ms) + 0.1 ms
= 7.4 + 4.2 + 4.0 + 0.1 ms = **15.7 ms**

2. Given 10 Barracuda 180 disk (in the above problem 1), calculate the effective storage capacity (the storage size that can be used to store data excluding the parity or backup) of RAID 0, RAID 1, RAID 4, and RAID 5 of 10 such disks.

10 disks, each with capacity of 180 GB

RAID level	Effective Storage Capacity
0	N x C = 10 disks x 180 GB = **1800 GB**
1	(N/2) x C = (10/2) x 180 GB = 5 x 180 GB = **900 GB**
4	(N-1) x C = (10-1) x 256 GB = 9 x 180 GB = **1620 GB**
5	(N-1) x C = (10-1) x 256 GB = 9 x 180 GB = **1620 GB**

3. Explain block storage, file storage, and object storage in cloud computing environment.

Storage types	**Characteristics**	**Performance**	**Access method**
Block storage	Operate at the operating system kernel level, and the data is stored and organized as an array of blocks	Data is stored without any concept of data format or type	Over the network as a Storage Area Network (SAN) using protocols such as iSCSI
File storage	Operate at the operating system user level, and the data is stored as data blocks which are managed by a file system	Data is managed as a named hierarchy of files and folders. Files have meta-data associated with them (such as file name, type, and creation date)	Over the network as a Network Attached Storage (NAS) using protocols such as Network File System (NFS) or Common Internet File System (CIFS), HDFS.
Object storage	Operate at the application level, and the data is stored as objects	Each object consists of an object identifier (OID), data, and meta-data	With protocols such as HTTP using REST APIs

4.

1) Given 8 hard drives, construct a RAID 5, how many disk failure can this RAID 5 tolerate?

RAID 5 uses striping with parity. It can tolerate **1 disk failure**, as it distributes parity information across all drives. If a single drive fails, the parity allows reconstruction of the lost data.

2) Given 8 hard drives, construct a (8,6) erasure code system, how many disk failures can this erasure code system tolerate?

The system can tolerate up to 8 – 6 = **2 disk failures** while still being able to reconstruct all the data.

3) Calculate the storage efficiency of the above RAID 5 and erasure code system. (The storage efficiency is the percentage of the storage system that can be used to store the data
excluding parity or backup).

RAID 5: 8 total disks – 1 disk for parity & 7 data disks

Storage efficiency = $\frac{\#\ data\ disks}{Total\ disks} \times 100\% = \frac{7}{8} \times 100\% = \mathbf{87.5\%}$

Erasure code system: 8 total disks – 2 disks for parity & 6 data disks

Storage efficiency = $\frac{\#\ data\ disks}{Total\ disks} \times 100\% = \frac{6}{8} \times 100\% = \mathbf{75\%}$