Question01:

$$T = \frac{b}{M - r}$$

where;

b = size of bucket (in bytes)

r = rate of bucket (in bytes/second)

M = maximum output (in bytes/second)

Question02:

a. AWS Direct Connect provides the functionality of connecting on-premises compute resources with the AWS cloud via a dedicated and secured connection. In a nutshell, it can help connecting a company private cloud with AWS public cloud. [see 1]
   AWS Direct Connect Pricing: [see 2]
   Pricing depends on the following components:
   a. Capacity: Maximum rate with which data can be transferred through the connection.
   b. Port Hours: The time a port is provisioned for use within AWS, it has two types;
      i. Dedicated Connection: physical connection between your network port and AWS port inside AWS Direct Connect Location.

   Port hours: Dedicated Connections

   Port hour pricing for dedicated connections is consistent across all AWS Direct Connect locations globally, except in Japan. The table below lists the port hour price by dedicated connection capacity selected.

Capacity	Port hour rate (Excluding Japan)	Port hour rate in Japan
1 Gbps	$0.30/hour	$0.285/hour
10 Gbps	$2.25/hour	$2.142/hour
100 Gbps	$22.50/hour	$22.50/hour

      ii. Hosted Port: logical connection that AWS Direct Connect Delivery Partner provisions on your behalf

Port hours: Hosted Connections

Contact an AWS Direct Connect Partner to order Hosted Connections. Hosted Connection port hour pricing is consistent across all AWS Direct Connect locations globally with the exception of Japan. The table below lists the port hour price by hosted connection capacity selected.

Capacity	Port hour rate (Excluding Japan)	Port hour rate in Japan
50 Mbps	$0.03/hour	$0.029/hour
100 Mbps	$0.06/hour	$0.057/hour
200 Mbps	$0.08/hour	$0.076/hour
300 Mbps	$0.12/hour	$0.114/hour
400 Mbps	$0.16/hour	$0.152/hour
500 Mbps	$0.20/hour	$0.190/hour
1 Gbps*	$0.33/hour	$0.314/hour
2 Gbps*	$0.66/hour	$0.627/hour
5 Gbps*	$1.65/hour	$1.568/hour
10 Gbps*	$2.48/hour	$2.361/hour

c. Data Transfer Out (DTO): cumulative network traffic sent out of AWS through your AWS Direct Connect Location.

To Direct Connect Location in: ↓↓↓↓	Contiguous United States*	Hawaii	Canada	Europe	Asia Pacific (Tokyo, Osaka)	Asia Pacific (Seoul, Singapore, Hong Kong, Bangkok)	Asia Pacific (Indonesia)	Asia Pacific (Manila)	Asia Pacific (India)	South America (Sao Paulo, Mexico)	Asia Pacific (Australia, Auckland)	Middle East (Bahrain, Israel, UAE)	Africa (Cape Town, Lagos)
Contiguous United States	$0.0200	$0.0350	$0.0200	$0.0282	$0.0900	$0.0900	$0.1062	$0.1062	$0.0850	$0.1500	$0.1300	$0.1100	$0.1100
Hawaii	$0.0350	$0.0200	$0.0350	$0.0432	$0.0900	$0.0900	$0.1062	$0.1062	$0.0850	$0.0165	$0.1300	$0.1260	$0.1260
Canada	$0.0200	$0.0350	$0.0200	$0.0300	$0.0900	$0.0900	$0.1062	$0.1062	$0.0850	$0.1500	$0.1300	$0.1100	$0.1100
Europe	$0.0200	$0.0350	$0.0300	$0.0200	$0.0600	$0.0900	$0.1062	$0.1062	$0.0850	$0.1107	$0.1300	$0.1000	$0.1100
Japan	$0.0491	$0.0491	$0.0500	$0.0600	$0.0410	$0.0420	$0.0547	$0.0547	$0.1132	$0.1700	$0.1132	$0.1500	$0.1700

If I own a Datacenter in Sapporo, Japan, I would opt for Equinix Inc. [3]

Quality of Service [see 3]
All Equinix Data Centers are equipped with:

a. Reliability: They deliver predictable performance and User Experience by leveraging low latency, high bandwidth connections.
b. Compliance: Enhanced compliance, sovereignty and privacy by specifying the location of your data via private, direct connectivity rather than public internet
c. Flexibility: Maintain private cloud and sensitive data in secure Equinix Data Centers.
d. Options: Choose between a Dedicated or Hosted Connection.
e. Low Latency: Reduce latency to as little as 1 millisecond per roundtrip

b. With AWS Direct Connect, business have the flexibility to choose either a 1Gbps or 10Gbps dedicated network connection between the AWS Direct Connect Location and AWS. This dedicated connection has the feature to be partitioned into a finite number of logical connections using Industry Standard 802.1QVLANs [5]. By doing so, this logical segregation

can help you create multiple connection such as objects stored in AWS S3 via a Public IP or an EC2 instance isolated in a VPC in a private subnet.

Question03:

The approach to using AWS Direct Connect with AWS VPC can be done using Private Interfaces, but this approach has a few pre-requisites:

- Installation of VPG (Virtual Private Gateway) in each VPC (OR)
- Single Direct Connect Gateway is configured to access all VPC(s)

After the completion of pre-requisite, below steps should be followed to connect VPC with Direct Connect.

1. Access AWS Direct Connect from AWS Management Console.
2. In the virtual interface section, go to Create Private Interface option.
3. Create the interface with:
    a. Name for private interface.
    b. Select AWS Direct Connection to be used.
    c. Specify the type of Access which you configured as part of pre-requisite i.e. VPG or Direct Connect Gateway
    d. Specify the account ID for the owner of Interface (it can be your account ID, or some third-party account which owns the interface)
    e. Select the VLAN id.
    f. Enter the BGP ASN number of on-premises peer router.

Question04:

a. The use of NAT in AWS Direct Connect Service is to allow instance isolated in private subnet to access internet, this access can be made for the purpose of data communication, software patches, etc. but to limit the connection initiation from within the instance running in private subnets, NAT is used, so that devices running in private subnets can access internet by initiating connection, but no one can initiate connection with the instances. The use case where NAT should not be used if the device making a connection needs to send out data directly into the internet without the use of any middleware. Example can be instance that requires the use of static IP addresses.
b. NAT Box maintains a total of 65,536 connection ports. But since the first 4,096 ports are reserved, it brings the total of valid connection ports to be 65,536 - 4,096. And each port can handle up to a specified number of connections simultaneously.

Question05:

a. AWS VPC and Direct Connect both reside in different AS, and to make different AS routing possible, an external routing protocol is required which is Border Gateway Protocol.

b. Yes, we can use our own Autonomous System Number (ASN).
c. There are 5 different RIR. Since our datacenter is in Japan, we will go to Asia-Pacific Network Information Center (APNIC)
d. BGP is external routing protocol which advertises its address to external router to enable cross-AS communication. Following security risk can arise:
    a. Since the address is advertised, AS can be exposed to possible DDoS attach by allowing unknown traffic to flow within the network. This can be mitigated using BGP-AS [7] validation, this feature allows the to validate the AS from which the request originates and decide based on pre-configured rules whether or not to allow the traffic to flow through.

Question06:

$$Distance\ between\ datacenters = 20\ km$$

$$Speed\ of\ Two\ dogs\ (Alpha\ \&\ Beta) = 15\frac{km}{h}$$

$$Time\ taken\ to\ travel\ from\ 1\ datacenter\ to\ another = \frac{20}{15} = 1.33hr => 4800s$$

$$Each\ dog\ can\ carry = 30 * 3 = 90GB\ of\ Data\ (90,000\ Bytes\ of\ Data)$$

$$Data\ Rate = 90,000 * \frac{8}{4800} = 150Mpbs$$

Therefore, dogs provide the same service as renting pipes.

References:

[1] https://aws.amazon.com/directconnect/

[2] https://aws.amazon.com/directconnect/pricing/

[3] https://www.equinix.com/

[4] https://www.equinix.com/partners/aws

[5] https://aws.amazon.com/directconnect/faqs/?nc=sn&loc=6

[6] https://docs.aws.amazon.com/directconnect/latest/UserGuide/virtualgateways.html

[7] https://www.juniper.net/documentation/us/en/software/junos/bgp/topics/topic-map/bgp_origin_validation.html#:~:text=a%20TCP%20connection.-,Overview,authenticate%20prefixes%20or%20prefix%20ranges.