Understanding JWST detectors questionnaire
(some questions have JDox links you might want to check).

1. What is the difference between the JWST NIR and MIR detectors?

The main difference between NIR And MIR detecors is the wavelength coverage and the material from which the detector is made. The NIR detectors are mercury-cadmium-telluride detectors that are sensitive from 0.6 out to 5 microns. The MIIR detector is a doped silicon:arsenic detector and is sensitive from 5 to 28 microns. The MIRI detector also has less pixels 1024 x 1024 instead of 2040x2040, which is what the NIR detectors have.

2. What is the fundamental difference between a CCD and a JWST detector readout?

In a CCD every readout is a hard destroy of the pixel values because charge is transferred between pixels. With a CCD, at the end of the readout register is an amplifier that measures the charge of the pixel and converts it to a voltage. There is just one readout amplifier for the entire array, so charge has to be transferred from one pixel to the next. On the bottom row you have the readout register and charge is moved from one pixel to the next toward the amplifier where each pixel's charge is read as a voltage. After the bottom row is read out, all the other pixels have their charge transferred down into the next row below and the process basically repeats, with each pixel being read individually and charge being transferred from one pixel to the next. There is no multireading of an array for a CCD. They are charge transfer devices.

For a near-infrared detector, charge transfer does not work. Instead each pixel has its own readout amplifier. Since there is no charge transfer, and each pixel has its own amplifier, you can read voltage for each pixel throughout the process of observing without destroying the charge that is accumulating. This is called a non-destructive read. To take full advantage of this ability, all the cameras on JWST operate in Multiaccum mode, where the charge in each pixel is read out multiple times as it accumulates charge during the integration.

3. What is a frame?

A frame is a single read of all the pixels in the detector array or subarray.

4. What is a group?

A group is the average of a number of frames. Only the group image will be downloaded by the telescope, the frame images used to create the group are not saved. This is important to not exceed memory storage issues.

So in Figure 3 of the homework document you have 3 groups in 1 integration, consisting of 4 frames each. JWST will take those 4 frames and average them to create one image (the group) and the group image is the only image downloaded. We lose the individual frames! So if we want information up the ramp, we are going to want multiple groups in a given integration. This may be why one group is not allowed.

5. What's the meaning of "group gap" or "dropframes" in the JWST NIR detectors?

These are frames that are ignored during the integration and are not read out or included in the average to create a group frame. During the creation of a MULTIACCUM mode you can determine the numbe of frames to be dropped. It could be 1 or 2, ore more. The only reason I think you would want to do this is if there are memory issues. You can decide the number of frames to drop at the beginning (DROPFRAMES1), the number to drop within the groups (DROPFRAMES2), and the number to drop at the end of the integration (DROPFRAMES3). For NIRISS readout there are no dropped frames and there is 1 reset at the beginning of each integration. See pages 77 and 78 below.

https://jwst-docs.stsci.edu/download/attachments/73024566/JWST_NIRISS_Documentation.pdf?version=1&modificationDate=1567791421365&api=v2

6. What is a reset?

Typical reset of any detector. Array is read out, pixels stop accumulating charge, and everything resets back down to the bias level. Resets are done between exposures and between integrations

7. What is an integration?

An integration is a set of groups. Each group frame is downloaded, and this gives me the ramp up to the final counts of the full integration. So I could integrate for 3 minutes, using 6 groups of 30 seconds. (Ignoring overhead). Then reset, and start another integration.

Integration times should not be so long that the target we are observing saturates the detector.

8. What is an exposure?

A set of identical integrations, separated by resets. So in the example above I could have an exposure of 9 minutes, consisting of 3 integrations, each consisting of 6 groups, each of which would have some set of frames being averaged to create the group image.

Be aware that each dither position is its own exposure! So you would complete an exposure before dithering to a new location on the detector and then repeating the exposure in the same filter. Also you cannot change anything in the exposure. Must be same location on detector (no dither), same filter, set number of groups and set number of integrations.

9. Suppose you have data from a CCD and from a JWST detector. They both reach the saturation level in one-half of the total integration time. Can you describe what the main difference is? Can you recover information in the saturated pixels?

In a CCD the image is toast! There is no recovery of the information in the pixels because there is just one readout. But with the JWST detector, you are in MULTIACCUM mode. That means that during the integration, you are continuously sampling the charge in the pixels. So each group image will have the average flux from the frames that make up the group. Looking at Figure 2B in the example, you can see the blue unsaturated groups and the red saturated groups. Because you have the individual group images, you can determine at which point the saturation occurred, and then ignoring all of the saturated groups, you can fit a function to the ~ linear increase in flux of the pixel from the unsaturated groups and determine what the final flux would have been in the pixel had it not saturated and use that value. Therefore you do not lose information and effectively increase the dynamic range of your detector to get signal for both bright and faint objects in the field of view. Yes you recover!

10. What will be the impact of a cosmic ray in a JWST integration? Can information be recovered?

When a cosmic ray hits, you will get an uneven jump in the charge in the pixel between two of the group reads. This produces a discontinuity in the ramp as seen in Figure 2A. Again this information can be recovered. Two possibilities. If the cosmic ray occurs relatively late in the exposure, then follow the same procedure you would follow for a saturated pixel since the addition of the last 1 or 2 groups will not contribute much.

Or, take both of the semi-ramps that form because of the CR hit, and piece back together the two semi-ramps to determine what the final flux in the pixel should have been. In this way, the information is recovered. Note that adjacent pixels will also be affected by a CR due to signal cross-talk and will also need to be corrected.

11. a) What is the practical difference between a MIRI SLOW mode exposure and a NIR exposure with NFRAMES=8?

b) Which has a higher data rate: a single MIRI Si:As detector running in SLOW mode or a single NIRCAM H2RG detector using the MEDIUM8 readout pattern?

https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-instrumentation/miri-detector-overview/miri-detector-readout-overview/miri-detector-readout-slow

https://jwst-docs.stsci.edu/observatory-functionality/jwst-data-rate-and-data-volume-limits

First just a side note, you cannot exceed 58.8 GB of science in a 24 hour period, so need to keep the memory issues in mind when planning observations and how many groups are actually being stored. Ideally, need to keep the data volume under 28.2 GB in a 12 hour period.

(a) The main difference is that MIRI Slow drops the first frame, and then averages the next 8 frames in the group. SO there are actually 9 frames in the MIRI Slow group. Dropping the first frame provides time for the pixels to settle between reads.

(b) If I am reading the website correctly, and looking at the limits for Medium8 with time betwee groups of about 100 s, you would generate 68 GB in a day with both modules. So using only one of the two modules would use 34 GB in a day. There is no information o MIRI in slow mode. NIRCam does have 4 amplifiers, so you could reduce the datea rate more by only reading one of the amplifiers. (Select Noutputs = 1).

12. Given a certain readout pattern, why is the group time different for full and subarray mode?

https://jwst-docs.stsci.edu/near-infrared-camera/nircam-instrumentation/nircam-detectors/nircam-detector-subarrays

Because the total readout time is shorter for a given frame in a subarray. So if I have a group that consists of 4 frames, in the subarray if the readout time for a frame is 1 second, then the time to get one group will be 4 seconds. In the full frame, if the readout time is 10 seconds for one frame, then it would take 40 seconds to get the same size group. Ten times longer. So it is because I can obtain frames at a much faster cadence.

13. If a user defines a single NIRCam exposure (i.e. no dithers) with all modules in FULL array and BRIGHT1 readout pattern, that uses 10 groups and 1 integration, the exposure time is 203.99 second. 10 groups and 2 integrations result in 418.73 seconds.

Why the total time of 2 integrations is not twice as long as one? Can you guess why that would not be the case for MIRI?

There is an extra 10 seconds that occurs to readout and reset the array between the two integrations. I calcualted that from Table 2 Exposure Overheads.

For MIRI, every exposure begins with a read-reset. The pixels are reset by row pairs. So for example row 1 and 2 are read and then reset, row 3 and 4 read, and reset, etc. This means that the read takes place right before the reset and the overhead time between integrations is basically negligible.

https://jwst-docs.stsci.edu/jppom/visit-overheads-timing-model/instrument-specific-overheads/nircam-overheads

Additional notes to myself:

When specifying what set-up we want for the observations, need to be aware of options.

Subarray – we can select smaller arrays on the camera to achieve faster readounts. Important where saturation can be an issue due to background sky.

Frame – a single read of all the pixels in the detector array or subarray

Group – a group is the average of a number of frames. So in Figure 3 you have 3 groups in 1 integration, consisting of 4 frames each. JWST will take those 4 frames and average them to create one image (the group) and the group image is the only image downloaded. We lose the individual frames! So if we want information up the ramp, we are going to want multiple groups in a given integration. This may be why one group is not allowed.

Drop/Skip frames – these are frames between the groups that are sampled but not included in the group average

Reset - typical reset of any detector. Array is read out, pixels stop accumulating charge, and everything resets back down to the bias level. Resets are done between exposures and between integrations

Integrations - An integration is a set of groups. Each group frame is downloaded, and this gives me the ramp up to the final counts of the full integration. So I could integrate for 3 minutes, using 6 groups of 30 seconds. (Ignoring overhead). Then reset, and start another integration.

Integration times should not be so long that the target we are observing saturates the detector.

Exposure – A set of identical integrations, separated by resets. So in the example above I could have an exposure of 9 minutes, consisting of 3 integrations, each consisting of 6 groups, each of which would have some set of frames being averaged to create the group image.

Be aware that each dither position is its own exposure!

Readout Pattern – This would be combination I described above of averaging and dropping frames that would define the group time

Readout Mode - scheme for reading all pixels of a detector array or subarray