Selected Response Section

Question	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
1	A	A	D	C	A	C
2	C	D	B	A	D	A
3	A	C	A	C	D	D
4	C	B	D	C	D	D
5	A	C	C	D	B	A
6	A	C	C	A	D	B
7	A	C	C	B	A	A
8	B	D	D	B	A	B
9	D	C	C	D	D	C
10	D	A	D	A	B	B
11	A	C	A	D	D	B
12	D	D	C	A	A	C
13	C	B	C	A	B	C
14	C	C	D	C	A	A
15	C	D	C	B	B	C
16	C	C	A	B	C	A
17	D	C	B	A	C	C
18	A	B	B	C	C	A
19	C	B	C	D	A	B
20	D	C	D	D	D	B

OPEN RESPONSE SCORING

This document includes benchmark answers to guide the scoring of the open response items on the *Earth/Space Science* DTAMS assessments. These are items numbered 21 – 25, each with part (a) and part (b).

Part (a) is scored on a scale from 0 – 1
Part (b) is scored on a scale from 0 – 2

This document includes general guidelines on the scoring rubric as well as specific benchmark answers to operationalize and illustrate the application of the guidelines with specific answers. These benchmark answers are actual answers from the initial round of field testing the assessments. Commentary after many of the benchmark answers is included describing the rationale for why particular benchmark answers received particular scores.

Also included immediately after each question are several paragraphs of background science content information to ensure scorers have a solid grasp of the relevant science so that they can better assess testtaker answers that fall outside the scope of this selected list of benchmark answers. This background information is written in lay terms with the goal of conveying the underlying concepts to scorers who may not have a strong content background in a particular area.

General Guidelines

This section provides an overview of the scoring rubric in general terms.

Part (a) 1 point for correct responses appropriately including keywords or phrases specifically related to the misconception. See sections below for lists of terms to look for with each question. If keywords or phrases are not appropriate, a point is still awarded for an accurate description of the central concept(s) at the core of the student misconception.

Part (b) 1 point each, up to 2 points total for responses which:

- Actively engage students in exploring concepts related to the topic. Which concepts are appropriately related to the topic is a function of each different item, requiring judgment calls informed by the benchmarks or criteria in the specific rubric of each question. Must have both parts (*active engagement, related*) for this 1 point. Active engagement might include: investigation, experiment, laboratory, demonstration with discussion, use analogy or metaphor, provocative questioning. The answer must provide enough details to judge this quality of "active engagement" as opposed to passive student listening or watching in order to earn this point. The degree of *how related to the topic* is more fully informed from the specific benchmark answers provided.

- Specifically target the misconception rather than teaching a more general concept.

General Decision Rules

A number of issues that arise somewhat frequently are addressed in this section. These decision rules reflect the consensus of the test development group and are applicable for all content areas. They apply across both parts (a) and (b) of the open response questions.

1. Incorrect terminology* doesn't automatically preclude earning points if the underlying concept is correct (e.g., referring to North & South poles as "charges" or misusing "velocity" instead of "energy") and the misuse is not directly targeting the intended content understanding.

**Terminology misuse that indicates lack of the targeted knowledge would earn ZERO. The context of the question and particular terminology misused is central to determining the relevance of the misuse.*

PART (a)

2. If part (a) makes 2 or more statements, ONE of which is right and the other which is scientifically wrong, score that as a ZERO if the incorrect statement contradicts the correct answer. Otherwise, the correct answer overrides the incorrect and scores a ONE.

3. Simply stating a law (e.g., Conservation of Energy or Newton's 1st Law) is not enough to earn a point – the response must describe the application of that law in the context of the question's scenario.

PART (b)

4. If the answer in part (b) indicates knowledge asked for in part (a), then go back and give part (a) credit even if the answer written in part (a) isn't satisfactory or even if (a) is blank, with the exception if part (a) directly contradicts the correct answer.

Comment: The most difficult part of the scoring guide seems to be that, for 1 point out of 2 in part (b), the problem is identifying if the experiment or demo etc. is relevant enough to earn a point. It is relatively easy to judge "active engagement" and relatively easy to judge "specifically target the misconception." Use the specific benchmark answers for guidance on what is "relevant enough."

21. While on a field trip at a rock quarry, your students argue that the folded rock layers they see are evidence that rocks were a lot softer when they folded in the ancient past than they are now.

(a) Please describe the currently accepted scientific explanation of the phenomenon that the students are not understanding. (See directions at beginning of the open response section for more detailed directions.)

NOTE: This specific question from version 1, but similar concepts underlie other versions.

Background Information – Item 21

Core concepts (across versions): Mountain & Canyon Formation, Uniformitarianism

Earth is constantly changing -- building up and tearing down. Based on the principle of uniformitarianism, forces and rocks are the same now as in the past; there is no reason to think that they were different.

Tectonic plates are in motion now as in the past. When tectonic forces put stress on rock layers, the layers may break (earthquakes, creating fault-block mountains) or the heat and pressure can cause the layers to bend or fold. The heat makes the rocks more pliable. This usually happens at convergent boundaries where two plates collide. Thus folded mountains are formed when rock layers are squeezed together into large folds by heat and pressure. Folds can also be very small. Also, volcanic mountains are constantly forming. Therefore, mountains are continuing to be built. Simultaneously, weathering and erosion of rock are on-going carving canyons.

Although earthquakes and volcanoes may be sudden and catastrophic, some of these earth processes, such as folding and erosion, may be very slow--too slow for us to notice a significant difference in our lifetimes--so it does not seem to us that anything is happening.

Marine fossils were formed at the bottom of shallow seas, covered by additional sedimentation, compacted, and gradually changed into rock by pressure before the mountains were created. Later tectonic forces can cause the layers to fold creating mountains and pushing rock layers from lower levels to higher ones.

Misconceptions for this item:

Students think rocks were softer in the past because the folding is so slow they cannot see the process. They also do not realize the extremes of heat and pressure that tectonic plate interactions can generate, which can make rock more pliable.

PART (a): Benchmark answers receiving 1 point:

Core Concepts to express: To address the misconception that the rocks were softer in the ancient past, the principle of uniformitarianism should be referenced (not necessarily the term, but the idea that things in the past were happening the same as they are today).

The students do not understand that the folding of the rock layers occurs over a very long period. The same forces that cause tectonic plate movements are still acting today. Therefore, rocks were not softer in the past--they folded over a long period of time.

This includes uniformitarianism concept, "still acting today." Also references a long time frame.

PART (a): Benchmark answers receiving 0 points:

Different rock form at different times, and so when the rocks in the quarry formed they may have been different rocks than would form today.

This response misses the concept of uniformitarianism and in fact suggests that the rocks themselves may somehow change over time without any plausible reason.

21b. Explain how you would address this misconception using best instructional practices. (See directions at beginning of the open response section for more detailed directions.)

Active engagement for this response might include:

1. Having students build and use models. For example, bending a chocolate bar. By heating it over a candle and slowly putting pressure to bend it, it can be 'folded' without breaking. Alternately using clay and first heat it with your hands (body heat) compared to cold out of the refrigerator.

2. Involving students in analogies to indicate how variables like heat and length of time can be important to think about (e.g. bending a piece of metal bar is easier when it is heated with a blow torch or in a fire, and often the process is still slower compared to bending something weak like a foam pool noodle)

PART (b): Benchmark answers receiving 2 points:

We could set up a lab that would allow students to see how compressional forces could bend layers of rocks by using many types of models such as layers of clay, stacks of paper. I could also get some materials--perhaps large cookies & demonstrate that if you bend them quickly they may break but if bent slowly they will fold without breaking. Include in the discussion the idea that as far as we know, rocks today are the same as they were in the past.

Active engagement for students. Intent to highlight key aspects such as the issue of how long time periods can be involved in changing of the rocks. Uniformitarianism expressed in last sentence.

PART (b): Benchmark answers receiving 1 point:

I would first discuss with the class the mechanism of seafloor spreading and how it causes tectonic plates to shift. …I would also show them visualizations of the process, including the forces of compression, tension and shear stress. The students would then model a block of rock layers with different colors of clay, showing what happens with each of these forces.

Students are actively engaged in activities broadly related to the target concepts, including some of the forces involved. The activities do not specifically target the misconception since students may end up thinking the clay is like the ancient, soft rock rather than serving as a model for thinking about how the heat/pressure can cause the phenomenon observed even with "hard" rocks like today.

PART (b): Benchmark answers receiving 0 points:

I would go through stages showing the students rock layers from different regions. I would show them how they can be different because of location. Then I would show them different minerals and rock layers that could have folded rock layers.

The proposed activity does not explicitly engage students actively (unclear what students are doing) and is not directly targeting the key concepts since it only targets superposition (newer rocks on top of older).

Find websites for the student to go to and research.

Activity is too general.

22. Your students assert that deserts are created in coastal areas because ocean salt water is being evaporated and deposited as rain on the ground, thus making the soil salty and infertile.

(a) Please describe the currently accepted scientific explanation of the phenomenon that the students are not understanding. (See directions at beginning of the open response section for more detailed directions.)

NOTE: This specific question from version 1, but similar concepts underlie other versions.

Background information – Item 22

The water cycle includes the continuous movement of water in the atmosphere and in the ground. Water evaporates from oceans, rivers, lakes, etc.(and leaves any salt or sediment behind), can be retained in the atmosphere for a long time as a vapor, moves around globally according to wind patterns, eventually precipitates (in several forms-rain, snow, hail), can go into creaks/rivers/oceans OR can seep into the ground and become part of underground aquifers; is absorbed by living things and transpired. All processes happening all the time all over the earth on land and sea.

All the water in the atmosphere is "fresh" water since it comes from evaporation. Wind blows clouds in all directions. The water is diffused throughout the atmosphere and not limited to specific locations nor only in clouds. Since only water evaporates from the oceans, i.e., changes from a liquid to vapor state, rain is not "salty." Water that is evaporated into the atmosphere is then dispersed and may travel across continents or around the world before condensing and forming rain.

Runoff from precipitation is the primary cause of fivers. Runoff collects in gullies that merge to form streams that merge to form rivers, etc. The major source of water in rivers is from precipitation, not from groundwater emerging from springs.

Water does flow from the ground as springs where the water table meets a sloping ground surface. Groundwater soaks through soil and permeable rock until it reaches a layer of rock which does not allow the water to pass through it (impermeable rock layer). The groundwater then moves across the top of the impermeable layer in whichever direction it is sloping. Where erosion has cut down through this layer and exposed it, the water flows out onto the surface creating a spring.

The scenario may cause some to focus on formation and characteristics of deserts, which is reasonable given the scenario, but the underlying intent of this item is to target water cycle concepts. Thus, a few background notes about deserts are included, but testtakers do not need to respond about desert formation to earn the points for this question.

Deserts are formed where there is little rain, lack of water, which is the defining characteristic of deserts (not "infertility," for example). Deserts are not necessarily hot.

Deserts can occur near the coast for several reasons. For example, coastal mountains can create rain shadows. Moist ocean air blown over a mountain island cools, condenses, precipitates and then the air is left dry as it descends the mountain on the other side (orographic effect). But mountains are not necessary for air to rise. Air rises because hot air has less pressure than cold air. Also, the mountains do not lift the ocean air, the wind blows it. The mountains act as barriers. The wind can only go up, and so it cools and drops the moisture it might be holding, so that on the back side of the mountains the air is dry and it rarely rains (hence, a desert).

Although hot desert soils can be quite saline (salty), this condition is the result of water evaporating from the soil leaving behind impurities that it had previously dissolved from lower in the soil profile. Saline soils are indeed less fertile than non-saline soils, as a general rule.

Misconceptions of students embedded in this scenario:

1. They think that salt is evaporated along with water and becomes a component of rain water (connected to misunderstanding of water cycle)
2. They think that rain is deposited adjacent to the source of evaporated water (connected to water cycle misunderstanding as a local phenomenon rather than global)
3. [***optional***] They think that deserts are formed from infertile soil (connected to concepts of weather and biomes)

PART (a): Benchmark answers receiving 1 point:

Core Concepts to express: Conceptions related to water cycle and contribution to weather. Response should include at a minimum misconceptions #1 and #2 identified above. (1) Response should include idea that water evaporates but leaves behind salt (and sediment, etc.). (2) After water evaporates, it does not necessarily fall adjacent to the ocean; it can travel great distances through the atmosphere before it returns to the surface as some form of precipitation.

Misconception #3 is optional since the target concepts for this question are about how water cycle functions as part of Earth's atmosphere/hydrosphere – connections to biome of desert not required.

The salt in the water is not evaporated with the water. It is what's left after the evaporation process. Plus once evaporated, the water can travel long distances and not just to coastal areas.

This response includes the two key misconceptions.

Rainwater does not include salt – it is fresh water. Rainwater can come from many different places, not just nearby.

This response is less detailed than the prior, but still includes the core concepts that are adequately clear to earn the point.

PART (a): Benchmark answers receiving 0 points:

Deserts are formed due to lack of rainfall & soil erosion.

This response misses both misconceptions about water cycle. The first part about deserts due to low rainfall is accurate but "soil erosion" is irrelevant in this scenario, but this is not the targeted misconception and so doesn't earn the point.

The student is thinking the salt is causing the ground to be infertile.

This response is merely restating the student's statement. Salt could render the ground infertile, which is not a misconception, and this misses water cycle misconceptions.

Evaporated ocean water leaves the salt behind and so deserts aren't necessarily salty.

This response does include the first aspect of the misconception, but does not address the second aspect of water cycle being global, and need to have both parts to earn this point.

22b. Explain how you would address this misconception using best instructional practices. (See directions at beginning of the open response section for more detailed directions.)

Active engagement might include: Students evaporating salt water collecting the vapor with a cooled (iced) piece of slanted glass sheet above so that the vapor condenses on the glass and runs into a cup. Students observe the salt left behind, plus possibly testing the evaporated water with taste test to note it is not salty. Connect this to Earth water cycle. To help students note that water cycle is global and not local, students can observe global or continental maps and average annual rainfall to note that rain falls far from large bodies of water like oceans or Great Lakes. Note wind patterns, and students create argument from this evidence that evaporated water can travel long distances before precipitating as rain.

PART (b): Benchmark answers receiving 2 points:

Students build a model of ocean water by dissolving table salt in drinking water, then evaporate that salty water with a hot plate. They observe (and taste) the salt left behind. They catch some of the evaporated water with a glass pot lid (brought from home if they have one, else I have a few to loan) so the steam condenses back to drops of water. They use a finger to taste a drop and see it isn't salty. To note that water cycle means water vapor travels long ways, watch selected weather reports (I choose) that shows how wind in the center of the USA far from oceans is bringing a thunderstorm. They use all of this evidence to write a short description of water cycle that includes evaporating, leaving salt behind, and moving over long distances before raining down.

This response include all aspects described above, and students are actively engaged.

PART (b): Benchmark answers receiving 1 point:

Evaporate salt water in a Petri dish in the classroom to observe the left over salt.

Beginning of a good pedagogical idea, but incomplete (what are students doing? How

are they connecting this to the scenario?) Plus this is missing the global nature of water cycle.

Have students research different deserts locations and compare results. See that deserts are not only on the coast. Have them find how to create rain barrels on the internet, and explain that rain barrels catch rainwater which is useful for gardens, flushing toilets, and other things because it is fresh water, not salty.

Students are actively engaged in tasks that are at least related to the core misconceptions and so earns 1 point. This is a bit disjointed, and the first part about deserts isn't the target misconception even though it is correct. The connection of the rain barrels to scenario is not clear, and missing global nature of water cycle.

PART (b): Benchmark answers receiving 0 points:

Teach the water cycle so the student understands that the salt is not carried back up into the clouds and causing infertile soil.

One aspect of the core set of misconceptions is accurately included but not a targeted activity to engage students. "Teach" is too vague about what teacher and students are actually doing.

Test several different items (by planting) and see if they will grow (experimentation).

Active student involvement but not related to the targeted misconception.

Find information from the textbook or internet to clear up the misconception

Too vague, not targeting the misconception, and no student engagement.

Use regular salt and water on a small tray. Set it in the window to show how the water is either absorbed [?] or evaporated leaving the salt to absorb and fertile ground.

Beginning of an appropriate idea, but description is unclear what students are doing or what is meant by the water being "absorbed." No connection to scenario and combination of lack of clarity and follow-up or connections means this response is scored a zero.

23. Your students believe that the chain of Hawaiian Islands was formed because a mid-oceanic ridge exists at that location in the Pacific Ocean.

(a) Please describe the currently accepted scientific explanation of the phenomenon that the students are not understanding. (See directions at beginning of the open response section for more detailed directions.)

NOTE: This specific question from version 1, but similar concepts underlie other versions.

Background information – Item 23

The core concepts for this item relate to the layers of the Earth and plate tectonics. The crust of the earth is mostly rock, and tectonic plates are segments of the crust (the crust is also called the "lithosphere" in terms of study of geospheres that include atmosphere, hydrosphere, sometimes biosphere (also known as biology in terms of a high school course). Most continents are made up of thin layers of sedimentary rock that covers mostly granite-like rocks. The ocean crust is mostly basalt rock covered with layers of sediments. Below the crust is the mantle, which includes some molten rock (magma). Sometimes there are pockets of liquid magma that push up all the way through the crust (volcanoes, for example) where the crust may be particularly thin or two plates are interacting at their edges. High heat creates pockets of molten rock (magma) at plate boundaries, and sometimes large plumes of upwelling magma create "hot spots" by melting some of the solid rock on the bottom of the crust in that location, eventually sometimes even reaching the surface (a volcano). These hot spots can occur in other parts of a tectonic plate other than the edges, such as near the center.

The mantle (below the thin crust) is often thought of as divided into two parts. The upper part of the mantle is called the Asthenosphere. It is a plastic-like thick fluid because of heat and pressure melting the rock. This is where the mantle convection currents (very slow currents by human standards – centimeters per year) occur that move tectonic plates slowly over time.

The core of the Earth is also divided into two parts. The outer core is thought to be a very hot liquid (heat and pressure again) composed mostly of iron and nickel. Earthquake S-waves do not pass through this liquid layer and that's how scientists have inferred the existence of this liquid portion of the core.

The inner core is a solid that is composed mostly of iron and nickel – at this depth, the pressure is so great that it 'overcomes' the high temperature in terms of not melting the iron.

Many volcanoes occur at diverging plate boundaries, which is also where mid-oceanic ridges form – these ridges are created by magma welling up to 'fill in' where the plates are pulling apart.

Although the Hawaiian islands (and adjacent submerged seamounts) are volcanic and created in a string they are not at a plate boundary or mid-oceanic ridge (since those ridges are created at plate boundaries where the plates are diverging). Rather, Hawaiian islands are created by magma welling up from the mantle to break through the crust in the middle of a plate (a "hot spot"), and as that plate moves very slowly over centuries, the hot spot moves and new islands are created in a string over time.

Misconceptions of students embedded in this scenario:

1. As part of study of tectonic plate movement and relationship to phenomena such as earthquakes and volcanoes, students should have become familiar with the "Ring of Fire" in Pacific Ocean. And note (from image teacher projected) that Hawaii is in the middle of this plate, not an edge. So first misconception is that mid-oceanic ridge can occur in the middle of a tectonic plate.
2. Second misconception is that mid-oceanic ridges are the only places where magma rises to the surface – not considering that thin places in the crust or underlying hot plumes of magma can 'melt through' at other places ("hot spots").

PART (a): Benchmark answers receiving 1 point:

Core Concepts to express: (1) Mid-oceanic ridges form at plate boundaries, not the middle of a tectonic plate (and explain how they are formed to support this point). (2) A explanation (broadly – not necessary for lots of detail) about "hot spots" to include idea that magma can push through crust in places other than plate boundaries, which is what happened to form Hawaii.

The Pacific Plate is slowly moving in a N.W. direction over a hot spot in the mantle allowing magma to force its way through the crust creating volcanoes that build into islands. As the plate moves the volcanic area moves off the hot spot and the new area starts a new volcano--chain of islands form.

Conveys the core concepts. The idea that "mid-oceanic ridges are at plate boundaries" is not explicitly conveyed, but from the phrase 'force its way through the crust' we can infer this concept and award the point.

PART (a): Benchmark answers receiving 0 points:

The Hawaiian Islands were formed from volcanoes. The volcanoes erupt, the lava runs down, and as the lava cools, then it turns into rock, this keeps happening ad eventually the islands or land form.

This is correct information, but does not address what the student is saying (they are not describing HOW the islands formed, but rather WHY (the underlying mechanism).

23b. Explain how you would address this misconception using best instructional practices. (See directions at beginning of the open response section for more detailed directions.)

Active Engagement might include:

Students using maps to identify plate boundaries and mid-oceanic ridges, noting relationship and that Hawaii is in the middle of a plate. Students then asked to describe how mid-oceanic ridges form (can use textbook, internet, etc.) and use this description to explain why they are at plate boundaries. Students could also build a model to illustrate/demonstrate the upwelling of magma at diverging plate boundaries. For example, they could use clay to represent magma, and two

small pieces of wood to represent tectonic plates on top of the clay. Working with partners, the show the wooden "plates" slowly moving apart (diverging), and another student applies pressure from below on the clay (representing internal pressure of Earth) to show the clay oozing up into the gap and making a small mountain ridge.

They can then use this same model to illustrate hotspots – using a thin flat piece of Styrofoam as the plate, poke a hole in it (or nearly through) with a pencil to create a hotspot. Then push the clay up from below so it oozes through the hole, creating a mountain in the middle of the plate.

PART (b): Benchmark answers receiving 2 points:

1) Get a map of the ocean floor and have students locate mid-oceanic ridges.
2) Do an experiment/demonstration using 2 burners, a pan, and pudding mix. As the burners heat the pudding mixture, bubbles burst upwards forming small volcanoes.

The students are actively involved in finding the mid-oceanic ridges – ideally would also need to indicate that students are to observe location of plate edges in relationship with where mid-oceanic ridges are. For the second part, even though they are presumably watching the pudding demonstration, we can infer that they are being asked to observe (the bubbles) and make the analogical connection ("forming small volcanoes") to the scenario. So while both parts would benefit from a bit more detailed description of what students are asked to think about or make connections with, we can infer that would be happening and award full 2 points.

PART (b): Benchmark answers receiving 1 point:

I could modeling clay on a sheet of paper moving it across a stationary pencil poking through occasionally, demonstrating where the volcanoes would form creating the chain of islands that runs all the way to the Aleutian Trench in Alaska.

On the right track, especially for the hotspot aspect. However, this does not address the "mid-oceanic ridge" aspect of the misconception expressed, and so earns 1 point instead of 2.

Show on a map that the mid-oceanic ridge is in the middle of the Atlantic, not the Pacific where Hawaii is. Show a video on how mid-oceanic ridge formed, discuss in groups from their notes, and have a whole-class discussion about it.

Addresses the mid-oceanic ridge aspect adequately, but not the hotspot aspect and the formation of Hawaii.

PART (b): Benchmark answers receiving 0 points:

Find websites for the student to go to and research

Too generic and no details.

24. Your students claim that tides are caused primarily by the winds blowing water toward shore or away from shore.

(a) Please describe the currently accepted scientific explanation of the phenomenon that the students are not understanding. (See directions at beginning of the open response section for more detailed directions.)

NOTE: This specific question from version 1, but similar concepts underlie other versions.

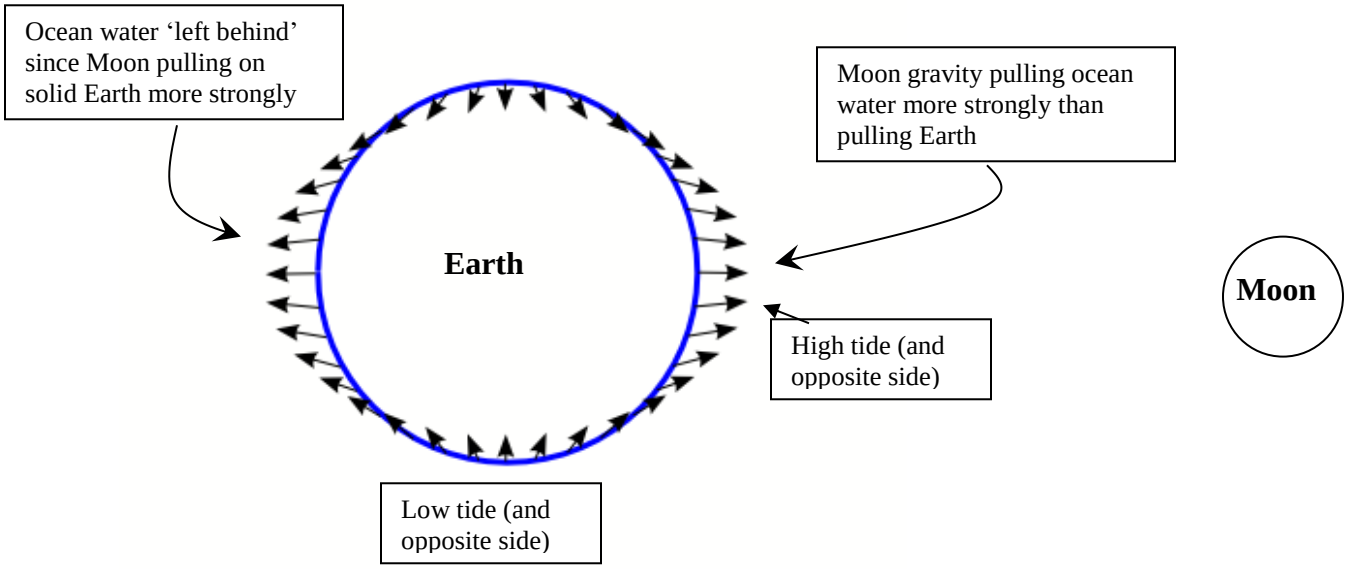
Background information – Item 24

The tide is the cyclic rising and falling of Earth's ocean surface caused by the both the gravitational attraction between the earth and the moon and the rotation of the earth.

The moon's gravitational forces pull on every particle of Earth, but the majority of the Earth is solid and it responds as a whole to this pull. The fluid components (such as oceans), however, are able to move toward the pulling body (the Moon) by flowing and distorting. The portions nearest the pulling body (Moon) move the most, thus creating a bulge. Because the Moon also pulls on the solid Earth somewhat, on the opposite side where the ocean water is farther away the water is 'left behind' creating a second bulge on the opposite side of the Earth. See picture below.

When the part of the Earth you are standing on spins into this bulge (the Earth is rotating in 1 day, much faster than the Moon is orbiting which takes about 29 days to orbit the Earth, so you can think of the bulge as essentially staying in place while the Earth rotates beneath it) it creates a high tide. When the Earth rotates away from the bulge 90-degrees (see picture below), a low tide ensues.

Tides are also affected by the gravitational attraction between the Sun and the Earth, but the effect is much less than that of the Moon because the difference in the Sun's gravitational pull from one side of the Earth to the other is much less than the Moon's.



It is not the revolution of the moon around the earth that creates the tides, but the rotation of the earth every 24 hours. As the earth rotates under the bulge, the tides move across the earth. There are some exceptions due to local topography, but most places have two high tides and two low tides each day.

Wind can affect the height of tides (e.g., a hurricane storm surge can cause a dramatic increase in tide height), but they are not the cause of tides. Waves are caused primarily by winds but also could be caused by underwater earthquakes.

Misconception of students embedded in this scenario:
Tides caused by wind.

PART (a): Benchmark answers receiving 1 point:

Core Concepts to express: Tides are (primarily) caused by the gravitational attraction between the Moon and the Earth, coupled with the Earth's rotation causing tides to move across the surface of the Earth in cyclic pattern.

Tides are caused by the gravitational pull of the moon & sun. Everything not attached to the earth (atmosphere & water) is pulled toward the moon and Sun. …Winds can add to the height of tides such as hurricanes.

Correct concept with adequate explanation about "water pulled toward…"

PART (a): Benchmark answers receiving 0 points:

Tides are caused by the slight gravitational pull of the moon.

Not enough information given – this does indicate that rather than wind it is gravitational pull of the Moon, but needs more detail to indicate how/why that is the causative agent.

Gravity-- pull and Moon phases cause high and low tides.

As above there is no (brief) explanation why gravity of Moon is responsible for tides, plus the phase of the Moon is near-negligible. NOTE: When the Moon and Sun are aligned (new Moon phase), then it is true that the combined gravitational pull is slightly stronger (and hence slightly higher tides) and when opposing (full Moon), the Sun's gravitational pull slightly negates a bit of the Moon's pull. So while not wrong to include "phases of the Moon" this is both a negligible effect and, more importantly, more detail is needed.

24b. Explain how you would address this misconception using best instructional practices. (See directions at beginning of the open response section for more detailed directions.)

Active engagement might include

1. Using mechanical forces to model the change in shape of water (water balloon) but not of solids (balls of various deformability) to **simulate** the effects of gravity on liquids (fluidity) vs solids.
2. Students prepare models or diagrams of the moon and earth as the earth rotates and how that affects the position of the tides on earth.
3. A hula hoop representing the oceans could be placed around a student with other students pulling on it to represent the force of gravity distorting the water compared to the earth. As the student in the hoop rotates like the earth, the students can see how the tides move across the earth.
4. Models with students - Example: Have one be the earth and one be the moon and four be the water on four sides. The water could hold a thin wire (made from clotheshangers, maybe) circle around the "earth" waist to simulate the surface level of oceans. The "water" closest to the moon pulls the wire slightly toward the moon showing strong attraction, creating an oval shape. The "earth" moves a tiny bit (less than the wire was pulled) toward the Moon to illustrate Earth attraction, and opposite-side water keeps wire where it is since that farthest distance ocean feels the Moon's gravity the least. You then have the two students on the sides still close to earth (because of oval shape made) showing low tides, and the other two stretched farther away showing high tide.

PART (b): Benchmark answers receiving 2 points:

[*see list of potential active engagement ideas above – any response along those lines would earn two points*]

PART (b): Benchmark answers receiving 1 point:

I would show films of the tides & of the wave actions on the earth (graphics). I could also use a rubber hose connected in an ellipse. See diagram [diagram: Student in center as Earth. Four students are holding the hose.] As the students walk around the center child, the motions of high and low tide are seen.

The students are involved in a good activity, but there is no indication how the students are to be guided to think about the ellipse shape of the hose being due to Moon's gravitational pull. Also, the center student (the Earth) should be spinning (rotating) rather than the tides following the moon around the earth. So this response includes active student engagement in related, relevant tasks, but does not directly target the misconception.

PART (b): Benchmark answers receiving 0 points:

We could use diagrams, charts, drawings to show the position of the sun, earth, and moon at each tide. We could also study Newton's law of gravity to see how mass attracts mass. Computer animation works well for this.

Too broad and non-specific about how these resources will be used, what students will do, how or what students will be guided to think about. Newton's law of gravity is not specifically relevant (just the concept of gravitational pull, no more detail needed).

25. Your students explain that the phases of the moon are caused by the earth's shadow falling on the moon.

(a) Please describe the currently accepted scientific explanation of the phenomenon that the students are not understanding. (See directions at beginning of the open response section for more detailed directions.)

NOTE: This specific question from version 1, but similar concepts underlie other versions.

Background information – Item 25

The illuminated portion of the Moon that you see (the phase) depends on its location in relationship to the Sun and Earth. The Sun always illuminates the half of the Moon facing the Sun (except during lunar eclipses, when the Moon passes through the earth's shadow, but this does not impact the phase since it is a relatively rare and short-term event of only a few hours when it happens). Since the Moon orbits the Earth approximately once a month, we see a cyclical pattern, or "phases," since we can consider the Earth-Sun positions to be essentially stationary with respect to each other while we consider only the motion of the Moon around the Earth.

Misconceptions of students embedded in this scenario:
Moon phases are caused by the earth's shadow falling on the moon. Students may be confusing this with a lunar eclipse (when the Moon does move into the Earth's shadow – relatively rare) or even solar eclipse when the Moon's shadow falls on Earth (even more rare).

PART (a): Benchmark answers receiving 1 point:

Core Concepts to express: The phases of the moon are caused by different views from Earth of the portion of the moon illuminated by the sun as the moon moves (orbits) around Earth--not by the earth's rotation nor earth's shadow.

Earth's Shadow is not falling on the Moon. It's the light casting on the moon from the Sun and OUR view on Earth as that light is cast

Describes all aspects of the correct explanation – light on Moon from Sun, our view from Earth.

PART (a): Benchmark answers receiving 0 points:

I would explain to them that the phases of the moon are because of the position of the moon in its orbit of the earth. And that only twice a year is it possible for the shadows of the moon and earth to fall on each other. They would have to know that it takes the moon about 4 weeks to orbit the earth.

The first sentence is not enough information – need explanation to include the position of the Sun and view from Earth. The second sentence is inaccurate, and the third is irrelevant to this misconception.

25b. Explain how you would address this misconception using best instructional practices. (See directions at beginning of the open response section for more detailed directions.)

Active engagement might include

1. Students modeling the Earth-Sun-Moon relationships, for example with a lamp bulb representing Sun, the student's head = Earth, and a small white ball orbits the head to represent Moon. From perspective of the head-Earth, the portion of the white ball illuminated by the lamp-Sun would appear different as it orbits the head.

NOTE: Given the well-known 3-dimensional challenges of this particular topic and the equally well-known physical modeling opportunity as described above, any 2-dimensional (only) representation (e.g. textbook-type diagrams) would earn at most 1 point, since that does not directly target the dimensionality inherent in this situation.

PART (b): Benchmark answers receiving 2 points:

[Some version of the 3-dimensional modeling described above. A possible alternate could be an online simulation where the student sees 3-dimensional representation on the screen rather than 2-D, and is able to move perspective around to notice how the illumination both falls on the Moon and what is visible from Earth.]

PART (b): Benchmark answers receiving 1 point:

3 students: 1 to be the sun with a flashlight, 1 to be earth, 1 to be the moon. Dim the lights and then have "the sun" shine the beam onto the moon. Have class sketch "phases/faces" of the moon that is lit.

Although the model proposed is aligned with the response described above as on target, this response does not include critical aspects such as: the Moon-person would have to orbit the Earth-person; the flashlight would best shine on the head of the Moon and not the body/torso/legs, but that is unclear; from the perspective of the rest of the class, they will all see different portions of the Moon-head illuminated based on where they are sitting in the room, and so this won't serve for all students; using 'faces' for 'phases' would only work if the Moon-person was gravitationally locked to the Earth (that is, kept her face toward the Earth the whole time while orbiting) but that issue isn't addressed. So overall this is active and relevant, but does not directly target the misconception.

Benchmark answers receiving 0 points:

I would show the students pictures of the sun and moon that NASA provides through the challenger center. I would show the students the phases of the moon as well as how the earth rotates on its axis. I would also have the students go to different websites as well as using their textbooks.

Showing pictures of Sun and Moon won't add value, unless perhaps the intent is to show pictures of different phases in case students have not made those real-world observations before. Earth rotating on axis is not relevant to this misconception. The last sentence is too vague.

Model with a globe, moon, and lamp (Sun) in the classroom so all students could see the different angles and shades that are produced from each angle

The right equipment is indicated for building a 3-dimensional model, but the rest of the response does not explicitly indicate how that will be used to address the misconception. The phrase "shades that are produced" may suggest that this would reinforce student misconceptions since this phenomenon isn't about shadows ("shades"?)