UNIVERSITY OF LOUISVILLE
CENTER FOR RESEARCH IN MATHEMATICS & SCIENCE TEACHER DEVELOPMENT
(CRIMSTED)

Selected Response Section

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

OPEN RESPONSE SCORING

This document includes benchmark answers to guide the scoring of the open response items on the *Physical 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:

- <u>Actively engage</u> students in exploring concepts <u>related</u> 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.

- <u>Specifically target</u> 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."

BENCHMARK ANSWERS

NOTE: THESE PARTICULAR QUESTIONS ARE TAKEN FROM VERSION 1. HOWEVER, THE PHYSICAL SCIENCE VERSIONS ARE PARALLEL AND IT IS ANTICIPATED THAT THE OTHER VERSIONS CAN BE SCORED WITH THE GUIDELINES AND EXAMPLES PROVIDED HERE FOR VERSION 1.

21. When studying inertia, your students point out that a ball will stop rolling if no one continues to hit, kick, or otherwise provide a force on it. They cite this situation as a violation of Newton's First Law of Motion (an object in motion continues in motion unless acted on by an outside force).

21a. Please describe the <u>currently accepted scientific explanation of the phenomenon</u> that the students are not understanding. See directions at beginning of the open response section for more detailed directions.

Background Information

Newton's Law of Motion

According to Newton's First Law, objects at rest will remain at rest while objects in motion will continue in motion (in a straight line) unless they are acted on by an outside force. This is sometimes called "inertia", the tendency of a body to resist change in its motion.

It is easy to see objects at rest remaining at rest, so many people (like Aristotle and other ancient philosophers) believed that 'at rest' was the 'natural' state for all objects. It is harder to find objects in motion continuing in motion. One example is a non-accelerating spacecraft in deep space far from the gravitational influence of any large body which keep traveling in a straight line at constant speed. Another example is an object or a person in a car, who continues to move forward when the car comes to a sudden stop (that's why we wear seat belts.)

But, if you just roll a car or a ball, why does it eventually stop? It is because the force of friction is acting on it, pushing against the motion of the rolling object, and slowing it down and stopping it. In virtually every situation on earth involving movement, friction is at work. You can lessen it, but almost never eliminate it completely.

One of the ways we lessen friction is to make a surface smoother, such as sanding a rough piece of wood to make it smooth; or we can add a lubricant such as oil to create a smooth surface for metal pieces to move passed each other. That is why you have oil in the car engine, so moving parts have less friction. Ice is so slippery because its frictional effects are small. Without the friction between feet and pavement, you can easily lose footing and fall.

In question 21, students have ignored the effect of friction. Friction <u>is an outside force</u> that is present in this situation, and so the part of Newton's Law stating that, "…unless acted on by an outside force" is what the student failed to consider.

One way to demonstrate and lessen friction is to slide a block of wood along progressively smoother surfaces. The block will stop quickly on a very rough surface (much friction); it will slide further before stopping on a smoother surface (less friction); it will go further still on slick or a well-oiled surface(extremely low friction). Then ask the student to extrapolate – "What happens to the block if there is NO friction?" The teacher can guide students to realize that the block will go forever (yes, forever) if there is no friction or other force to act on it and slow it down.

Answer requires something about students ignoring/ forgetting / neglecting…friction as an outside force.

Keywords: friction, air resistance.

NOTE: "gravity" itself isn't relevant, but the presence of gravity does contribute to frictional effects through the normal force. Thus mentioning 'gravity' only does not earn a point, but mentioning 'gravity' can be ignored if 'friction' or similar is also part of the answer.

PART (a): Benchmark answers receiving 1 point:

1.1) "Exp. the planets rotating and revolving around the Sun. Once they were placed in motion there is not enough friction to slow them down." 0553
Mentioned the words "friction to slow them down." Does not address students' ignoring, but the key concept is present which earned a point.

1.2) "There are outside forces acting upon the objects in what we consider their natural state. Gravity, friction, air all act upon the object." 5028
Mentioned the outside force of friction and air. Answer implies that student ignored these outside forces.

1.3) "The 1st law is correct because the objects would be moving if the force of friction was not acting on them." 7934
This addresses the point clearly and directly

1.4) "Objects at rest also stay at rest unless acted upon by an outside force… but we don't tend to see the continuous motion because of friction (outside force)" 4994
The second part earns the point. The first part is irrelevant because the scenario does not have an object 'at rest,' but this does not contradict the answer in the second part.

1.5) "The misconception is that the student thinks that Newton has taken friction into account, however friction is actually an 'outside force'."
'Friction is an outside force' earns the point. The rest of the answer doesn't make much sense because it isn't about what Newton thinks, but it doesn't contradict the correct answer.

PART (a): Benchmark answers receiving 0 points:

0.1) "Ex. The solar system – objects are in motion and continue in motion; i.e. orbit around the sun. Other objects; i.e. meteors occasionally crash into earth, moon or other objects and are no longer moving." 2319
Does not mention frictional effects, unlike Benchmark 1.1, which got a point because it did.

0.2) "The law states that when an object is put in motion, it will continue in motion, unless it is acted on. The key idea is that something was put in motion by an outside force." 2956

First sentence simply restates the law and the second sentence is irrelevant to the misconception.

0.3) "Newton's 1st Law States an object is at rest and will remain at rest and an object moving at a constant velocity will continue at a constant velocity unless acted on by an unbalanced force." 4285

States the law but doesn't address the misconception about what unbalanced force is present.

0.4) "Their misconception is the point of the objects' 'being in motion.' If the object is in motion and everything is constant (V,A,?) then the net force is zero. If a force is applied, then the object would speed up or slow down depending on the direction of the force." 4805

This is close because it's considering net forces, but does not specifically target friction, so it got ZERO points.

0.5) "I will point out different forces such as gravity which oppose the movement of objects."

*A right idea might be floating around there about 'opposing motion' but gravity isn't it. Since 'friction' is a common enough term, would want to see it***.**

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

Active engagement might include explorations on different surfaces with different frictional effects (see discussion in last paragraph of "background information") and extending student thinking to include the situation of no friction.

<u>PART (b): Benchmark answers receiving 2 points:</u>

2.1) "This is the hard part for me. We would experiment with reducing these forces. Also I would bring up movement of objects in space, measure distance in water with less friction." 5028

Active ("experiment") and relevant ("reducing the forces.")
Targets friction by using different media ("distance in water.")

2.2) **"To best help students understand Newton's 1st Law I would have them each run outside a short sprint and ask them to stop immediately when I yell stop. Their body of course will not be able to do this which shows a body at motion wants to stay in motion unless acted upon by an outside force which would be the force of friction between the ground and their feet. This could be broadened in a discussion of how hard / easy stopping would be on different materials. Example ice, sand, etc." 7934**
Active ("them each run outside") and relevant ("force of friction")
Targets friction by using different media ("ice, sand, etc.")

<u>PART (b): Benchmark answers receiving 1 point:</u>

1.1) **"What do they perceive as the object at rest? Would investigate the sum of the forces on the object and investigate 'what if's as those forces change. 4805**
Active ("investigate") and relevant enough ("Sum of forces"- i.e. net force). However, this is not specific enough to indicate what will be done to directly target the misconception.

1.2) **"When describing Newton's Laws the idea 'neglection of air' is required. Free fall can only be effectively and mathematically described without the effect of air resistance. …. Air resistance also implies friction with the air, friction another outside force. I have several videos of experiments showing free fall in a vacuum." 4634**
Not active enough (does not describe what will be done with the video and rest of response is not about what students would do).
Does target the central misconception of the presence of an outside force – friction or air resistance.

<u>PART (b): Benchmark answers receiving 0 points:</u>

0.1) **"Demonstrate with a weight tied to a string. Spin around and change the speed. Notice that if spin too slow, the weight falls (gravity). Examples are satellites in space orbiting Earth. They must keep a certain speed. Too fast and they will be flung into space (the string breaks – gravity)." 0553**
It is active, but not relevant to frictional forces so it doesn't earn a point.

0.2) **"Use data to show orbital path of planets – additional data to show what happens when meteors strike earth or moon."2319**
Not active engagement and not relevant.

0.3) **"Using hands-on activity that show's Newton's Law of Motion." 4854**
Too general

0.4) **"Having hands on approach and presenting a lot of examples of different opposing forces."**
Active but not relevant enough since not specific enough – too vague.

0.5) "Use ice."

'Use ice' as complete answer contains the germ of a good idea, but without elaboration, I don't know if it will actively involve the students <u>or</u> *what he'll do with ice.*

22. During a unit on magnetism, students say that a long, thin bar magnet is not magnetized in the middle, but rather only on the ends where there are north and south poles. They state that by breaking the magnet in half, they can create a magnet that has only a north pole without an accompanying south pole.

22a. Please describe the <u>currently accepted scientific explanation of the phenomenon</u> that the students are not understanding. See directions at beginning of the open response section for more detailed directions.

<u>Background Information</u>

Magnets

Magnets, like all matter, consist of atoms. Atoms have electrons (negatively charged particles) which have a property of quantum spin. Ultimately, it is unpaired electrons with the same quantum spin that are responsible for magnetic fields (in middle school student terms, the spins of these electrons 'line up' and are not canceled out). The reason most materials aren't magnetic is because these electrons and atoms are aligned randomly, and so the tiny magnetic fields of each electron tend to cancel out with surrounding atoms and electrons. In magnets, atoms are aligned in such a way that they all "point" in the same direction and create a magnetic field that is noticeable (e.g. can pick up paper clips or affect a compass) for the material as a whole since they are all working together. A field is an area around the magnet in which the effects of the magnet are felt.

If you break a magnet, the atoms in each piece are still lined up (assuming that the process of breaking didn't jumble the atomic alignment). The 2 smaller pieces will still generate a magnetic field, and both will have a North and a South Pole. The smaller, broken magnets tend to be weaker than the original because fewer atoms are "working together" to create that magnetic field, but for any magnet students would encounter in a lab, this magnetic field would still be noticeable and would still do essentially the same things as the original magnet (e.g. pick up paper clips, cause iron filings to align, make a compass point move, etc.). In fact, you could keep breaking the magnet until it was so small that it would only be one atom big, and it would STILL be a magnet (though a very weak one). Thus, in science we say that there is no such thing as a magnetic monopole – that is, there is no such thing as a magnet with only one pole (North or South) without the accompanying opposite pole. Thus magnets are ALWAYS dipoles. This is different from electrical charges, where it is possible to have a negative charge (such as an electron) without a corresponding positive charge (e.g. a proton).

Many students use the term "charge" when referring to the poles, which is not the proper term. Unlike electricity, where charges move, in magnets there is nothing moving but rather the atoms turn to align themselves in the presence of a magnetic field, but still stay in the same location. However, since this rubric evaluates the concepts of the testtakers and not the terminology, for scoring these tests it is acceptable to not deduct any points based on incorrect use of terminology.

Answer requires something about the continuous nature of magnetic material and that domain alignment throughout the material is responsible for the macroscopic effect of magnetism. Thus it is impossible to have a magnetic monopole.

PART (a): Benchmark answers receiving 1 point:

1.1) Students do not understand the concept of magnetic fields. They need to realize that there will always be a north and south pole to the bar magnet regardless of the length of the magnet. 0031

Weak 1-point. Concept of magnetic fields implies that dipoles exist throughout the material through using "regardless of the length…".

1.2) In a magnet, the magnetic domains are aligned. The south pole is facing the same direction for all the molecules making up the magnet
If the magnet were broken along the dotted line, you would have 2 magnets, each with a north and south pole. 0936

S-N	S-N	S-N	S-N
S-N	S-N	S-N	S-N
S-N	S-N	S-N	S-N

Answer directly and clearly expresses the concept of domain alignment continuously distributed throughout the magnet. The diagram they drew helps the answer quite a lot.

1.3) The entire bar is magnetized, the magnetic field is not as evident in the middle. 2698

Weak 1-point. The does express the concept of continuous distribution of magnetism throughout the magnet, which earns it the point.

PART (a): Benchmark answers receiving 0 points:

0.1) The misconception is that the charges migrate. It is not that they migrate, it is that the end has been polarized. 9065

Answer focuses on 'migration' which is both incorrect and irrelevant, and 'polarized' is an incorrect concept in this scenario as well.

0.2) The iron fillings will migrate to the closest part of the magnet. 0553

Answer focuses on 'migration' which is both incorrect and irrelevant.

0.3) The magnet has a positive and a negative (charge?). The side that is positive will push other positives away, and draw the negatives closer. 2956

Focusing on attraction and repulsion which is irrelevant.

0.4) The stronger field is the magnetic north. 4285

Incorrect and irrelevant.

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

Active engagement might include students breaking a magnet (magnets that are scored and intended to be broken can be bought at school science supply dealers) and then testing that broken magnet to see if the broken ends still pick up paper clips, etc. OR students could put two bar magnets together and recognize that this behaves as if it is one big magnet, which could then be "broken" by separating the two again with each retaining both poles. The pedagogy needs to include some technique for students to use to test the presence or absence of magnetic poles (e.g. iron filings to make field lines visible, testing with a known magnet with N and S poles, using a compass, picking up paper clips).

PART (b): Benchmark answers receiving 2 points:

2.1) Cut the bar magnet in half – 2 magnets with N and S. Put these two bar magnets on an overhead projector with iron filings – show the N and S 4994
This expresses the pedagogical idea above.

2.2) I would have students take bar magnets. First we would determine north and south poles using a compass and/or demonstrate the magnet has opposite poles by feeling attraction/repulsion when we put them end to end. Then we would break the bar magnets and repeat the above procedure to determine that they do indeed have north and south poles when broken. 4107
This expresses the pedagogical idea above but uses either compasses or other known magnets to test the concept rather than iron filings.

PART (b): Benchmark answers receiving 1 point:

1.1) Demo – place iron fillings (sic) on overhead projector and place a magnet next to it (not touching) they will move the pattern. 0553
Does not specifically address the misconception, but is active and involves making visible the magnetic field lines (the "pattern") which is related to identification of the existence of poles. A weak 1-point answer since the extension to the concept that magnetic monopoles don't exist is still a large stretch.

1.2) Demonstrate magnetic fields using iron filings and magnets. Demonstrate domains using a collection of magnets and iron filings to create magnetic fields. 1234
Does not specifically address the misconception, but is active and involves making visible the magnetic field lines which is related to identification of the existence of poles. Also a weak 1-point answer.

1.3) Test objects using bar magnets. Use the poles of the magnet, as well as the middle. Test the magnetic field!"
This is active and relevant. Not 2 points because not enough detail about how they will 'test'. The idea of "testing the middle" begins to lead to the correct conception that magnetism is a property distributed throughout, but not enough detail given about what students will do and discover. This is a stronger 1 point than the two above – more detail on what students will do to "test the magnetic field" and what conclusions they will be led to would push this into the 2-point category.

PART (b): Benchmark answers receiving 0 points:

0.1) Allow students to investigate magnetic forces, and allow them to experiment movement of magnets (pushing and pulling). 2956
Too general and vague and not targeted to the misconception.

0.2) Use a variety of magnet bars and iron filings on overhead to demonstrate the concept. 4285
Unlike 1.1 above, this answer doesn't give enough specifics to earn a point. Not sure if they intend students to make visible the field lines or what "demonstrate the concept" means.

0.3) Show the students an experiment using magnets and metal shavings. 5632
Too general and vague.

0.4) Use the filings method, question why the filings don't move as well. 4805
Seems to be suggesting iron filings to make visible the field lines, but unlike those above which earned a point for this, the second part of 'don't move as well' suggests that this person mistakenly believes that the poles would no longer exist on the broken ends.

23. Observing the heating of ice, students noticed the ice changing to water and finally into gaseous vapors, leaving behind an empty container. They concluded that since the ice had disappeared, the mass of the system (ice and the container) had decreased, thus violating the principle of conservation of mass.

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

Background Information

Law of Conservation of Mass

This Law states that matter cannot be created or destroyed in ordinary chemical and physical changes. (That happens only in nuclear reactions, which are not occurring here.) In many cases, matter changes phase, or state, from liquid to gas, and is no longer visible, but it is still present and still has the same mass as originally.

Liquids can change to gases by boiling, or by just evaporating into the air. It is necessary to make it clear to the student that the matter is still present but that it left the 'system' of the container and went into the air. Helping students recognize this is done most easily by catching the evaporated liquid (vapor) and condensing it so it is visible, or containing it in a closed system so the weigh is not lost. The student is not considering a closed system wherein nothing goes in or leaves, but is erroneously trying to apply the Law of Conservation of Mass to an open system.

An easy way to condense the vapor is to let it touch a cool surface, where it will condense and form water droplets on the surface. If the container has a lid, such as a beaker of hot water with a watch glass on top, droplets of condensed water will form there and be easily seen. An alternate technique could be as simple as putting an airtight lid on a pot so you don't let the steam escape. Then cool down the closed pot and students will see the water recondensed inside – it didn't disappear.

Answer requires indication that the testtaker understands that the mass hasn't "disappeared" but that it has gone into the atmosphere and still exists. Concept of closed vs. open system may be described but not necessary to use that terminology.

PART (a): Benchmark answers receiving 1 point:

1.1) Misconception of what the system is. The system could include the air in the room or that some of the particles had left the system. 4805
Indicates understanding of need to define the system and that the air in the room is part of the system in this case.

1.2) The system is more than the bowl and water. It also includes the air particles.4994
Indicates understanding of need to define the system and that the air in the room is part of the system in this case.

1.3) The lost mass is water evaporating, since the bowl was open the system is open and includes the air surrounding it, which is where the water has moved to. If the system were closed, the water would not have evaporated.5028
Nice clear description of open vs. closed system.

1.4) The water in the bowl has evaporated thus causing more air mass than water mass in the container.5632
Indicates the concept that the mass still exists but has moved into the air.

1.5) The mass is lower because the water evaporated therefore it was still conserved but just changed form from liquid to gas7934
Indicates conservation of mass concept during change of state, even though first part seems to suggest mass is lost ("mass is lower"). But rest of response indicates that first statement is about water, not the total mass.

<u>PART (a): Benchmark answers receiving 0 points:</u>

0.1) The water evaporated so the mass changed, but was not violated. 0553
Says that the "mass changed" without indicating where that mass went, thus lacking evidence of understanding conservation of mass. Unlike 1.5 above, this answer doesn't indicate understanding of conservation in spite of a phase change.

0.2) Describe the water cycle and explain evaporation of water molecules. 2956
Focus on the process of evaporation isn't the central point of this misconception.

0.3) Conservation of mass equation. 4285
Vague and not relevant to misconception.

0.4) The student's misconception is that they don't understand conservation. 4854
Restates the question.

0.5) "The mass of the bowl is the same, the water is less due to evaporation?"
Said that water evaporated, but nothing to indicate that he knew this water had mass.

0.6) "The water evaporated."
*See above***.**

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

Active engagement might include using a technique to capture the evaporated water (e.g. lid or cooled hood over the pot) and then mass the condensation captured from this lid to demonstrate that the mass was conserved.

PART (b): Benchmark answers receiving 2 points:

2.1) Place water in a container with a sealed cover. Observe the evaporated water on the domed lid. 0553
Given two points because the word "observe" suggests that this is what they would focus students' attention on – would be better to write "measure"

2.2) Matter may change from one form to another – liquid to gas, but may not be created or destroyed. Cover bowl with clear wrap to show evaporation. 2319
Similar to 2.1 – technique to focus students attention on the evaporated water but would be stronger to indicate measuring the mass of that water.

2.3) To demonstrate the law of conservation of mass use a flask with ice and a balloon on the mouth of the flask. Find the mass of the apparatus. Gently heat the apparatus until the ice/water disappears into the balloon. Find the mass again and it should be the same. Since the balloon enlarges this will help illustrate the fact that the water molecules still exist. 0031
Good 2-point answer. Contains specifics about how the water vapor will be captured and measured to illustrate conservation of mass.

PART (b): Benchmark answers receiving 1 point:

1.1) "Create a similar environment that is fully enclosed. Test again."
Active engagement (someone is doing it rather than talking about it). Not 2 pts because not enough detail of what students will 'test' or how they will create the "fully enclosed" environment.

1.2) "Design & do an experiment that will collect the evaporating H2O."
Because it is active, and because the focus of the experiment is to collect the evaporating water, but haven't said how they would do the experiment in practice.

1.3) Students do a lab using a closed system. ??? tube (sealed tube) weighed, cooled, heated, weighed each time. 1234
Active and relevant, but not 2 points because not specifically targeted to the misconception. Need to target the concept that students observed in the lab.

1.4) "Evaporate H2O & condense it before it leaves."
Good idea, but needs to say something about how it will be done and measuring mass to show conservation.

PART (b): Benchmark answers receiving 0 points:

0.1) Discuss evaporation and the water cycle. 1550

Not active and not targeting the misconception.

0.2) Have students make a model of the water cycle. 2956

Not relevant to the misconception.

0.3) You would have to compare the relative humidity of the air each day using a barometer. 4285

Barometers measure air pressure, not humidity. Doing this "each day" wouldn't show anything relevant to the evaporation water since atmospheric humidity would change more than would be reflected by the bowl of water.

0.4) Show the experiment in class. Allow the students a chance to do visual observation. 4854

Vague and too general.

0.5) "Test by measuring a cup of water (how much water in it) and measure again a few days later; or make something similar to a greenhouse."

Zero points because the active part doesn't address the problem of open vs. closed system which is the heart of this misconception. In fact, this would confirm students' conceptions that mass is lost.

24. To investigate energy transfers between potential and kinetic energies, students are setting up a model roller coaster where a marble is released and rolls to the end of the track. Assume the friction in this situation is small and can be safely ignored. When designing their roller coaster, the students state, "Each summit has to be lower than the one before it." (*Note: "summit" refers to the tops of the hills that students create in their model roller coaster*)

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

Background Information

Conservation of Energy

Energy of a roller coaster is constantly being transformed between potential energy (due to height in a gravitational field) and kinetic energy (energy of motion). If no energy is lost to friction or any other source, then all this energy is conserved during these transformations and can be readily converted between the two in any proportion. The only consideration is how much total energy is available to start with.

The total energy in this situation is determined by the height of the first summit from which the marble is released – this is all potential energy. The only constraint on the rest of the roller coaster is that the marble can never go higher than the initial summit since that would require more energy than is available from the start. Thus, a roller coaster could be designed with any pattern of summits as long as none are higher than the first. There is no reason that the summits have to consistently get lower (for example, the third could be higher than the second); or no reason that the end has to be the lowest point (the end could be anything as long as not higher than the first summit).

Any frictional losses with a marble on a set of tracks would be small, but if the testtaker considers this friction, then the only constraint is that no summit can be as tall as the first – how much lower they have to be depends on how much energy is lost due to friction, but it would generally be only a small loss in this situation.

Answer requires indication that the lowest summit could be at the end or anywhere inbetween – might include the concept that the highest summit has to be the first as the only restriction.

PART (a): Benchmark answers receiving 1 point:

1.1) Misconception is that lowest energy had to be at end, could have been lower in the middle and increased. Kinetic energy which could be converted back to energy of gravity with an up-hill slope. 4805

Includes concept that energy can be transferred between the two without necessity of monotonically decreasing summits.

1.2) The highest point must be at the beginning but not necessarily the lowest at the end … just lower than the highest point.4994

Conveys concept that only restriction is 'not higher than the first.' Although this answer focuses only on the endpoint and not the middle summits, it addresses the central point of the misconception.

1.3) They are not understanding that each "summit" must be smaller than the 1st summit, because the first summit represents the original amount of potential energy available. The marble will have no more potential or kinetic energy than this. 3rd, 4th hills may be larger than the 2nd, but not the 1st."

Very clear answer that is right on target.

PART (a): Benchmark answers receiving 0 points:

0.1) The kinetic energy created while falling down will also create potential energy to allow it to continue travel up hill until the force of gravity, friction cause the marble to fall back again. 0553

Going down doesn't "create potential energy" – rest of answer doesn't address the height of the subsequent summits which is at the heart of the misconception.

0.2) Energy is conserved and transferred from one form to another. 2319

Too general and vague – no indication of how this would be applied in the context of the question.

0.3) Each time the marble goes down a summit, it is gaining energy, so the expended energy is regained as it comes down the summit. 2956

Too general and vague – no indication of how this would be applied in the context of the question.

0.4) Each rise past the initial rise would be at a point where the roller coaster would gain potential energy. 4285

Too general and vague – no indication of how this would be applied in the context of the question.

0.5) "An object will continue to move, it will move up from a low summit if there is still energy."

'Moving up from low summit' makes indication of the heights of the summits. This is not addressing the misconception.

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

Active engagement might include building roller coasters with different summit height patterns to test the idea that they must monotonically decrease. One realistic way to do this in the classroom is with clear tubing and marbles – easy to obtain, and easy to manipulate into different configurations. Answer must indicate specifically what they will have students investigate rather than simply "build a roller coaster." Answer needs to indicate that the pattern of summits heights will vary, including that later summits can be higher than earlier ones as long as none is higher than the first.

A nice addition would be to have students notice relative speed at different summit heights to note that lower summits have higher speeds – a qualitative way of investigating conservation of energy. However, this would not be strictly required in order to address the misconception.

<u>PART (b): Benchmark answers receiving 2 points:</u>

2.1) I would allow students to design coasters in which the 1st hill is the highest and each successive hill is smaller, as they suggested. I would also have them design coasters in which the 3rd & 4th hills are higher than the 2nd but not the 1st to demonstrate my explanation above (in part a). They may also design one in which the 1st hill is not the highest. They could test their design with the marble.

Clear description of what students would investigate – targets the misconception directly.

2.2) Have them design their own track and move the lowest summit to the middle to see if the marble stopped there. 4805

Clear and concise about what students will investigate. Does not detail how they will build their own track, but since this is something relatively easy for teachers to visualize doing an answer without this detail will be given the benefit of the doubt.

2.3) I would have them experiment with placing the lowest summit in various positions on the roller coaster. 5028

Implies that students either build or use a roller coaster model built by the teacher. Clear description of what students will investigate.

2.4) Build identical roller coasters with varying summit heights at the end. 5632

Focuses on only "the end" but the central point of the concept is valid even if only working with the end. Implies experimentation and observation of what happens with different summit patterns. Not clear who is building – ideally would be students but even if teacher built it, active engagement could be achieved through student experimentation and/or observation, so benefit of doubt is given.

PART (b): Benchmark answers receiving 1 point:

1.1) Have the students construct roller coasters to test this hypothesis. Insulation tubing that goes around water pipes can be cut in half and use duct tape to construct the rollercoasters. Then students can use stacks of books to construct roller coasters with various summits, using a marble as the car.

Active and relevant, but does not specifically target the misconception since "various summits" isn't specific enough.

PART (b): Benchmark answers receiving 0 points:

0.1) Have students create several models to test their theories. 2956

Too vague.

25. As an assignment, a teacher asked his students to write short stories that correctly applied scientific principles. Some students wrote a story about a battle in outer space containing the following passage:

> The two spaceships were nearly a hundred miles apart. Even so, the *Starbeam's* guns shot a hole in the enemy spaceship's hull, and the captain of the *Starbeam* was first blinded and then deafened by the enormous explosion of the enemy ship.

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

Background Information

Sound Traveling in Space

Light and sound both travel in waves, but they are very different kinds of waves. Light travels in electromagnetic waves which can go through empty space. They actually move faster if there is no matter for them to move through, so they are faster in space than when they move through air or water.

Sound cannot travel without some material to carry it along – this type of wave is called a mechanical wave. For example, imagine a football stadium where the fans do "the wave" (move their arms up and down in sequence so that the arm-waving pattern moves down the line and around the stadium). If the stadium were empty of people, it is impossible to do this "wave" since there is nobody to carry it. Alternately, consider a rope tied at one end, and you are shaking the loose end up and down to make waves on it. If you were to do the same thing without a rope present, it wouldn't generate any waves since there is no rope to carry it (and you'd look stupid doing it).

Similarly, sound needs something to carry the wave – the generic term for this "something" is "medium." Most commonly, air is the medium that carries sound. However, it is possible for sound to be carried through other media such as water or along a steel pipe. If you were on the Moon or elsewhere without air (and without radios), you could hear a sound travel through a pipe if someone tapped on one end and you put your ear to the other. However, if you lifted your ear off the pipe, you'd hear nothing because the sound would have to travel from the pipe to your ear through a vacuum, which it can't do.

In this scenario, the student's misconception is that sound would travel through the vacuum of space. To demonstrate that sound needs a medium, in particular air to target this misconception directly, a teacher could put a battery-powered alarm clock or a ringing cell phone in a bell jar (a big, thick, upside-down glass jar) and use a vacuum pump to pump the air out of the jar. At the beginning, the alarm clock bell is audible through the glass jar. However, as the air is pumped out, the sound becomes fainter and fainter until you can't hear it when there is too little air to carry the sound anymore. When the teacher lets air back into the jar, the sound is once again audible, thereby demonstrating the necessity of air to carry the sound. A good teacher would need to make this connection explicit for the students so that they understand why the sound disappears and reappears.

Answer requires reference to the concept that sound cannot travel in a vacuum.

PART (a): Benchmark answers receiving 1 point:

1.1) With no atmosphere on the moon there would be no atoms to vibrate the motion (sound) 0553

Explains the need for a medium to vibrate (atoms) in order to carry sound.

1.2) No sound on the moon.

Weak 1-point because it doesn't say WHY there isn't any sound on the moon, but implication is that space (which is the context of this question – not the moon) can't carry sound. Since this is the heart of the misconception in the student story, the point is awarded.

1.3) Sound waves have to have a medium to pass through. Little gravity does not permit an atmosphere for waves to pass.

First statement earns the point. Since this scenario is in open space, the second sentence is largely irrelevant in this context although it would be relevant in a moon scenario as an explanation why there is no atmosphere on the moon.

1.4) Sound does not travel in space.

Similar to 1.2 above, with improvement that the context is more appropriate to the questions (space rather than the moon).

PART (a): Benchmark answers receiving 0 points:

0.1) Explosions don't happen in space because there isn't any oxygen.

A ship does contain oxygen, and so an explosion can happen. This doesn't address the correct misconception.

0.2) You couldn't see or hear a ship a hundred miles away.

In space without the interference of other substances, you can see vast distances. This answer is focusing on the magnitude of the distance rather than the 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 (see last paragraph of the background information for suggestion of how this might be taught). A second example might be a description of investigating sound travel through different media (steel bar, wooden table, taut string, water, cotton, etc.) and engage students in a discussion of how the medium makes a difference in the ability to carry sound. Would then lead the discussion to help students imagine what it would be like to carry sound with no medium (air) present. Pedagogically valid to have students asymptotically approach the concept and then have them imagine the actual scenario which is difficult to produce in the classroom (a vacuum).

Might have students generate a model of this with students playing the role of air molecules and "passing the sound" from one end of the room to another. Removing more and more students makes it harder and harder to pass the sound along until, with no students, no sound is transmitted.

PART (b): Benchmark answers receiving 2 points:

2.1) In a bell jar, pump out all air pressure and have a bell inside the jar. Ring the bell before and after. 0553
Clear description of the activity.

2.2) Have them investigate the sound of a bell in a vacuum at different pressures. 4805
Summarizes an investigation targeting the misconception.

2.3) Use the old bell in a vacuum demonstration showing that sound is not conducted without air. 5028
Summarizes an investigation targeting the misconception. Since this demonstration is well-known to many physics and physical science teachers, summarizing it as "old bell in a vacuum demo" suggests a more thorough knowledge of how that would be carried out than the text indicates.

PART (b): Benchmark answers receiving 1 point:

1.1) Demonstrate waves traveling through a medium. Discuss the difference between air & vacuum.
Active engagement with demo makes relevant link between air, vacuum and medium, but it is not targeted enough for 2 points. More description of using different media (rather than "a medium") and conceptually approaching a vacuum would shift this answer to the 2-point category.

1.2) "1. Try to simulate a vacuum to demonstrate. 2. Look at how sound travels under different conditions."
1 point because relevant and active. Not enough detail what they will do. Suggests this teacher doesn't have knowledge of how they will do their first step.

1.3) I would have them transmit sound through various mediums (sic) and notice the difference. 4107
Idea on the right track, but not specific enough to what students should notice and what eventual conclusion they should come to.

1.4) Provided you could create a vacuum which would void the medium, you could demonstrate how light can travel but sound can not. 5441
Has the germ of a good idea, but doesn't possess the specifics of how to carry it out.

<u>PART (b): Benchmark answers receiving 0 points:</u>

0.1) Try to simulate the gravity on the moon, and recreate the scenario. Contact NASA and see if they could have video teleconference with students to explain gravitational pull of moon. 2956
Gravity isn't the issue in this question. Contacting NASA might be feasible (they have lots of K-12 outreach programs) but this doesn't indicate knowledge of any applicable program that might be feasible.

0.2) Students could put ear plugs inside of their sweatshirts and turn up a t.v. to see if they would have the same effect. 4854
Blocking the sound is not equivalent to lack of transmission due to lack of a medium.