

2020 MIT Science Olympiad Invitational Tournament

Sounds of Music: Exam Scoring Guidelines

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Exploring the World of Science

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This document features a point-by-point breakdown of scoring for both the Written Exam and the Aural Exam.

FOR ALL CALCULATIONS: *If the correct answer is given, award full credit even if work is not shown. If the correct value is given without work shown but with inappropriate units and/or incorrect significant figures, award full credit minus 1 point.*

Problem 1:

- (a) **1pt:** $n = 3$
2pts: cannot be $n = 4$ because then there would be a node (zero displacement) at the center
 (only **1pt** for saying that there is an antinode at $x = L/2$ in $n = 3$ without explaining why it cannot be $n = 4$)
- (b) **1pt:** curve is sinusoidal and starts out negative after $t = 0.0$ s
1pt: curve is sinusoidal and has lower amplitude than the original
1pt: new amplitude is labeled on graph as 1.4 or $\sqrt{2}$
 (–**1pt** if the curve has a different period from the original, minimum score 0)
- (c) **1pt:** all correct positions ($L/4$, $3L/4$, and $11L/12$)
 (Unsimplified fractions are also acceptable: $3L/12$, $9L/12$, and $11L/12$.)
 If $n = 4$ was answered for part (a), full credit is also awarded for $L/6$, $7L/12$, and $2L/3$.
- (d) **1pt:** substitution of variables into $f = mv/2L$
1pt: substitution of variables into $v = (\tau/\mu)^{1/2}$ and calculation of mass from linear density
1pt: correct answer to two significant figures with appropriate units (2.7×10^{-4} kg or 0.27 g)
 Full credit is also awarded for 4.8×10^{-4} kg or 0.48 g if $n = 4$ is used from part (a).

Problem 2:

- (a) **2pts:** 2.5 wavelengths drawn
1pt: maximum displacement at both ends of the pipe AND nodes and antinodes correctly labeled according to drawing (can be earned even if the number of wavelengths is incorrect)
- (b) **2pts** for three correct answers; **1pt** for two correct answers; **0pts** for one or zero correct answers
 (Correct answers: (i) moving right; (ii) moving left; (iii) no net movement)
 Credit is also awarded for answers that are consistent with an incorrect answer to part (a).
- (c) **1pt:** correct order ($x = 0.60L < x = 0.75L < x = 0.90L$)
 Credit is also awarded for a different ordering that is consistent with an incorrect answer to part (a).
- (d) **1pt:** correct substitution of variables into $f = mv/4L$ (point also earned if at least one frequency is correct)
1pt: correct lowest frequency with appropriate units and two significant figures (540 Hz)
1pt: correct second-lowest frequency with appropriate units and two significant figures (1600 Hz)
 If both frequencies are correct but have incorrect units or significant figures, award **2pts** out of 3 total.
- (e) **1pt:** correct position ($x = 0.80L$; can also be given as $x = 4L/5$ or $x = 0.64$ m)

Problem 3:

- (a) **1pt:** correct value of amplitude s_{\max} with units (2 mm or 0.002 m)
1pt: correct value of angular wavenumber k ($\pi/3 \text{ m}^{-1}$ or 1.05 m^{-1} , units not necessary)
1pt: correct value of angular frequency ω ($343\pi/3 \text{ s}^{-1}$ or 359 s^{-1} , units not necessary)
 Answer must be written in equation format to receive credit: $s = (2 \text{ mm}) \sin((1.05 \text{ m}^{-1})x - (359 \text{ s}^{-1})t)$
- (b) **1pt:** curve is below y -axis from $0 \text{ m} < x < 2.5 \text{ m}$, above y -axis from $2.5 \text{ m} < x < 7.5 \text{ m}$, and below y -axis again from $7.5 \text{ m} < x < 10.0 \text{ m}$
1pt: curve is a smooth sinusoidal wave with an amplitude of 4 mm
- (c) **1pt:** correct answer with appropriate units (30 m)
- (d) **2pts** for all correct answers circled; **1pt** if one correct answer is missing or one additional wrong answer is circled; **0pts** otherwise
 (Correct answers: $x = 7.0 \text{ m}$; $x = 13.0 \text{ m}$; $x = -2.0 \text{ m}$)
- (e) **2pts:** correct curve (first graph horizontally mirrored, y -intercept begins at value at $x = \lambda/2$ in first graph)

Problem 4:

- (a) **2pts** for all correct answers circled; **1pt** if one correct answer is missing or one additional wrong answer is circled; **0pts** otherwise
 (Correct answers: trombone, voice)
- (b) **1pt:** correct substitution of values into $f'/f = 2^{n/12}$ (or another equivalent formula)
1pt: correct answer as a whole number (8)
- (c) **1pt** for each interval (**2pts** max): minor sixth, augmented fifth
 Only score the first two answers listed. If the answer given for part (b) is incorrect, 1pt is also awarded without penalty to each correct interval (2pts max) based on the number of semitones given in part (b).
- (d) **1pt:** correct curve (always double the frequency of the fundamental curve)
- (e) **1pt:** correct answer (the same as)
- (f) **2pts:** correct curve (ascending concave down from $2 \text{ s} < t < 4 \text{ s}$, flat line at $t > 4 \text{ s}$ depending on number of semitones given for part (b))
 (**-1pt** if the region at $t > 4 \text{ s}$ is not consistent with part (b), minimum score 0)

Problem 5:

- (a) **1pt:** both correct answers (equal to; shorter than)
- (b) **1pt:** both correct answers (speeding up; speeding up)
- (c) **1pt:** correct system of equations: $2.20 \text{ kHz} = f * v_{\text{snd}} / (v_{\text{snd}} - v_{\text{car}})$ and $1.80 \text{ kHz} = f * v_{\text{snd}} / (v_{\text{snd}} + v_{\text{car}})$
1pt: correct speed to at least two significant figures with appropriate units (34 m/s)
1pt: correct frequency to at least three significant figures with appropriate units (1.98 kHz)
- (d) **1pt:** curve is continuous and descends smoothly near $t = 3 \text{ s}$
1pt: curve converges on/is coincident with original curve near $t = 0 \text{ s}$ and $t = 6 \text{ s}$
- (e) **1pt:** curve increases from $0 \text{ s} < t < 3 \text{ s}$ and decreases from $3 \text{ s} < t < 6 \text{ s}$
1pt: curve is concave up on both sides of $t = 3 \text{ s}$ (steepest near $t = 3 \text{ s}$ on both sides)
1pt: curve suddenly jumps from high intensity to low intensity at $t = 3 \text{ s}$ (or the downward slope after $t = 3 \text{ s}$ is visibly steeper than the upward slope before $t = 3 \text{ s}$)

Problem 6:

- (a) **1pt:** correct intensity value (0.0955 W/m^2) OR correct substitution into both formulas ($I = P / (4\pi r^2)$ and $\beta = 10 \log(I/I_0)$) if a calculation error was made with the intensity value
1pt: correct answer to at least one decimal place (109.8 dB)
- (b) **1pt:** oscillating interference pattern with intensity peaks and troughs
1pt: intensity is highest at $y = 3.00 \text{ m}$ AND peak heights decrease outward from center
- (c) **2pts:** same interference pattern as in part (b), but with shorter spacing between peaks
- (d) **1pt:** “C” curve is a flat line at a non-zero intensity
1pt: “D” curve oscillates up and down
1pt: “D” curve has a period of 0.10 ms
1pt: curve D is smoothly continuous AND the maximum value of “D” is the same as the value of “C”
 (–1pt if curves are not labeled “C” and “D,” minimum score 0)
 The initial and minimum values of “D” do not matter as long as the period and maximum value are correct.

Problem 7:

- (a) **1pt:** the word “resonance” or the phrase “resonant frequency”
1pt: complete description (e.g. each point on the membrane vibrates maximally in response when a sound wave stimulates it at its natural resonant frequency)
- (b) **1pt:** correct answer (at the base)
- (c) **2pts:** correct range (625 Hz and below, $0 < f \leq 625$ Hz, or $20 \leq f \leq 625$ Hz)
(only **1pt** for simply saying “625 Hz” or for saying “625 Hz and above”)
- (d) **1pt:** correct answer (8)
- (e) **1pt:** correct frequency (200 Hz)
1pt: supports temporal/volley theory (only awarded if the correct frequency was also given)
2pts: in temporal theory, the overall waveform has a period of 200 Hz and would maximally stimulate neurons to fire at that same rate OR in place theory, regions of different frequencies are spatially segregated, so there would be no reason for any of these frequencies to stimulate the 200-Hz region

Problem 8:

- (a) **2pts:** curve is drawn such that flow velocity is highest in the middle (glottis) and lowest at the ends
- (b) **1pt:** curve is inversely related to the curve drawn for part (a)
1pt: curve is drawn such that pressure is lowest in the middle (glottis) and highest at the ends
1pt: the phrase “Bernoulli effect”/“Bernoulli’s principle” (“Venturi effect” is also acceptable)
1pt: regions of high air velocity have lower pressure
- (c) **1pt:** increases tension/stiffness OR stretches the vocal folds
1pt: increases frequency/pitch
1pt for connecting the two above points together in the explanation
(only **1pt** for saying that it lengthens the vocal folds and therefore decreases frequency/pitch)
- (d) **1pt:** both correct answers (shorter, less mass)

Problem 9:

- (a) **1pt** for each correct row (**3pts** max)
(Correct answers: intensity \rightarrow distance at which objects are located; frequency \rightarrow movement of objects; interaural time difference \rightarrow angle/direction in which objects are located)
- (b) **2pts**: correct answer (12 m) (only **1pt** partial credit for 24 m, or for correct process but incorrect value)
(**-1pt** for incorrect or missing units, minimum score 0; no penalty for incorrect significant figures)
- (c) **1pt**: Chamber A
1pt: all sound waves will reflect off the smooth metal wall at the same angle in Chamber A (specular reflection) OR sound waves will reflect off the jagged rock wall at a greater variety of angles in Chamber B (diffuse reflection)
1pt: no sound waves will return to the bat in Chamber A OR more sound waves will return to the bat in Chamber B than in Chamber A
- (d) **1pt** for each correct symbol (**2pts** max) (Correct answers: $>$, $>$)

Problem 10:

- (a) **1pt**: both correct answers (hertz, larger)
- (b) **1pt** for each correctly circled letter (**2pts** max): B, B
2pts for ONE of the following points in the first question justification:
- high frequencies are absorbed/scattered more than low frequencies
 - low frequencies diffract around obstacles better than high frequencies
 - the many different components and frequencies of Bird A's call would be distorted by reverberations and would not stay synchronized during transmission
 - (without further elaboration, award only **1pt** for saying that high frequencies do not travel as far)
- 1pt** for each of the following points in the second question justification (**2pts** max):
- the waveform on the right is formed by a combination of multiple harmonics
 - Bird A's song only has very faint harmonics OR Bird B's song has two clear overtones above the fundamental (only accepted if #1 above is given)
- Alternate justification for the second question (**1pt** per bullet point, **2pts** max):
- the waveform on the right has a regular period
 - Bird A's song has a wide range of frequencies and an ill-defined overall period OR Bird B's song is a single tone with a well-defined frequency and wave period
- (c) **1pt**: a musical trill involves rapid variation in pitch/rapid alternation between two adjacent notes
1pt: Bird A's song involves restriking the same note repeatedly, not two adjacent notes OR Bird A's song involves rapid variation in amplitude, not in frequency/pitch
1pt: tremolo

Aural Passage 1:

- (a) **2pts** for all eight notes correct; **1pt** for only six or seven notes correct; **0pts** otherwise
(Correct notes: *do la sol re ti sol mi do*) (*si* is also acceptable in place of *ti*)
- (b) **1pt**: correct highest note (A6)
1pt: correct lowest note (E2)
It is not required to explicitly indicate which note is highest and which note is lowest.
- (c) **1pt**: grace notes (also accept “acciaccatura” or “appoggiatura”)
- (d) **1pt**: any of the following adjectives: courtesy, cautionary, or reminder
1pt: naturals
- (e) **3pts** if zero mistakes; **2pts** if one mistake; **1pts** if two mistakes; **0pts** if three or more mistakes
(Mistake = either a correct answer that was not circled or an incorrect answer that was circled)
(Correct answers: B, F, G, I)

Aural Passage 2:

- (a) **2pts**: $7/4$ (also accept $7/8$ or $(4+3)/4$)
- (b) **2pts**: Phrygian
- (c) **1pt**: perfect fifth (no credit for just “fifth”)
- (d) **1pt**: 4 OR subdominant
- (e) **2pts**: answer is within 130–132 bpm
(only **1pt** if answer is not between within this range bpm but is between 127 and 135 bpm)
- (f) **1pt**: B (Risolute)
- (g) **1pt**: A (Imitation)

Aural Passage 3:

- (a) **1pt** for each correct answer (**2pts** max): chordophone, electrophone
("String" and "electric" are also acceptable.)
Only the first two answers given are scored.
- (b) **1pt** per correct measure (**4pts** max) (only rhythm is scored; pitches are included for reference)



Instead of a dotted half note, measure 6 may be written with a quarter note tied to a half note or a half tied to a quarter (although the latter is technically improper). A rest at the end of measure 6 is also acceptable.

- (c) **1pt**: B minor (no credit for D major)
- (d) **3pts** for all four boxes correct; **2pts** for three boxes correct; **1pt** for two boxes correct; **0pts** if only one or zero boxes correct

Correct answers:

- Measures 5 & 9: B
- Measures 6 & 10: F#
- Measures 7 & 11: G
- Measures 8 & 12: A, A#

If an incorrect key is given for part (c), whether major or minor, award credit EITHER based on the correct answers above OR based on tonic of that key, whichever earns more points. For example, if "D major" or "D minor" is given, either B, F#, G, A+A# or D, A, Bb, C+C# would earn full credit.