2A

Action

Educator Preparation Committee

Proposed Adoption of Revised Science Subject Matter Requirements in Alignment with the Next Generation Science Standards

Executive Summary: This agenda item provides the draft revised Subject Matter Requirements (SMRs) for the CSET: Multiple Subjects, and Single Subject Science examinations in alignment with the Next Generation Science Standards (NGSS) to the Commission for potential adoption. The SMRs have undergone a content validation study since initial presentation to the Commission in February 2016.

Policy Question: Do the proposed revisions to the selected subject matter requirements adequately and appropriately align with the Next Generation Science Standards?

Recommended Action: That the Commission adopt the draft revised SMRs and the draft revised test design as presented in this agenda item.

Presenter: Mike Taylor, Consultant, Professional Services Division

Strategic Plan Goal

II. Program Quality and Accountability

a) Develop and maintain rigorous, meaningful, and relevant standards that drive program quality and effectiveness for the preparation of the education workforce and are responsive to the needs of California's diverse student population.

Proposed Adoption of Revised Science Subject Matter Requirements in Alignment with the Next Generation Science Standards (NGSS)

Introduction

This item provides the draft revised Subject Matter Requirements (SMRs) for the CSET: Multiple Subject, and Single Subject Science examinations in alignment with the Next Generation Science Standards (NGSS) to the Commission for potential adoption. SMRs define the content knowledge expected at the level of a beginning California teacher earning a preliminary credential. These SMRs were presented to the Commission for initial review in February 2016 and have undergone a Content Validation study during March and April 2016.

Background

Education Code (EC) section 44281 requires the Commission to "administer subject matter examinations….to assure minimum levels of subject matter knowledge by certified personnel." The Commission's CSET examinations serve this statutory purpose. The CSET examinations are required to be aligned with the state-adopted content standards for students. As these content standards change over time, the corresponding CSET examinations are updated to remain in alignment with the most current sets of California TK-12 content standards.

Updating the CSET examinations requires a two-stage process: first, the revision of the Commission-adopted Subject Matter Requirements that identify the content eligible to be assessed on the examination, and then, following Commission adoption of revised SMRs, the revision, redevelopment, and/or new development of test items that validly and reliably assess candidate levels of knowledge specific to the content area of the credential. In addition, Commission-approved subject matter preparation programs must also update their coursework and assessments to be aligned with the revised SMRs and must respond to the Commission documenting the transition to implementing the revised SMRs. The entire examination revision and transition process typically takes a minimum of two years to complete.

In addition, EC section 44288 specifies the use of subject matter advisory panels to "advise in the selection, administration, and interpretation of examinations." The subject matter advisory panels "shall consist of recognized leaders in the subject matter fields to be examined and shall be composed primarily of full-time public school classroom teachers and full-time college or university classroom teachers." The Commission's usual practice, consistent with statutory requirements, has been and continues to use advisory panels of California content experts to advise the Commission in the development of the Commission's subject matter examinations, the California Subject Examinations for Teachers (CSET).

When the state adopted the California Common Core State Standards, the Commission directed staff to align the affected CSET examinations with these new standards, and also directed staff to do the same once the NGSS standards were adopted by the State Board of Education.

Commission staff worked with advisory panels of California English and Mathematics content experts to develop the revised SMRs that were ultimately adopted by the Commission in 2013. Item development followed Commission adoption of the revised SMRs and the corresponding CSET examinations were updated to align with the Common Core State Standards for English and Mathematics. The updated CCSS-aligned CSET examinations in Multiple Subjects, English, and Mathematics have been operational since 2013.

Now that the state has adopted the Next Generation Science Standards, work has begun to align the array of CSET: Science subject matter examinations with these standards.

The Process for Revising the CSET: Science Examinations

Six CSET examinations have Science-related content*:

- CSET: Multiple Subjects
- CSET: General Science
- CSET: Biology/Life Science
- CSET: Chemistry
- CSET: Earth and Planetary Science
- CSET: Physics

*The Commission took action to discontinue the Specialized Science examinations and credentials since the preparation and authorization was very narrow—focusing only on the named science topic and the NGSS standards focus on integration across science content. Prior to the discontinuation of the Specialized Science credentials and examinations, there were 10 science examinations rather than the six that are currently in development.

The revision process for the CSET series of examinations follows the testing industry-standard practices that include the following sequential set of activities outlined with approximate dates for CSET: Science included in the table below:

Activity	When
1) Recruitment and appointment of Subject Matter Advisory Panels of California content experts	Summer 2015
2) Development and review of draft Subject Matter Requirements • Bias review of the draft SMRs by the Commission's standing Bias Review Committee • Content reviews of the draft SMRs by the Subject Matter Advisory Panels	Fall 2015
3) Content validation of the draft SMRs	Spring 2016
4) Review and approval of the draft SMRs by the Commission	June 2016
5) Review and validation of test items currently in the item bank for each examination	Summer 2016
6) Item revision and/or new item development • Bias review of revised and new test items • Content review by the Subject Matter Advisory Panels of the revised and new test items • Revisions of test items as needed	Summer 2016
7) Field testing of revised and new test items	Fall 2016

Activity	When
8) Revision to Test Guides available to candidates on the Examinations website	Spring 2017
9) Initial test administration • Scoring of initial test administration • Identification of marker scoring papers, if needed	Summer 2017
10) Standard Setting	Summer 2017
11) Adoption of a passing score standard by the Commission	Fall 2017

Steps 1, 2 and 3 above have already been completed. For each of these six Science-related CSET examinations, a California content expert advisory panel was recruited and appointed by the Executive Director. Demographic information about these panels is provided in Appendix B.

Between August and December 2015, the Commission's standing Bias Review Committee, and expert panels of California Science educators participated in NGSS Alignment Objective Review Conferences held at the facility of the Commission's CSET contractor, Evaluation Systems group of Pearson and via web conference.

Orientation activities focused the panel members on the objective of the meeting to align the current CSET: Multiple Subjects and the CSET: Science Subject Matter Requirements with the Next Generation Science Standards. Participants were reminded that the SMRs define the content knowledge expected at the level of a beginning California teacher earning a preliminary credential. The proposed revisions were discussed first by the Bias Review Committee and their comments were subsequently provided to the six content expert panels for consideration. Commission staff attended the Bias Review Committee meeting as well as each of the six technology-mediated content expert panel meetings.

Discussion of the CSET: Multiple Subjects NGSS-Related Proposed Revisions

Because the CSET: Multiple Subjects contains content from across the various domains of the NGSS and because the CSET: Multiple Subjects examination also measures other content areas appropriate for elementary school teachers, the overall formatting of the SMRs did not change from the previous version. Though the content has been updated to include the concepts and skills contained in the NGSS appropriate for elementary level teachers, the content expert committee did not feel it needed as extensive reformatting as did the expert panels reviewing the single subject area science SMRs. The Multiple Subjects expert panel preferred to leave the format similar to the format of SMRs for the other content areas included in the CSET: Multiple Subjects examination, which was updated in 2013 to align more closely with California's Common Core State Standards. The changes recommended for the Multiple Subjects SMRs include revisions to specific wording of concepts to match NGSS terminology, updated content to closely align with NGSS content, language about the relationships between people and the natural world added as is emphasized in NGSS, and new language regarding crosscutting concepts across science and engineering.

Discussion of the CSET: Science NGSS-Related Proposed Revisions

The single subject science content area SMRs were restructured and heavily revised to closely align with the NGSS. Each of the content expert panels carefully considered each statement

contained in the current SMRs and recommended revisions and additions of appropriate knowledge to be demonstrated by beginning teachers in each of the examination fields. Lengthy and in-depth discussions were held by the content area experts regarding the structure and specific content of the SMRs in each content area focusing on the content knowledge that must be demonstrated by California teachers prepared to teach the NGSS to California students.

The majority of the revisions are structural, rearranging the various topics to more closely and more clearly match the structure of the NGSS. Within each content area document, specific content statements were matched and reconciled between the currently adopted CSET SMRs and the NGSS. As a result, the documents contained in Appendix C represent the content expert recommendations for knowledge, skills, and abilities within the content area that must be demonstrated by beginning teachers credentialed to teach science in California.

Because of the extensive nature of the recommended edits and the amount of structural reorganization, it is not feasible to provide a copy of the original SMRS plus the revisions highlighting the changes. However, the current approved SMRs for CSET: Science can be found at the links below:

CSET: Multiple Subjects, Subtest II
http://www.ctcexams.nesinc.com/PDF/CSET_Prep/CS_102subtestdescription.pdf

CSET: Single Subjects
Subtest I: General Science
http://www.ctcexams.nesinc.com/PDF/CSET_Prep/CS_118subtestdescription.pdf

Subtest II: General Science
http://www.ctcexams.nesinc.com/PDF/CSET_Prep/CS_119subtestdescription.pdf

Subtest III: Biology/Life Science
http://www.ctcexams.nesinc.com/PDF/CSET_Prep/CS_120subtestdescription.pdf

Subtest III: Chemistry
http://www.ctcexams.nesinc.com/PDF/CSET_Prep/CS_121subtestdescription.pdf

Subtest III: Earth and Planetary Science
http://www.ctcexams.nesinc.com/PDF/CSET_Prep/CS_122subtestdescription.pdf

Subtest III: Physics
http://www.ctcexams.nesinc.com/PDF/CSET_Prep/CS_123subtestdescription.pdf

The revised CSET: Science SMRs discussed in this item are presented in Appendix C.

Statewide Content Validation Survey of the Revised Draft CSET Subject Matter Requirements
Since the February 2016 Commission meeting, Evaluation Systems has completed the statewide survey to determine if California educators consider the revised draft CSET subject matter

requirements valid for the content knowledge expected of a preliminary Multiple Subject, or Single Subject Science candidate, as applicable. The content validation survey targeted two main groups of California educators: teachers and subject matter program faculty. Their responses served to help refine the recommended draft CSET Subject Matter Requirements being presented to the Commission for adoption.

With the assistance of California employers, institutions, and teacher unions, Evaluation Systems distributed this survey to over 10,000 educators reflecting the state's ethnic diversity, school population areas (urban, suburban, and rural), and school types (preschool, elementary, middle school, secondary, and adult education). Prior to opening the survey period, Evaluation Systems requested the superintendent of every district and county office of education as well as the dean of education and, for alternative certification programs, the program directors of each institution with approved programs to encourage their staff to complete the survey. Thus, invitations to participate in the statewide survey were initially distributed to the following:

- Every district and county administrator identified in the California Department of Education's database, the California Basic Educational Data System (CBEDS).

- Each teacher educator in Commission-accredited Multiple Subject and Single Subject Science subject matter programs whose email was available from the institution's website or, when these websites did not include this information, those identified by their dean or program director.

Because of the initial low number of survey responses, Evaluation Systems sent follow-up emails and made numerous phone calls to potential responders. The final numbers of responders are shown for each question in each of the tables in Appendix A. Also shown are the numbers of responders who are credentialed teachers in public school classrooms and the number who are faculty members at Commission-approved teacher preparation programs.

The survey asked individuals to respond to the various aspects of the applicable CSET Subject Matter Requirements, both individually and as a whole. The following lists the content validation survey's specific questions with their respective rating scale range:

- With respect to the subdomains: "*How important are the knowledge, skills, and abilities described by the competency below for acceptably performing the job of an educator in this field in California public schools?*" Rating scale: one = "no importance" to five = "very great importance."

- With respect to the set of competency statements: "*How well does the set of descriptive statements below represent important aspects of the knowledge, skills, and abilities addressed by the competency?*" Rating scale: one = "poorly" to five = "very well."

- With respect to the subdomains as a whole: "*How well does the set of subject matter requirements as a whole represent important aspects of the knowledge, skills, and abilities required for acceptably performing the job of a California public school teacher providing*

instruction authorized by the <credential>?" Rating scale: one = "poorly" to five = "very well."

In addition to the three specific survey questions, the respondents were also given an opportunity to provide feedback about the draft CSET subject matter requirements, particularly for any low ratings they may have given. While many general and specific comments were provided by responders no consensus revisions emerged from the content validation survey.

The data collected during the content validation survey is contained in Appendix A.

The tables in Appendix A show for each of the proposed SMRs the numbers of professional California educators who served as content experts to validate each statement. All of the means show that these professionals feel that each of the statements falls within the range of moderate to very great importance for California teachers. None of the means or responses indicated that any of the SMRs was unimportant, with most of the means falling above 4, indicating that the skills described by the proposed revised SMRs are of great importance and that the statements describe the important skills very well. As a result, no changes or revisions to the draft SMRs are being proposed as a result of the content validation study.

Next Steps in the Revision of the Item Bank for the CSET Multiple Subjects and Single Subject Science Examinations

If the Commission adopts the revised CSET Subject Matter Requirements as presented in this Agenda item, the standard Commission process for examination development will continue based on the adopted SMRs. This process includes: developing a revised and augmented item bank which allows sufficient operational items for year-round computer-based testing and conducting standard setting studies to help determine a recommended minimum passing score. The recommended passing score standards will be brought to the Commission for adoption following the initial administrations of these three examinations.

Within the item development and review process, staff and the content expert panel will look at the question of the rigor of the examination questions and assure that new questions are aligned appropriately with content-related depth, breadth and development of conceptual understanding of key academic content within the field. Over time, the entire item bank for these examinations will be reviewed to ensure alignment with these considerations as well as with the Common Core State Standards.

Proposed New Test Design for Single Subject Sciences

To better align with the content structure of the NGSS, the test structures below are being proposed for CSET: Science examinations. The structure below for CSET: Multiple Subjects Subtest II (science portion only) is not obviously different from the current structure with 26 multiple choice questions (MCQ) and 3 constructed response questions (CRI), except for the suggestion that one of the constructed response questions be an “NGSS-enhanced” item specifically measuring content related to related to Scientific Practices, Engineering Design and Applications, and/or Crosscutting Concepts.

Proposed Test Structure for the Revised CSET: Multiple Subject Subtest II (Science portion only)

Test Structure	26 MCQs + 2 CRIs (1 CRI will be NGSS-enhanced + 1 CRI will address Disciplinary Core Ideas)
Content Includes	Physical Sciences; Life Sciences; Earth and Space Sciences; Subject Matter Skills and Abilities Applicable to the Content Domains in Science

The structure below proposed for the single subject sciences examinations would alter the examinations from their current three subtest structure to just two subtests. In this design, Subtest I would be taken by all examinees seeking any of the science credentials and would measure general science concepts as outlined by NGSS using 100 multiple choice questions (MCQ) and 4 constructed response questions (CRI), all enhanced to specifically measure NGSS concepts as described above for multiple subjects. Subtest II would be specific to each of the single subject science disciplines and would include 50 multiple choice questions (MCQ) and 3 constructed response questions (CRI).

Proposed Test Structure for the Revised CSET: Science Single Subjects

Subtest	**I**	**II**
Field Name	General Science	Concentration Areas
Test Structure	100 MCQs + 4 CRIs (all CRIs will be NGSS-enhanced)	50 MCQs + 3 CRIs (1 CRI will be NGSS-enhanced + 2 CRIs will address Disciplinary Core Ideas)
Content Includes	Scientific Practices; Engineering Design and Applications; Crosscutting Concepts; Physical Sciences; Life Sciences; Earth and Space Sciences	One of the following concentration areas: Life Sciences, Chemistry, Earth and Space Sciences, Physics
Additional Notes	NGSS-enhanced refers to content related to Scientific Practices, Engineering Design and Applications, and/or Crosscutting Concepts presented in the context of a Disciplinary Core Idea.	Candidates seeking a concentration area credential must take and pass both Subtest I and Subtest II. NGSS-enhanced refers to content related to Scientific Practices, Engineering Design and Applications, and/or Crosscutting Concepts presented in the context of a Disciplinary Core Idea.

Under this proposed test design candidates for the General Science credential would need to pass Subtest I only. Candidates for singe subject credentials in Life Sciences, Chemistry, Earth and Space Sciences or Physics would also need to pass Subtest II as appropriate for their concentration.

Alignment of Subject Matter Requirements for Examinations and Program Standards

There is a related issue of the alignment between the content of the subject matter examination and the focus of subject matter programs, since the candidate competencies expected within both approaches should be the same. The respective subject matter program standards will need to demonstrate that they incorporate the SMRs. This will require

submission of an updated course matrix showing how the SMRs are addressed in the subject matter program. The course matrix and syllabi will be reviewed to ensure alignment with the revised subject matter program standards.

Staff Recommendation

Staff recommends that the Commission

1. adopt the revised Subject Matter Requirements for Multiple Subjects and Single Subject Sciences (Appendix C) to align with the Next Generation Science Standards
2. adopt the proposed revised test designs for CSET: Science – related examinations
3. direct staff to work with the approved science subject matter programs to understand the revised SMRs and submit an updated course matrix with course syllabi and have the submissions reviewed by subject matter experts to ensure alignment with the revised SMRs

Next Steps

If the Commission adopts the SMRs and the proposed revised test design, CSET item development would take place in accordance with Commission policy and practice for examinations development. New test items will be developed over the summer and will be field-tested in December 2016. Initial administration of the updated CSET: Science examinations is scheduled for summer 2017. The corresponding Subject Matter Program Standards will also need to be updated in alignment with the revised SMRs, since the SMRs are also used within subject matter programs as the basis for assessment of candidate competency.

Appendix A
CSET: Science – related Content Validation Survey Results

CSET: MULTIPLE SUBJECTS
CONTENT VALIDATION SURVEY RESULTS

From March 7th through April 11th, 2016, Evaluation Systems group of Pearson (Evaluation Systems) surveyed California educators for the purpose of gathering information to ensure that the CSET® Science and Multiple Subjects Subject Matter Requirements (SMRs) continue to meet the needs of California schools for qualified teachers. Each set of CSET SMRs describe the job-related content eligible to be included on an examination. A summary of the results of the survey is shown below. As a result of this review, no changes are recommended to the draft subject matter requirements.

MEAN IMPORTANCE RATING: COMPETENCY STATEMENT LEVEL

"How important are the knowledge, skills, and abilities described by the competency below for acceptably performing the job of an educator in this field in California public schools?"

1 = No importance
2 = Little importance
3 = Moderate importance
4 = Great importance
5 = Very great importance

Multiple Subjects: Science

Competency	Public School Teacher[1] (N=284)	Teacher Educator[2] (N=24)
1	3.90	4.58
2	3.95	4.42
3	3.92	4.55
4	3.93	4.67
5	3.88	4.58
6	3.94	4.58
7	3.91	4.50
8	3.91	4.58
9	3.89	4.42

[1] Public school teachers, who hold a Multiple Subject Teaching Credential and have taught at the elementary level within the past three years in California public schools

[2] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Multiple Subject Teaching Credential, employed at least half-time in this capacity

MEAN IMPORTANCE RATING: DESCRIPTIVE STATEMENT LEVEL

"How well does the set of descriptive statements below represent important aspects of the knowledge, skills, and abilities addressed by the competency?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

Multiple Subjects: Science

Descriptive Statement	Public School Teacher[3] (N=284)	Teacher Educator[4] (N=24)
1	3.93	4.33
2	3.95	4.17
3	3.85	3.64
4	3.97	4.25
5	3.91	3.83
6	3.84	3.64
7	3.94	4.17
8	3.76	3.58
9	3.78	3.75

MEAN COMPOSITE RATING

"How well does the set of subject matter requirements as a whole represent important aspects of the knowledge, skills, and abilities required for acceptably performing the job of a California public school teacher providing instruction authorized by the Multiple Subject Teaching Credential?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

	Public School Teacher (N=280)	Teacher Educator (N=24)
Composite Rating	3.95	4.00

[3] Public school teachers, who hold a Multiple Subject Teaching Credential and have taught at the elementary level within the past three years in California public schools

[4] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Multiple Subject Teaching Credential, employed at least half-time in this capacity

CSET: GENERAL SCIENCE
CONTENT VALIDATION SURVEY RESULTS

From March 7th through April 11th, 2016, Evaluation Systems group of Pearson (Evaluation Systems) surveyed California educators for the purpose of gathering information to ensure that the CSET® Science Subject Matter Requirements (SMRs) continue to meet the needs of California schools for qualified teachers. Each set of CSET SMRs describe the job-related content eligible to be included on an examination. A summary of the results of the survey is shown below. As a result of this review, no changes are recommended to the draft subject matter requirements.

MEAN IMPORTANCE RATING: COMPETENCY STATEMENT LEVEL

"How important are the knowledge, skills, and abilities described by the competency below for acceptably performing the job of an educator in this field in California public schools?"

1 = No importance
2 = Little importance
3 = Moderate importance
4 = Great importance
5 = Very great importance

CSET: General Science

Competency	Public School Teacher[5] (N=86)	Teacher Educator[6] (N=12)
1.1	4.33	4.83
1.2	3.88	4.50
1.3	4.14	4.67
2.1	4.24	5.00
2.2	3.95	4.67
2.3	4.07	4.83
2.4	3.76	4.50
2.5	4.26	4.80
2.6	3.79	4.67
3.1	4.24	4.83
3.2	4.14	4.67
3.3	4.10	4.80
3.4	4.17	4.50
3.5	4.02	4.67
3.6	4.17	4.33
4.1	4.21	4.50
4.2	4.14	4.67
4.3	4.26	4.67
4.4	4.31	4.50

[5] Public school teachers, who hold a General Science Teaching Credential and have taught the content within the past three years in California public schools

[6] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the General Science Teaching Credential, employed at least half-time in this capacity

MEAN IMPORTANCE RATING: DESCRIPTIVE STATEMENT LEVEL

"How well does the set of descriptive statements below represent important aspects of the knowledge, skills, and abilities addressed by the competency?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

CSET: General Science

Descriptive Statement	Public School Teacher[7] (N=86)	Teacher Educator[8] (N=12)
1.1	4.21	4.67
1.2	4.10	4.50
1.3	4.02	4.83
2.1	4.21	4.67
2.2	4.00	4.33
2.3	4.20	4.17
2.4	3.90	4.17
2.5	4.19	3.83
2.6	3.90	4.33
3.1	4.10	4.50
3.2	4.19	4.00
3.3	4.00	4.50
3.4	4.24	4.40
3.5	4.00	4.00
3.6	4.10	4.00
4.1	4.12	4.60
4.2	4.08	4.20
4.3	4.19	4.17
4.4	4.12	4.00

[7] Public school teachers, who hold a General Science Teaching Credential and have taught the content within the past three years in California public schools

[8] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the General Science Teaching Credential, employed at least half-time in this capacity

MEAN COMPOSITE RATING

"How well does the set of subject matter requirements as a whole represent important aspects of the knowledge, skills, and abilities required for acceptably performing the job of a California public school teacher providing instruction authorized by the Single Subject Teaching Credential?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

	Public School Teacher (N=280)	**Teacher Educator (N=24)**
Composite Rating	4.29	4.33

CSET: BIOLOGY/LIFE SCIENCE
CONTENT VALIDATION SURVEY RESULTS

From March 7th through April 11th, 2016, Evaluation Systems group of Pearson (Evaluation Systems) surveyed California educators for the purpose of gathering information to ensure that the CSET® Science and Multiple Subjects Subject Matter Requirements (SMRs) continue to meet the needs of California schools for qualified teachers. Each set of CSET SMRs describe the job-related content eligible to be included on an examination. A summary of the results of the survey is shown below. As a result of this review, no changes are recommended to the draft subject matter requirements.

MEAN IMPORTANCE RATING: COMPETENCY STATEMENT LEVEL

"How important are the knowledge, skills, and abilities described by the competency below for acceptably performing the job of an educator in this field in California public schools?"

1 = No importance
2 = Little importance
3 = Moderate importance
4 = Great importance
5 = Very great importance

CSET: Biology/Life Science

Competency	Public School Teacher[9] (N=268)	Teacher Educator[10] (N=18)
1.1	4.41	4.67
1.2	4.16	4.78
1.3	4.10	4.67
1.4	4.28	4.89
2.1	4.21	4.89
2.2	4.16	4.78
2.3	4.08	4.78
3.1	4.55	4.89
3.2	4.26	4.67
4.1	4.07	4.89
4.2	4.42	4.78
4.3	4.18	4.56

[9] Public school teachers, who hold a Biology/Life Science Teaching Credential and have taught at the elementary level within the past three years in California public schools

[10] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Biology/Life Science Teaching Credential, employed at least half-time in this capacity

MEAN IMPORTANCE RATING: DESCRIPTIVE STATEMENT LEVEL

"How well does the set of descriptive statements below represent important aspects of the knowledge, skills, and abilities addressed by the competency?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

CSET: Biology/Life Science

Descriptive Statement	Public School Teacher[11] (N=268)	Teacher Educator[12] (N=18)
1.1	4.02	3.78
1.2	3.89	4.00
1.3	3.91	4.00
1.4	3.91	4.25
2.1	3.99	3.86
2.2	4.02	4.00
2.3	4.01	4.11
3.1	4.33	4.00
3.2	4.13	4.38
4.1	3.82	4.00
4.2	4.05	4.25
4.3	4.01	4.38

MEAN COMPOSITE RATING

"How well does the set of subject matter requirements as a whole represent important aspects of the knowledge, skills, and abilities required for acceptably performing the job of a California public school teacher providing instruction authorized by the Single Subject Teaching Credential?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

	Public School Teacher (N=266)	Teacher Educator (N=18)
Composite Rating	4.06	4.22

[11] Public school teachers, who hold a Biology/Life Science Teaching Credential and have taught at the elementary level within the past three years in California public schools

[12] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Biology/Life Science Teaching Credential, employed at least half-time in this capacity

CSET: CHEMISTRY
CONTENT VALIDATION SURVEY RESULTS

From March 7th through April 11th, 2016, Evaluation Systems group of Pearson (Evaluation Systems) surveyed California educators for the purpose of gathering information to ensure that the CSET® Science and Multiple Subjects Subject Matter Requirements (SMRs) continue to meet the needs of California schools for qualified teachers. Each set of CSET SMRs, describe the job-related content eligible to be included on an examination. A summary of the results of the survey is shown below. As a result of this review, no changes are recommended to the draft subject matter requirements.

MEAN IMPORTANCE RATING: COMPETENCY STATEMENT LEVEL

"How important are the knowledge, skills, and abilities described by the competency below for acceptably performing the job of an educator in this field in California public schools?"

1 = No importance
2 = Little importance
3 = Moderate importance
4 = Great importance
5 = Very great importance

CSET: Chemistry

Competency	Public School Teacher[13] (N=202)	Teacher Educator[14] (N=16)
1.1	4.63	4.50
1.2	4.55	4.50
1.3	4.25	4.43
1.4	3.85	3.86
2.1	4.63	4.75
2.2	4.51	4.63
2.3	4.53	4.50
2.4	3.63	3.75
3.1	4.35	4.63
3.2	3.99	4.38

[13] Public school teachers, who hold a Chemistry Teaching Credential and have taught at the elementary level within the past three years in California public schools

[14] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Chemistry Teaching Credential, employed at least half-time in this capacity

MEAN IMPORTANCE RATING: DESCRIPTIVE STATEMENT LEVEL

"How well does the set of descriptive statements below represent important aspects of the knowledge, skills, and abilities addressed by the competency?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

CSET: Chemistry

Descriptive Statement	Public School Teacher[15] (N=202)	Teacher Educator[16] (N=16)
1.1	4.24	4.38
1.2	3.96	4.13
1.3	4.01	3.75
1.4	3.94	4.00
2.1	4.15	4.29
2.2	4.10	4.00
2.3	4.15	3.75
2.4	3.67	3.86
3.1	4.11	4.25
3.2	3.74	4.13

MEAN COMPOSITE RATING

"How well does the set of subject matter requirements as a whole represent important aspects of the knowledge, skills, and abilities required for acceptably performing the job of a California public school teacher providing instruction authorized by the Single Subject Teaching Credential?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

	Public School Teacher (N=200)	Teacher Educator (N=16)
Composite Rating	4.09	4.25

[15] Public school teachers, who hold a Chemistry Teaching Credential and have taught at the elementary level within the past three years in California public schools

[16] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Chemistry Teaching Credential, employed at least half-time in this capacity

CSET: EARTH AND SPACE SCIENCES
CONTENT VALIDATION SURVEY RESULTS

From March 7th through April 11th, 2016, Evaluation Systems group of Pearson (Evaluation Systems) surveyed California educators for the purpose of gathering information to ensure that the CSET® Science and Multiple Subjects Subject Matter Requirements (SMRs) continue to meet the needs of California schools for qualified teachers. Each set of CSET SMRs describe the job-related content eligible to be included on an examination. A summary of the results of the survey is shown below. As a result of this review, no changes are recommended to the draft subject matter requirements.

MEAN IMPORTANCE RATING: COMPETENCY STATEMENT LEVEL

"How important are the knowledge, skills, and abilities described by the competency below for acceptably performing the job of an educator in this field in California public schools?"

1 = No importance
2 = Little importance
3 = Moderate importance
4 = Great importance
5 = Very great importance

CSET: Earth and Space Sciences

Competency	Public School Teacher[17] (N=94)	Teacher Educator[18] (N=6)
1.1	4.06	4.67
1.2	4.11	4.67
1.3	4.21	5.00
2.1	4.23	4.67
2.2	4.30	4.67
2.3	4.04	4.67
2.4	4.32	5.00
3.1	4.15	5.00
3.2	3.96	4.67
3.3	4.27	4.67
3.4	4.32	4.67

[17] Public school teachers, who hold a Earth and Planetary Science Teaching Credential and have taught at the elementary level within the past three years in California public schools

[18] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Earth and Planetary Science Teaching Credential, employed at least half-time in this capacity

MEAN IMPORTANCE RATING: DESCRIPTIVE STATEMENT LEVEL

"How well does the set of descriptive statements below represent important aspects of the knowledge, skills, and abilities addressed by the competency?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

CSET: Earth and Space Sciences

Descriptive Statement	Public School Teacher[19] (N=94)	Teacher Educator[20] (N=6)
1.1	4.06	4.00
1.2	3.94	4.00
1.3	4.11	4.33
2.1	3.98	4.00
2.2	4.09	4.33
2.3	3.85	4.67
2.4	3.91	4.67
3.1	3.69	4.50
3.2	3.64	4.00
3.3	3.62	4.00
3.4	3.83	3.67

MEAN COMPOSITE RATING

"How well does the set of subject matter requirements as a whole represent important aspects of the knowledge, skills, and abilities required for acceptably performing the job of a California public school teacher providing instruction authorized by the Single Subject Teaching Credential?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

	Public School Teacher (N=94)	Teacher Educator (N=6)
Composite Rating	4.09	3.67

[19] Public school teachers, who hold a Earth and Planetary Science Teaching Credential and have taught at the elementary level within the past three years in California public schools

[20] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Earth and Planetary Science Teaching Credential, employed at least half-time in this capacity

CSET: PHYSICS
CONTENT VALIDATION SURVEY RESULTS

From March 7th through April 11th, 2016, Evaluation Systems group of Pearson (Evaluation Systems) surveyed California educators for the purpose of gathering information to ensure that the CSET® Science and Multiple Subjects Subject Matter Requirements (SMRs) continue to meet the needs of California schools for qualified teachers. Each set of CSET SMRs describe the job-related content eligible to be included on an examination. A summary of the results of the survey is shown below. As a result of this review, no changes are recommended to the draft subject matter requirements.

MEAN IMPORTANCE RATING: COMPETENCY STATEMENT LEVEL

"How important are the knowledge, skills, and abilities described by the competency below for acceptably performing the job of an educator in this field in California public schools?"

1 = No importance
2 = Little importance
3 = Moderate importance
4 = Great importance
5 = Very great importance

CSET: Physics

Competency	Public School Teacher[21] (N=116)	Teacher Educator[22] (N=8)
1.1	4.79	5.00
1.2	4.76	5.00
2.1	4.41	4.75
2.2	3.84	4.75
2.3	4.62	4.75
3.1	4.53	4.75
3.2	4.28	4.75
4.1	3.28	4.50
4.2	3.45	4.00

[21] Public school teachers, who hold a Physics Teaching Credential and have taught at the elementary level within the past three years in California public schools

[22] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Physics Teaching Credential, employed at least half-time in this capacity

MEAN IMPORTANCE RATING: DESCRIPTIVE STATEMENT LEVEL

"How well does the set of descriptive statements below represent important aspects of the knowledge, skills, and abilities addressed by the competency?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

CSET: Physics

Descriptive Statement	Public School Teacher[23] (N=116)	Teacher Educator[24] (N=8)
1.1	4.18	4.50
1.2	4.19	4.50
2.1	3.88	4.50
2.2	3.66	4.50
2.3	3.88	4.50
3.1	4.03	4.25
3.2	3.81	4.50
4.1	3.37	4.50
4.2	3.57	4.00

MEAN COMPOSITE RATING

"How well does the set of subject matter requirements as a whole represent important aspects of the knowledge, skills, and abilities required for acceptably performing the job of a California public school teacher providing instruction authorized by the Single Subject Teaching Credential?"

1 = Poorly
2 = Somewhat
3 = Adequately
4 = Well
5 = Very well

	Public School Teacher (N=116)	Teacher Educator (N=8)
Composite Rating	3.98	4.50

[23] Public school teachers, who hold a Physics Teaching Credential and have taught at the elementary level within the past three years in California public schools

[24] Current faculty members or providers of Commission-approved programs of subject matter preparation for candidates of the Physics Teaching Credential, employed at least half-time in this capacity

Appendix B

Demographics of the CSET: Science Content Expert Panels

CSET: Multiple Subjects *

Committee Members from the August 2015 WebEx			
Role (Faculty/Teacher/Department Chair)	**Years of Experience**	**Gender**	**Geographic area**
Elementary Science Specialist	11 or more years	Female	South Bay
		Female	
Curriculum Specialist	11 or more years	Female	Southern
Teacher Educator, Other: University Faculty	4-6 years	Female	Los Angeles
Curriculum Specialist	11 or more years	Female	Los Angeles
District-Level Administrator	11 or more years	Male	Southern
		Female	
Teacher Educator	11 or more years		Southern

*a blank cell indicates a non-response from the panel member

CSET: General Science*

Committee Members from the August 2015 WebEx			
Role (Faculty/Teacher/ Department Chair)	**Years of Experience**	**Gender**	**Geographic area**
Middle School Science	7-10 years	Male	Los Angeles
		Male	
		Female	
		Male	
Teacher Educator, Other: Science Department Chair		Female	Southern
Secondary Teacher	11 or more years	Female	Los Angeles
Committee Members from the December 2015 WebEx			
Secondary Teacher	11 or more years	Female	Los Angeles
Middle school science	7-10 years	Male	Los Angeles
		Male	
		Female	
County-level Administrator	11 or more years	Male	Bay
Secondary Teacher	11 or more years	Male	Costa Del Sur
		Male	
Secondary Teacher	11 or more years	Female	Los Angeles
Secondary Teacher	11 or more years	Female	Los Angeles

*a blank cell indicates a non-response from the panel member

CSET: Chemistry*

Committee Members from the August 2015 WebEx			
Role (Faculty/Teacher/ Department Chair)	**Years of Experience**	**Gender**	**Geographic area**
Secondary Teacher	11 or more years	Male	Southern
Secondary Teacher	11 or more years		Los Angeles
Teacher Educator	11 or more years	Female	Bay
Secondary Teacher, Teacher Educator	11 or more years	Female	RIMS
Teacher Educator	11 or more years	Male	RIMS
Secondary Teacher, Curriculum Specialist	0-3 years	Male	Los Angeles
Secondary Teacher	11 or more years	Female	South Bay
Teacher Educator	11 or more years	Female	Los Angeles
Committee Members from the December 2015 WebEx			
Teacher Educator, Science District Lead/Teacher/Science Department Chair	7-10 years	Male	Central Valley
Teacher Educator	11 or more years	Female	Bay
Secondary Teacher, Teacher Educator, College-level Chemistry Instructor and College-level Professional Development for Faculty	11 or more years	Female	RIMS
Teacher Educator	11 or more years	Male	RIMS
Secondary Teacher	11 or more years	Female	South Bay
Secondary Teacher	11 or more years	Female	Bay
Teacher Educator	11 or more years	Female	Los Angeles
Secondary Teacher, Department Chairman	11 or more years	Female	Delta Sierra

*a blank cell indicates a non-response from the panel member

CSET: Physics*

Committee Members from the August 2015 WebEx			
Role (Faculty/Teacher/ Department Chair)	**Years of Experience**	**Gender**	**Geographic area**
Secondary Teacher	11 or more years	Female	Southern
Secondary Teacher, Teacher Educator	7-10 years	Male	Los Angeles
Professor at College/University	7-10 years	Female	Los Angeles
College Faculty-Science teacher education and science content	0-3 years	Female	Los Angeles
Secondary Teacher, Curriculum Specialist	11 or more years	Male	Southern
Committee Members from the December 2015 WebEx			
Secondary Teacher	4-6 years	Male	Los Angeles
Secondary Teacher	7-10 years	Female	Los Angeles
Secondary Teacher	11 or more years	Female	Southern
Secondary Teacher, Teacher Educator	7-10 years	Male	Los Angeles
		Male	
College Faculty-Science teacher education and science content	0-3 years	Female	Los Angeles
Secondary Teacher	11 or more years	Female	Southern
Secondary Teacher	11 or more years	Female	Central Valley

*a blank cell indicates a non-response from the panel member

CSET: Life Sciences *

Committee Members from the August 2015 WebEx			
Role (Faculty/Teacher/ Department Chair)	**Years of Experience**	**Gender**	**Geographic area**
Secondary Teacher	7-10 years	Female	North Coast
Secondary Teacher	11 or more years	Female	RIMS
		Male	
Secondary Teacher	11 or more years	Male	Southern
Secondary Teacher, Curriculum Specialist	11 or more years		Los Angeles
Professor of Education	7-10 years	Male	Capital
Secondary Teacher	11 or more years	Female	Capital
Committee Members from the December 2015 WebEx			
Secondary Teacher	11 or more years		Costa Del Sur
Secondary Teacher, Secondary Admin	4-6 years	Female	Southern
Teacher Educator	11 or more years	Male	RIMS
Secondary Teacher, Curriculum Specialist	0-3 years	Female	Bay
Secondary Teacher, Curriculum Specialist	11 or more years		Los Angeles
Secondary Teacher	11 or more years	Female	Los Angeles
Secondary Teacher	11 or more years	Female	Capital
Secondary Teacher	11 or more years	Female	South Bay

*a blank cell indicates a non-response from the panel member

CSET: Earth and Space Sciences*

Committee Members from the August 2015 WebEx			
Role (Faculty/Teacher/ Department Chair)	**Years of Experience**	**Gender**	**Geographic area**
Secondary Teacher	11 or more years	Male	RIMS
College Faculty	4-6 years	Male	Costa Del Sur
Secondary Teacher	4-6 years	Female	RIMS
Secondary Teacher	4-6 years	Female	Los Angeles
	11 or more years	Male	Central Valley
Committee Members from the December 2015 WebEx			
Secondary Teacher	11 or more years	Female	Central Valley
Secondary Teacher	11 or more years	Female	Los Angeles
Secondary Teacher	11 or more years	Female	Central Valley
Secondary Teacher	4-6 years	Female	RIMS
Secondary Teacher	11 or more years	Female	Southern
Elementary Teacher, Secondary Teacher, Teacher Educator, research & development	11 or more years		
Secondary Teacher	11 or more years	Male	Southern

*a blank cell indicates a non-response from the panel member

Appendix C
DRAFT CSET: Science – related Subject Matter Requirements

Multiple Subjects Domains and Competencies

Domain: Physical Sciences

1. **Structure and Properties of Matter**

   Candidates for Multiple Subject Teaching Credentials understand the physical properties of solids, liquids, and gases, such as color, mass, density, hardness, and electrical and thermal conductivity. They know that matter can undergo physical changes (e.g., changes in state such as the evaporation and freezing of water) and chemical changes (i.e., atoms in reactants rearrange to form products with new physical and chemical properties) and understand conservation laws with respect to matter and energy. They know that matter consists of atoms and molecules in various arrangements, and can give the location and motions of the parts of an atom (protons, neutrons, and electrons). They can describe the constituents of molecules and compounds, naming common elements (e.g., hydrogen, oxygen, iron), and explain how elements are organized on the periodic table on the basis of the characteristics of atoms and their chemical properties. They can describe characteristics of solutions (such as acidic, basic, and neutral solutions) and they know examples with different pH levels, such as soft drinks, liquid detergents, and water. They know that mixtures may often be separated based on physical or chemical properties.

2. **Domain: Principles of Motion and Energy**

   Candidates for Multiple Subject Teaching Credentials describe an object's motion based on position, displacement, speed, velocity, and acceleration. They know that forces (pushes and pulls), such as gravity, magnetism, and friction, act on objects and may change their motion if these forces are not in balance. They know that "like" electrical charges or magnetic poles produce repulsive forces and "unlike" charges or poles produce attractive forces. They describe simple machines in which small forces are exerted over long distances to accomplish difficult tasks (e.g., using levers or pulleys to move or lift heavy objects). Candidates identify forms of energy, including solar, wind, chemical, electrical, magnetic, nuclear, sound, light, and electromagnetic. They know that total energy in a system is conserved but may be changed from one form to another, as in an electrical motor or generator, and that speed and energy are related. They understand the difference between heat (thermal energy) and temperature, and understand temperature measurement systems. Candidates know how heat may be transferred by conduction, convection, and radiation (e.g., involving a stove, Earth's mantle, or the sun). They describe sources of light, including the sun, lightbulbs, or excited atoms (e.g., neon in neon lights), and interactions of light with matter (e.g., vision, photosynthesis). Candidates can describe the properties of waves (e.g., wavelength, amplitude, frequency) and applications and technologies associated with these properties. They know and can apply the optical properties of waves, especially light and sound, including reflection (e.g., by a mirror) or refraction (e.g., bending light through a prism). They explain conservation of energy resources in terms of renewable and nonrenewable natural resources and their use in society

Domain: Life Sciences

3. **Structure of Living Organisms and Their Function (Cell Biology)**

   Candidates for Multiple Subject Teaching Credentials describe levels of hierarchical organization and related functions in plants and animals, including organ systems (e.g., the digestive system),

organs, tissues (e.g., ovules in plants, heart chambers in humans), cells, and subcellular organelles (e.g., nucleus, chloroplast, mitochondrion). They know structures and related functions of systems in plants and animals, such as the nervous, reproductive, respiratory, circulatory, and digestive systems. They understand the fundamental principles of chemistry underlying the functioning of biological systems (e.g., carbon's central role in living organisms, water and salt, DNA, the energetics of photosynthesis).

4. **Living and Nonliving Components in Environments (Ecology)**
   Candidates for Multiple Subject Teaching Credentials know that all living things are made up of cells and can describe the characteristics of many living organisms (e.g., growth, reproduction, stimulus response). They understand the basic needs of all living organisms (e.g., food, water, space) and how organisms can alter their environments to meet those needs, and can distinguish between environmental adaptations and accommodations. They describe the relationship between the number and types of organisms an ecosystem can support and relationships among members of a species and across species. They illustrate the transfer of energy and the cycling of matter through an ecosystem from sunlight through individual organisms in food chains and food webs (including primary producers, consumers, and decomposers). They identify the resources available in an ecosystem, and describe the environmental factors that support the ecosystem, such as temperature, water, and soil composition, as well as how the ecosystem responds to changes in these factors. They identify ways in which human activities and natural processes impact the local and global climate and possible solutions to reduce adverse impacts.

5. **Life Cycle, Reproduction, and Evolution (Genetics and Evolution)**
   Candidates for Multiple Subject Teaching Credentials compare the characteristics of bodies of water, such as rivers, lakes, oceans, and estuaries. They describe tides and explain the mechanisms causing and modifying them, such as the gravitational attraction of the moon, sun, and coastal topography. Candidates understand the water cycle, including the properties of water and how changes in the form of water are driven by energy from the sun and gravity. They know that Earth's hydrosphere interacts with Earth's other major systems to affect Earth's surface materials and processes.

Domain: Earth and Space Sciences

6. **The Solar System and the Universe (Astronomy)**
   Candidates for Multiple Subject Teaching Credentials identify and describe the components of the solar system (e.g., planets, comets, asteroids) and their predictable patterns of motion around the sun. They explain time zones in terms of longitude and the rotation of Earth, and understand the reasons for changes in the observed position of the sun, moon, and stars in the sky during the course of the day and from season to season. They name and describe bodies in the universe (e.g., sun, stars, galaxies) in terms of apparent brightness and/or relative size.

7. **The Structure and Composition of the Earth (Geology)**
   Candidates for Multiple Subject Teaching Credentials describe the formation and observable physical characteristics of minerals (e.g., quartz, calcite, hornblende, mica, common ore minerals) and different types of rocks (i.e., sedimentary, igneous, and metamorphic). They identify characteristics of landforms, such as mountains, rivers, deserts, and oceans. They explain chemical and physical weathering, erosion, deposition, and other rock-forming and soil-changing processes and the formation and properties of different types of soils and rocks. They describe layers of the earth (crust, lithosphere, mantle, and core) and plate tectonics, including its convective source. They explain how mountains are created, identify the factors that cause volcanoes and earthquakes to occur, and describe the effect of these phenomena on the earth's

surface, ecosystems, and human society. They know the commonly cited evidence supporting the theory of plate tectonics. They identify factors influencing the location and intensity of earthquakes. They describe the effects of plate tectonic motion over time on climate, geography, and distribution of organisms, as well as more general changes on the earth over geologic time as evidenced in landforms and the rock and fossil records, including plant and animal extinction. They identify potential technological solutions to reduce the impact of these natural Earth processes on humans and society and to reduce human impact on Earth's processes.

8. **The Earth's Atmosphere (Meteorology)**
   Candidates for Multiple Subject Teaching Credentials explain the influence and role of the sun and oceans in weather and climate and the role of the water cycle. They describe causes and effects of air movements and ocean currents (based on convection of air and water) on daily and seasonal weather and on climate. They describe the importance of technology with regard to predicting and mitigating the impact of severe weather and other natural hazards.

9. **The Earth's Water (Oceanography)**
   Candidates for Multiple Subject Teaching Credentials compare the characteristics of bodies of water, such as rivers, lakes, oceans, and estuaries. They describe tides and explain the mechanisms causing and modifying them, such as the gravitational attraction of the moon, sun, and coastal topography. Candidates understand the water cycle, including the properties of water and how changes in the form of water are driven by energy from the sun and gravity. They know that Earth's hydrosphere interacts with Earth's other major systems to affect Earth's surface materials and processes.

General Science Domains and Competencies

Domain 1: Scientific Practices, Engineering Design and Applications, and Crosscutting Concepts

1.1 Understand scientific practices

a. Demonstrate knowledge of how to ask questions that can be addressed by scientific investigation, help further understanding of observed phenomena, and help clarify scientific explanations and relationships.
b. Apply knowledge of the development of important scientific ideas and models over time and of how history shows that evaluating a model's merits and limitations leads to its improvement.
c. Apply knowledge of planning and conducting scientific investigations, including safety considerations and the use of appropriate tools and technology.
d. Apply modeling and the mathematical concepts of statistics and probability to the analysis and interpretation of data, including analysis of errors and their origins.
e. Demonstrate the ability to analyze scientific data and information and draw appropriate and logical conclusions.
f. Use mathematics (e.g., dimensional analysis, statistics, proportional thinking) and computational thinking to represent and solve scientific problems and to assess scientific simulations.
g. Demonstrate the ability to construct and analyze scientific explanations.
h. Demonstrate the ability to evaluate scientific arguments in terms of their supporting evidence and reasoning.
i. Demonstrate knowledge of the ability to obtain, evaluate, interpret, and communicate scientific information (e.g., determining central ideas, integrating information from multiple sources, evaluating the validity of claims, using multiple formats to communicate scientific results).

1.2 Understand engineering practices, design, and applications

a. Apply knowledge of engineering practices to define problems, determine specifications of designed systems, and identify constraints.
b. Evaluate design solutions in terms of their scientific and engineering constraints and the environmental, social, and cultural impacts of these solutions.
c. Apply knowledge of the roles of models (e.g., mathematical, physical, computer simulations) in the engineering design process.
d. Demonstrate knowledge of the process used to optimize a design solution (e.g., prioritizing criteria, refining a design due to test results).
e. Apply knowledge of the interdependence of science, engineering, and technology (e.g., in agriculture, health care, and communications).
f. Demonstrate knowledge of the influence of engineering, technology, and science on society and the natural world (e.g., in land use, transportation, and energy production).

1.3 Understand crosscutting concepts among the sciences and engineering.

a. Apply knowledge of patterns characteristic of natural phenomena and engineered systems.
b. Analyze cause-and-effect relationships and their mechanisms in natural phenomena and engineered systems.
c. Apply knowledge of the concepts of scale, proportion, and quantity to describe and compare natural and engineered systems.
d. Apply knowledge of how systems are defined and studied and of how system models are used to make predictions.
e. Apply knowledge of the flow, cycling, and conservation of energy and matter to analyze natural and engineered systems.

f. Analyze the relationship between structure and function in natural and engineered systems.
g. Analyze the factors contributing to stability and change in systems (e.g., static and dynamic equilibrium, feedback) and the rates at which systems change.

Domain 2. Physical Sciences

2.1 Understand structure and properties of matter.

a. Analyze the basic substructure of an atom (i.e., protons, neutrons, and electrons).
b. Differentiate between atoms and their isotopes, ions, molecules, elements, and compounds.
c. Apply knowledge of the development and organization of the periodic table and predict the properties of elements on the basis of their positions in the periodic table.
d. Demonstrate knowledge of nuclear forces that hold nuclei together and are responsible for nuclear processes (e.g., fission, fusion) and radioactivity (e.g., alpha, beta, and gamma decay).
e. Demonstrate knowledge of the characteristics of the different states of matter.
f. Apply knowledge of physical changes of matter and physical properties of matter.
g. Demonstrate knowledge of the physical and chemical characteristics, including pH, of acids, bases, and neutral solutions.
h. Apply knowledge of the physical and chemical properties of water.

2.2 Understand chemical reactions and biochemistry.

a. Recognize that chemical reactions can be understood in terms of the collisions between ions, atoms, or molecules and the rearrangement of particles.
b. Apply knowledge of the principles of conservation of matter to chemical reactions, including balancing chemical equations.
c. Describe the effect of temperature, pressure, and concentration on chemical equilibrium (Le Chatelier's principle) and reaction rate.
d. Analyze chemical bonding with respect to an element's position in the periodic table.
e. Demonstrate knowledge of the central role of carbon in the chemistry of living systems.

2.3 Understand motion and stability: forces and interactions.

a. Apply knowledge of Newton's laws of motion and law of universal gravitation and recognize the relationship between these laws and the laws of conservation of energy and momentum.
b. Demonstrate knowledge of the definition of pressure and how pressure relates to fluid flow and buoyancy, including describing everyday phenomena (e.g., the functioning of heart valves, atmospheric pressure).
c. Identify the separate forces that act on a system (e.g., gravity, tension/compression, normal force, friction), describe the net force on the system, and describe the effect on the stability of the system.
d. Analyze displacement, motion, and forces using models (e.g., vector, graphic representation, equations).
e. Identify fundamental forces, including gravity, nuclear forces, and electromagnetic forces (magnetic and electric), and recognize their roles in nature, such as the role of gravity in maintaining the structure of the universe.

2.4 Understand waves and their applications in technologies for information transfer.

a. Compare the characteristics of mechanical and electromagnetic waves (e.g., transverse/longitudinal, travel through various media, relative speed).
b. Demonstrate knowledge of the relationship between wave frequency, wavelength, and amplitude and energy.

c. Demonstrate knowledge of resonance and of the reflection, refraction, and transmission of waves.
d. Apply knowledge of electromagnetic radiation, including analyzing evidence that supports the wave and particle models that explain the properties of electromagnetic radiation.
e. Evaluate evidence that indicates that certain wavelengths of electromagnetic radiation may affect living cells.
f. Demonstrate knowledge of how lenses are used in simple optical systems, including the camera, telescope, microscope, and eye.
g. Compare and contrast the transmission, reflection, and absorption of light in matter.
h. Demonstrate knowledge of how energy and information are transferred by waves without mass transfer, including recognizing technology that employ this phenomenon.

2.5 Understand energy.

a. Demonstrate knowledge of kinetic and potential energy.
b. Demonstrate knowledge of the ways in which energy manifests itself at the macroscopic level (e.g., motion, sound, light, thermal energy).
c. Demonstrate knowledge of the principle of conservation of energy, including analyzing energy transfers.
d. Demonstrate knowledge of how the transfer of energy as heat is related to changes in temperature and interpret the direction of heat flow in a system.
e. Apply knowledge of heat transfer by conduction, convection, and radiation, including analyzing examples of each mode of heat transfer.
f. Analyze how chemical energy in fuel is transformed to heat.
g. Demonstrate knowledge of the energy changes that accompany changes in states of matter.

2.6 Understand electricity and magnetism.

a. Demonstrate knowledge of electrostatic and magnetostatic phenomena, including evaluating examples of each type of phenomenon.
b. Predict charges or poles on the basis of attraction/repulsion observations.
c. Relate electric currents to magnetic fields and describe the application of these relationships, such as in electromagnets, electric current generators, motors, and transformers.
d. Demonstrate knowledge of how energy is stored and can change in electric and magnetic fields.
e. Interpret simple series and parallel circuits.
f. Demonstrate knowledge of the definitions of power, voltage differences, current, and resistance and calculate their values in simple circuits.

Domain 3. Life Sciences

3.1 Understand the structure and function of cells.

a. Demonstrate understanding that a small subset of elements (C, H, O, N, P, S) makes up most of the chemical compounds in living organisms by combining in many ways.
b. Recognize and differentiate the structure and function of molecules in living organisms, including carbohydrates, lipids, proteins, and nucleic acids.
c. Demonstrate knowledge of evidence that living things are made of cells.
d. Analyze the similarities and differences among prokaryotic and eukaryotic cells and viruses.
e. Demonstrate knowledge of organelles and their structures and functions in the cell and how differences in the structure of cells are related to cell function.
f. Demonstrate knowledge of the process and significance of protein synthesis.

3.2 Understand growth, development, and energy flow in organisms.

a. Demonstrate knowledge of the importance of mitosis and meiosis as processes of cellular and organismal reproduction.
b. Compare single-celled and multicellular organisms, including the role of cell differentiation in the development of multicellular organisms.
c. Recognize the hierarchical levels of organization (e.g., cells, tissues, organs, systems, organisms) in plants and animals.
d. Demonstrate knowledge of the major anatomical structures and life processes (e.g., reproduction, photosynthesis, cellular respiration, transpiration) of various plant groups.
e. Demonstrate knowledge of feedback mechanisms responsible for maintaining homeostasis in animals, including humans, and plants, including the anatomical structures and systems involved in regulating internal conditions.
f. Analyze the processes of cellular respiration (anaerobic and aerobic).
g. Demonstrate knowledge of the conversion, flow, and storage of energy in the cell.

3.3 Understand ecosystems: interactions, energy, and dynamics.

a. Demonstrate knowledge of the abiotic and biotic factors in an ecosystem and their relationship to the growth of individual organisms.
b. Demonstrate knowledge of the interrelationships within and among ecosystems and recognize factors that affect population types, size, and carrying capacity in ecosystems (e.g., availability of biotic and abiotic resources, predation, competition, disease).
c. Apply knowledge of energy flow, nutrient cycling, and matter transfer in ecosystems (e.g., food webs, biogeochemical cycles), including recognizing the roles played by photosynthesis and aerobic and anaerobic respiration.
d. Demonstrate knowledge of possible solutions for minimizing human impact on ecosystem resources and biodiversity.

3.4 Understand heredity: inheritance and variation of traits.

a. Demonstrate knowledge of the roles of DNA (deoxyribonucleic acid) molecules in cells (e.g., storing genetic information, coding for proteins, regulatory functions, structural functions).
b. Apply knowledge of the structure of DNA and the process of DNA replication.
c. Apply knowledge of how genetic variation may be the result of errors that occur during DNA replication or mutations caused by environmental factors and explain their causes and effects.
d. Demonstrate knowledge of how the coding of DNA controls the expression of traits by genes and influences essential life functions (e.g., how DNA determines protein structure and other heritable genetic variations).
e. Demonstrate knowledge of the relationship between genes and their interaction with the environment in terms of organisms' development and functions.
f. Compare and contrast sexual and asexual reproduction.
g. Apply knowledge of genotypes and phenotypes and the inheritance of traits that are determined by one or more genes (e.g., dominant, recessive, and sex-linked alleles; incomplete dominance).
h. Solve problems from representations of monohybrid and dihybrid crosses.

3.5 Understand biological evolution: unity and diversity.

a. Apply knowledge of anatomical, embryological, and genetic evidence of biological evolution and common ancestry and interpret branching diagrams (cladograms).
b. Demonstrate knowledge of the theory of natural selection, including how genetic variation and its expression leads to differences in characteristics among individuals in a population, adaptation, speciation, and extinction.

c. Demonstrate knowledge of major events that affected the evolution of life on Earth (e.g., climate changes, asteroid impacts).
d. Demonstrate knowledge of technologies that allow humans to influence the genetic traits of organisms.

Domain 4. Earth and Space Sciences.

4.1. Understand Earth's place in the universe.

a. Demonstrate knowledge of the evidence for the Big Bang model (e.g., light spectra, motion of distant galaxies, spectra of primordial radiation).
b. Demonstrate knowledge of how astronomical instruments are used to collect data and how astronomical units are used to describe distances.
c. Demonstrate knowledge of the factors that contribute to a star's color, size, and luminosity and how a star's light spectrum and brightness can be used to identify compositional elements, movements, and distance from Earth.
d. Demonstrate knowledge of nuclear fusion in stars, including the relationship between a star's mass and stage of its lifetime and the elements produced.
e. Demonstrate knowledge of the formation and structure of the solar system, its place in the Milky Way galaxy, and the characteristics of various objects in the solar system.
f. Recognize how evidence from the study of lunar rocks, asteroids, and meteorites provides information about Earth's formation and history.
g. Compare and contrast uniformitarianism and catastrophism.
h. Demonstrate knowledge of the regular and predictable patterns of movements of stars, planets, and the moon and their effects on Earth's systems (e.g., seasons, eclipses, tides).
i. Apply knowledge of how Kepler's laws are used to predict the motion of orbiting objects.

4.2 Understand Earth's materials and systems and surface processes.

a. Recognize various forms of evidence (e.g., seismic waves, iron meteorites, magnetic field data) that led to the current model of Earth's structure (i.e., hot but solid inner core, a liquid outer core, a solid mantle and crust).
b. Demonstrate knowledge of the dynamic processes of erosion, deposition, and transport, including evidence for connections between these processes and the formation of Earth's materials.
c. Demonstrate knowledge of relative and absolute dating techniques, including how half-lives are used in radiometric dating and of how evidence from rock strata is used to establish the geologic timescale.
d. Recognize the factors that can alter the flow of energy into and out of Earth's systems (e.g., tectonic events, ocean circulation, volcanic activity, vegetation).
e. Relate the abundance of liquid water on Earth's surface and water's physical and chemical properties to the dynamic processes shaping the planet's materials and surface.
f. Demonstrate knowledge of surficial processes that form geographic features of Earth's surface (e.g., mechanical, chemical, and biological weathering).

4.3 Understand plate tectonics and large-scale system interactions.

a. Demonstrate knowledge of the evidence for plate tectonics (e.g., the ages of crustal rocks, distribution of fossils and rocks, continental shapes) and relate plate movements to continental and ocean-floor features.
b. Demonstrate knowledge of the thermal processes driving plate movement and relate density and buoyancy to plate tectonics.

c. Demonstrate knowledge of the differences between types of plate boundaries, causes of volcanoes, earthquakes, and how Earth's resources relate to tectonic processes.
d. Demonstrate knowledge of the factors contributing to the extent of damage caused by an earthquake (e.g., epicenter, focal mechanism, distance, geologic substrate).

4.4 Understand weather and climate.

a. Demonstrate knowledge of the water cycle and the interrelationships of surface and subsurface reservoirs.
b. Demonstrate knowledge of the causes of daily, seasonal, and climatic changes and analyze the uneven heating of Earth by the sun.
c. Analyze the effects of air movements on weather and interpret weather maps to predict weather patterns.
d. Demonstrate knowledge of the energy transfer processes of convection, conduction, and radiation in relation to the atmosphere/ocean and Earth's interior structure.
e. Demonstrate knowledge of the mechanisms and the significance of the greenhouse effect on Earth, including the roles of the oceans and biosphere in absorbing greenhouse gases.
f. Demonstrate knowledge of human activities and their impact on global climate change.

4.5 Understand natural resources and natural hazards.

a. Demonstrate knowledge of renewable and nonrenewable energy resources (e.g., fossil fuels, nuclear fuels, solar, biomass).
b. Demonstrate knowledge of Earth's materials as resources (e.g., rocks, minerals, soils, water) that have a global distribution affected by past and current geological processes.
c. Analyze extraction and recycling processes in relation to energy, cost, and demand.
d. Demonstrate knowledge of sustainable uses of resources with respect to utility, cost, and demand.
e. Demonstrate knowledge of the effects of natural hazards (e.g., earthquakes, landslides, floods) on natural and human-made habitats.
f. Demonstrate knowledge of how the availability of natural resources and the existence of natural hazards and other geologic events have influenced the development of human society

Life Sciences Domains and Competencies

Domain 1: From Molecules to Organisms: Structures and Processes

1.1 Understand the structure and function of cells.

a. Apply knowledge of the process by which DNA (deoxyribonucleic acid) within cells is responsible for determining the structure of the proteins that carry out the work of cells.
b. Analyze prokaryotic cells, eukaryotic cells, and viruses in terms of complexity, general structure (e.g., structure and function of cell organelles), and differentiation.
c. Demonstrate knowledge of the role of the endoplasmic reticulum and Golgi apparatus/complex in the production, transport, and secretion of proteins.
d. Apply knowledge of the structure of membranes (e.g., those found in chloroplasts, mitochondria, and cells) and analyze their role in cellular communication, transport, energy flow, and chemiosmosis.
e. Analyze methods of transport across the membrane (e.g., diffusion, active transport, endocytosis, exocytosis).

1.2 Understand the hierarchical organization and functioning of systems in multicellular organisms.

a. Demonstrate knowledge of the hierarchical structure, functions, and interactions of major organ systems (e.g., nutrient uptake, water delivery, physical support, reproduction) in plants and fungi.
b. Demonstrate knowledge of the hierarchical structure, functions, and interactions of major organ systems (e.g., circulatory, digestive, excretory, reproductive, respiratory) in animals, including humans.
c. Analyze feedback mechanisms that maintain homeostasis in plants and animals, including humans (e.g., endocrine and nervous systems), and mediate behaviors under a range of external conditions.
d. Analyze the various responses of the human immune system to infection, including the consequences of a compromised immune system as it relates to interactions with other systems.

1.3 Understand growth and development of organisms.

a. Demonstrate knowledge of the stages of the cell cycle.
b. Distinguish between the processes of mitosis and meiosis, including their purposes.
c. Demonstrate knowledge of the stages of mitosis; its significance in asexual reproduction; and its role in the growth, development, and maintenance of organisms.
d. Explain how cell division and differentiation produce and maintain a complex organism composed of systems of tissues and organs that work together to meet the needs of the whole organism.

1.4 Understand matter and energy flow in organisms.

a. Demonstrate knowledge of the process of photosynthesis, including the role of chloroplasts in obtaining and storing usable energy.
b. Analyze the process of cellular respiration, including the role of mitochondria and how cellular respiration results in the net transfer of energy from one system of interacting molecules to another.
c. Demonstrate knowledge of the anabolic and catabolic pathways involved in the metabolism of macromolecules (e.g., polysaccharides, nucleic acids, proteins, lipids).

d. Analyze the role of enzymes in chemical reactions and analyze experiments designed to investigate the catalytic role of enzymes and factors that affect enzyme activity (e.g., levels of protein organization, temperature, ionic conditions, concentration of enzyme and substrate, pH).

Domain 2: Ecosystems: Interactions, Energy, and Dynamics

2.1 Understand interdependent relationships in ecosystems.

a. Analyze factors affecting the carrying capacity of an ecosystem (e.g., availability of abiotic and biotic resources).
b. Apply knowledge of factors affecting population sizes of species within an ecosystem (e.g., carrying capacity, predation, disease, life history characteristics).
c. Analyze the biotic interactions among organisms in ecosystems (e.g., competition, mutualism, pollination).
d. Analyze how individual and group behavior (e.g., nest building, flocking, schooling, herding, hunting) influence the chances of survival and reproduction for individuals and species.

2.2 Understand cycles of matter and energy transfer in ecosystems.

a. Analyze the roles of organisms in the flow of matter and energy in food webs (e.g., producers, consumers, decomposers).
b. Analyze the flow of matter and energy through trophic levels of ecosystems.
c. Demonstrate knowledge of how photosynthesis and cellular respiration (including anaerobic respiration) provide the energy for life processes.
d. Analyze how chemical elements are transferred among biotic and abiotic components of ecosystems (e.g., biogeochemical cycles) and how changes in amount and distribution of chemical elements can impact ecosystems.

2.3 Understand ecosystem dynamics, functioning, and resilience.

a. Apply knowledge of the biodiversity (e.g., genetic diversity, species diversity, ecosystem diversity) present in different types of biomes.
b. Demonstrate knowledge of how natural events and human activity (e.g., fire, flood, habitat destruction, introduction of invasive species) can adversely affect biodiversity and can disrupt an ecosystem.
c. Apply knowledge of how ecosystems respond to modest and catastrophic change (e.g., resilience, ecological succession).
d. Evaluate possible solutions for mitigating adverse impacts of human activity on biodiversity.

Domain 3. Heredity: Inheritance and Variations of Traits

3.1 Understand inheritance of traits.

a. Analyze the structure of DNA and its relationship to genes.
b. Apply knowledge of how genes expressed by a cell may be regulated in different ways and that specialization of cells in multicellular organisms is due to different patterns of gene expression.
c. Analyze how DNA codes for proteins and DNA's regulatory or structural functions.
d. Apply knowledge of the role of alleles and chromosomes in determining phenotypes (e.g., sex determination, chromosomal aberrations).
e. Predict the probable outcome of phenotypes in a genetic cross from the genotypes of the parents and mode of inheritance (e.g., autosomal or X-linked, dominant or recessive, codominance).

f. Apply knowledge of the genetic and cellular basis of Mendel's laws of dominance, segregation, and independent assortment.

3.2 Understand variation of traits and genetic engineering.

a. Recognize how sexual reproduction results in genetic variation as a result of chromosomal reorganization.
b. Apply knowledge of how genetic variation may be the result of errors that occur during DNA replication or mutations caused by environmental factors, how these mutations are inherited, and the factors affecting whether or not these mutations are expressed.
c. Relate the structure and function of DNA and RNA (ribonucleic acid) to the concept of variation in organisms.
d. Apply knowledge of the genetic and environmental factors that affect variation and distribution of traits in a population, including how alleles that are lethal in a homozygous individual may be maintained in a gene pool.
e. Demonstrate knowledge of how genetic engineering (i.e., biotechnology) produces biomedical and agricultural products.
f. Demonstrate knowledge of issues of bioethics, including those related to genetic engineering, cloning, the Human Genome Project, and gene therapy and its medical implications.

Domain 4. Biological Evolution: Unity and Diversity

4.1 Understand evidence of common ancestry and diversity.

a. Apply knowledge of how conditions on early Earth led to the evolution of life, as well as how the evolution of life altered Earth's conditions.
b. Apply knowledge of anatomical, embryological, and genetic evidence to explain biological evolution and common ancestry.
c. Analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction.
d. Analyze a branching diagram (cladogram) illustrating the phylogeny between organisms of currently identified taxonomic groups and demonstrate understanding that cladograms are hypotheses and can change with the discovery of new information (e.g., fossils, genetics).

4.2 Understand natural selection.

a. Apply knowledge of how genetic variation and its expression leads to differences in reproductive success among individuals in a population.
b. Analyze how natural selection acts on the phenotype rather than the genotype of an organism to alter genotypes in populations.
c. Analyze the role of diversity in gene pools.
d. Apply knowledge of Hardy-Weinberg equilibrium and its assumptions, and solve equations to predict the frequency of genotypes in a population.
e. Demonstrate knowledge of evolutionary mechanisms (e.g., genetic drift, reproductive isolation, patterns of selection) and their effects on patterns of speciation (e.g., convergent evolution).

4.3 Understand adaptation.

a. Apply knowledge of factors affecting the adaptation of species (e.g., heritable genetic variation, competition, differential survival and reproduction of organisms).
b. Distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.
c. Apply knowledge of how natural selection results in genetic change in populations.
d. Analyze how changes in the physical environment may result in changes in the distribution of traits in a population and the emergence, decline, or extinction of species over time.

Chemistry Domains and Competencies

Domain 1. Structure and Properties of Matter

1.1 Understand the structure of matter.

a. Analyze the evidence used in the development of the quantum model of the atom (e.g., the Bohr model, atomic spectroscopy, and the photoelectric effect).
b. Demonstrate knowledge of the positions of protons, neutrons, and electrons within atoms and their properties.
c. Differentiate periodic groups and families of elements and their properties.
d. Relate valence electrons and the electron shell structure (*s*, *p*, *d*, *f* orbitals) to an element's chemical properties and position in the periodic table.
e. Predict periodic trends, including electronegativity, ionization energy, reactivity, and the relative sizes of ions and atoms.

1.2 Understand the properties of matter.

a. Use the kinetic molecular theory to compare and contrast solids, liquids, and gases and to interpret phase diagrams.
b. Relate the electrostatic interactions between particles in a substance, such as types of intramolecular and intermolecular forces, to the substance's physical and chemical properties (e.g., melting point, solubility, vapor pressure, flammability).
c. Solve problems involving the ideal gas law under standard temperature and pressure (STP) and non-STP conditions and predict the relationships between pressure and volume, pressure and temperature, and volume and temperature for ideal gases (e.g., Boyle's law, Charles's law).
d. Demonstrate the ability to convert between the Kelvin and Celsius temperature scales and knowledge of the significance of absolute zero.
e. Solve problems using Dalton's law of partial pressures and Graham's law of effusion.

1.3 Understand the behavior and properties of solutions.

a. Demonstrate knowledge of the behavior of solutions, including identifying solutes and solvents and methods of calculating concentration (e.g., molarity, parts per million, percent composition).
b. Demonstrate knowledge of the process of dissolution at the molecular level, including factors that affect solubility (e.g., temperature, pressure, surface area).
c. Apply knowledge of simple methods for the separation of mixtures (e.g., chromatography, distillation).
d. Distinguish between strong and weak acids and bases on the basis of degree of dissociation and their chemical properties.
e. Calculate pH and hydrogen ion concentration in strong and weak acid or base solutions.
f. Use Arrhenius, Brønsted-Lowry, and Lewis acid-base definitions appropriately to characterize acids and bases and in acid-base reactions.
g. Apply knowledge of buffer solutions, including solving problems related to buffer solutions.

1.4 Understand nuclear processes.

a. Demonstrate knowledge of mass-energy relationships in nuclear reactions and radioactive decay($E = mc^2$).
b. Compare and contrast alpha, beta, and gamma decay, including changes in the nucleus, balancing nuclear reactions, and the relative kinds of damage to matter caused by alpha, beta, and gamma rays.
c. Compare and contrast fission and fusion.

d. Perform calculations involving half-life.
e. Apply knowledge of the radiometric dating of rocks and other materials.

Domain 2. Chemical Reactions and Chemical Bonding

2.1 Understand chemical reactions.

a. Demonstrate knowledge of different types of chemical reactions, including predicting the products of chemical reactions.
b. Interpret potential energy diagrams of reactions (e.g., determining activation energies with and without catalysts, identifying reactions as endothermic or exothermic).
c. Demonstrate knowledge of collision theory and factors that influence reaction rate, including catalysts.
d. Predict the effect of temperature, pressure, and concentration on chemical equilibrium (Le Chatelier's principle).
e. Demonstrate knowledge of chemical equilibrium, including determining equilibrium constant expressions and/or values for given reactions.
f. Apply knowledge of Gibbs energy to analyze the spontaneity of chemical reactions and predict the relative amounts of products and reactants

2.2. Understand chemical bonding.

a. Compare and contrast ionic, covalent, and metallic bonding.
b. Demonstrate knowledge of models representing the structure of molecules and compounds and the bonding between atoms (e.g., Lewis electron dot structures for compounds and ions).
c. Predict molecular geometries using Lewis electron dot structures and hybridized atomic orbitals (e.g., valence shell electron pair repulsion [VSEPR] model).

2.3 Understand conservation of matter and stoichiometry.

a. Calculate molar mass, mass, moles, number of particles, and volume at standard temperature and pressure (STP) for elements and compounds.
b. Calculate quantities of reactants and products and percent yield using balanced chemical equations, including problems with a limiting reagent.
c. Use the law of conservation of matter to balance chemical equations, including oxidation-reduction reactions.

2.4 Understand organic chemistry and biochemistry.

a. Demonstrate knowledge of the bonding characteristics of carbon.
b. Recognize the chemical structure of various organic functional groups (e.g., alcohols, ketones, ethers, amines, esters, aldehydes, organic acids).
c. Demonstrate knowledge of basic chemical reactions involving organic functional groups (e.g., substitution, addition, esterification).
d. Recognize the ten simplest hydrocarbons that contain single bonds, multiple bonds, and benzene rings.
e. Analyze the differences in structures and properties between biologically significant monomers and their polymers (e.g., sugars forming carbohydrates, amino acids forming proteins, glycerol/fatty acids forming lipids, nucleotides forming nucleic acids).
f. Demonstrate knowledge of materials (e.g., medicine, synthetics) produced from natural resources.

Domain 3. Energy

3.1 Understand the definitions of energy, conservation of energy, and energy transfer.

a. Analyze the energy in a system, including describing energy in terms of the motion and interactions of matter and radiation and recognizing that energy in systems is continually transferred from one object to another and between its possible forms (e.g., kinetic, potential).
b. Demonstrate knowledge of how different manifestations of energy (e.g., sound, light, thermal energy) can be modeled as a combination of energy associated with the motion of particles and energy associated with the relative position of these particles.
c. Apply knowledge of heat, specific heat, enthalpy of fusion, enthalpy of vaporization, and enthalpy of reaction to perform calculations (e.g., calorimetry) and explain phenomena.
d. Interpret heating and cooling curves.
e. Apply knowledge of the energy changes associated with the breaking or forming of chemical bonds during a chemical process.

3.2 Understand energy in chemical processes and everyday life.

a. Analyze the benefits and hazards of the use of radiation, radioactivity, and nuclear energy, in comparison to nonnuclear processes.
b. Demonstrate knowledge of electric power generation from fossil fuels and alternative fuels (e.g., solar, tidal, nuclear).
c. Apply knowledge of the source of the energy produced by the sun and how this energy is captured on Earth.
d. Demonstrate knowledge of energy production and use associated with photosynthesis and cellular respiration.

Earth and Space Sciences Domains and Competencies

Domain 1: Earth's Place in the Universe

1.1. Understand the universe and its stars.

a. Analyze evidence for the Big Bang model (e.g., light spectra, motion of distant galaxies, spectra of primordial radiation).
b. Analyze the roles of gravity and nuclear fusion in the formation and life cycle of stars, including the sun.
c. Apply knowledge of how a star's light spectrum and brightness can be used to identify its temperature, age, and evolution.
d. Analyze the characteristics of galaxies (e.g., size, origin, shape), including the role of gravity in their structural development.
e. Analyze the process of the nuclear synthesis of both lighter and heavier chemical elements and of how scientists model these processes (i.e., in stars and supernovas).
f. Apply knowledge of the use of various instruments to collect data about stars.

1.2. Understand Earth and the solar system.

a. Analyze the motion of orbiting objects using Newton's laws and Kepler's laws.
b. Analyze evidence used to explain how and when the solar system was formed, including differences and similarities among the sun, planets, and other objects in the solar system.
c. Evaluate evidence for the existence of celestial objects and other solar systems.
d. Analyze the history and evolution of the solar system over time (e.g., orbital migration, Late Heavy Bombardment, solar output).
e. Analyze the cyclic patterns of the Earth, moon, and sun systems (e.g., lunar phases, eclipses, the seasons, tides, motion of planets in the sky relative to stars).
f. Apply knowledge of astronomical measurements to determine the scale of the solar system and the universe and the proximity of the planets in the solar system in relation to Earth, stars, and the universe.

1.3. Understand the history of planet Earth.

a. Analyze plate tectonics theory to explain changes in Earth's surface over time.
b. Analyze the formation and evolution of Earth's atmosphere over geologic time (e.g., outgassing, carbon dioxide concentration, origin of atmospheric oxygen).
c. Analyze evidence that Earth and other planets have changed over time, including the role of collisional processes in the formation and shaping of Earth's surface and layers and life on the planet.
d. Apply knowledge of the development and the major divisions of the geologic timescale.
e. Analyze evidence from rocks and fossils to interpret Earth's history and the origins and development of life on Earth.

Domain 2: Earth's Systems

2.1 Understand Earth's materials and systems.

a. Explain how the properties of rocks are due to the physical conditions under which they are formed and their chemical composition.
b. Analyze the properties of common rock-forming minerals and techniques for identifying minerals.
c. Analyze the processes of mechanical, chemical, and biological weathering.

d. Analyze the role of biogeochemical cycles on Earth (e.g., carbon, oxygen, nitrogen).
e. Analyze the interconnectedness of Earth's systems in their response to changing conditions (e.g., feedback effects, such as El Niño and deforestation).
f. Analyze how changes in Earth's systems alter the flow of energy into and through the systems (e.g., ocean circulation, volcanic activity, atmospheric conditions).

2.2 Understand plate tectonics and large-scale systems.

a. Apply knowledge of the thermodynamic process driving the motion of Earth's mantle, tectonic plates, and the effects on the cycling of matter.
b. Analyze the characteristics (e.g., formation, rock composition) of volcanoes, including volcanoes that are due to hot spots and those due to subduction.
c. Analyze the causes of and characteristics (e.g., intensity, epicenter) of earthquakes, including basic interpretation of seismograms.
d. Analyze geologic structures and their relationships to tectonic settings and forces.
e. Interpret geologic maps as a basis for understanding the tectonic evolution of California.

2.3 Understand oceanography and the role of water in Earth's surface processes.

a. Apply knowledge of the chemical and physical properties of seawater.
b. Demonstrate knowledge of the mechanisms that cause wave action and tides.
c. Analyze how the properties of seawater (e.g., penetration of sunlight, density, salinity) are related to the layered structure of the oceans (e.g., ocean currents, distribution of marine organisms).
d. Analyze the processes that drive the water cycle.
e. Relate the abundance of liquid water on Earth's surface and water's physical and chemical properties to the dynamic processes shaping the planet.
f. Demonstrate knowledge of deposition and transport in aquatic environments, including factors controlling these processes.

2.4 Understand the atmosphere, weather, and climate.

a. Analyze the properties of different atmospheric layers (e.g., composition, thermal structure, density).
b. Apply knowledge of the role of the ozone layer in the upper atmosphere and the way in which this layer varies both naturally and in response to human activities.
c. Analyze the role of water in Earth's atmosphere (e.g., clouds, precipitation, air masses) and the causes and effects of severe weather.
d. Analyze how insolation contributes to the formation of Earth's global climate systems.
e. Analyze factors that affect climate (e.g., latitude, elevation, topography).
f. Identify the bands at specific latitudes where rain forests and deserts are distributed and analyze the causes of these patterns.
g. Analyze the characteristics of the El Niño/Southern Oscillation (ENSO) cycle in terms of sea-surface and air temperature variations across the Pacific and climatic results of this cycle.

Domain 3: Earth and Human Activity

3.1 Understand natural resources.

a. Analyze the origin of California's water (e.g., precipitation, California State Water Project, desalination) and the environmental, political, and economic effects resulting from its distribution, conservation, and uses.

b. Analyze the development, conservation, recycling, and importance of California's major economic resources (e.g., energy, minerals) and how the environmental impacts of their use can be minimized (e.g., in agriculture, mining, and energy extraction).
c. Recognize how scientific modeling can be used to preserve the long-term availability of resources.

3.2 Understand natural hazards.

a. Analyze the location of natural hazards in California (e.g., floods, landslides, fires), the factors that increase their frequency and intensity, and their relationship to California's geology.
b. Demonstrate knowledge of monitoring methods used to reduce the impact of natural hazards.
c. Analyze published geologic hazard maps of California (e.g., to identify past geologic events, to predict geologic changes).

3.3 Understand human impacts on Earth's systems.

a. Analyze the effects of human activities and increasing population size on Earth's systems, including feedback from one system to another.
b. Evaluate strategies for mitigating the effects of human activities on Earth's systems (e.g., recycling, treating sewage, designating marine conservation areas).

3.4 Understand global climate change.

a. Analyze the potential short-term and long-term impacts of human activities on regional and global climate changes.
b. Analyze methods used to study past and current climate conditions, including how modeling and simulations are used to study and make predictions about how Earth's systems respond to human activities.

Physics Domains and Competencies

Domain 1: Motion and Stability: Forces and Interactions

1.1 Understand forces and motion.

a. Use Newton's law of universal gravitation and Coulomb's law to describe and predict the effects of gravitational energy and electrostatic forces between distant objects.
b. Solve problems using Newton's laws of motion and universal gravitation (e.g., problems involving time, velocity, and space-dependent forces).
c. Analyze free body diagrams of many-body problems (e.g., problems involving two or more coupled masses).
d. Solve periodic motion problems, including problems involving simple harmonic motion.
e. Solve two-dimensional problems involving vector analysis of motion and forces, including projectile motion, uniform circular motion, and statics.
f. Analyze functional relationships of graphs showing distance, velocity, and acceleration versus time (e.g., evaluating slopes and areas using algebra and calculus).
g. Demonstrate knowledge of relationships among variables for linear motion and rotational motion, including solving problems involving linear and rotational motion in terms of forces and torques.
h. Evaluate the relative motion of systems of objects.
i. Evaluate the statics and dynamics of Newtonian fluids.

1.2 Understand conservation of energy and momentum.

a. Differentiate between kinetic energy and potential energy and demonstrate knowledge of the variables in these states of energy.
b. Analyze kinetic-potential energy systems such as oscillating systems (pendula and springs), projectile motion, and roller coasters in terms of conservation of energy, including analyzing graphs.
c. Analyze elastic and inelastic collisions and solve problems involving collision for unknown values.
d. Solve problems involving linear and rotational motion in terms of conservation of momentum and energy.
e. Analyze relationships between energy/momentum conservation principles and Newton's laws.
f. Demonstrate knowledge of the impact of retarding forces (e.g., friction, air resistance) on conservation principles.
g. Analyze force-versus-time and force-versus-distance graphs (e.g., to find work done or impulse on a system).
h. Solve problems involving momentum quantities in two dimensions.
i. Solve problems involving moment of inertia of standard geometric objects, including objects requiring the use of the parallel axis theorem.

Domain 2. Energy

2.1 Understand definitions of energy and energy in everyday life.

a. Analyze the energy in a system, including describing energy in terms of the motion and interactions of matter and radiation and recognizing that energy in systems is continually transferred from one object to another and between its possible forms (e.g., kinetic, potential).
b. Demonstrate knowledge of how different manifestations of energy (e.g., sound, light, thermal energy) can be modeled as a combination of energy associated with the motion of particles and energy associated with the relative position of these particles.

c. Apply knowledge of the benefits and hazards of the use of radiation, radioactivity, and nuclear energy in comparison to nonnuclear processes.
d. Analyze electric power generation from fossil fuels and alternative sources (e.g., solar, wind, tidal, geothermal, hydro) and compare their relative efficiencies.
e. Analyze energy transformations in systems, including identifying factors that contribute to inefficiencies in energy transfer (e.g., all types of heat loss).

2.2 Understand thermal energy and kinetic molecular theory.

a. Apply knowledge of the laws of thermodynamics using the relationships among work, heat, energy, and entropy, including solving thermodynamic problems.
b. Solve problems using the thermodynamic properties of materials (e.g., kinetic theory of matter, specific heat [heat capacity], heats of fusion and vaporization, thermal conductivity, thermal expansion).
c. Apply knowledge about ideal gas systems, including solving problems involving ideal gas systems.
d. Analyze graphs and solve problems involving phase changes, cyclic processes, work done, heat gain/loss, and entropy change.
e. Demonstrate knowledge of a plasma, state its characteristic properties, and contrast it with an ideal gas.

2.3 Understand electricity and magnetism.

a. Analyze electric and magnetic forces, charge, and fields using Coulomb's law, the Lorentz force, and the right-hand rule.
b. Apply energy principles to analyze problems in electricity, magnetism, and circuit theory involving capacitors, resistors, and inductors.
c. Apply knowledge of power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors, and solve problems involving such circuits.
d. Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors.
e. Apply knowledge of and explain the relativistic relationship between electric and magnetic phenomena.
f. Solve problems involving the change of magnetic flux and induced current.
g. Demonstrate knowledge of properties of transistors, diodes, and semiconductors.
h. Apply knowledge of electric potential energy.
i. Determine the electric field flux through a surface for systems with a uniform distribution of charge using Gauss's law.
j. Analyze capacitors in terms of geometry, dielectrics, charge, and energy storage.

Domain 3. Waves and Their Applications

3.1 Understand wave properties.

a. Explain the relationship between the wavelength, frequency, and speed of travel of a wave.
b. Demonstrate knowledge of the properties of waves, including the relationship between amplitude and energy.
c. Analyze wave propagation with respect to properties of materials (e.g., predicting wave speed from density and tension and index of refraction).
d. Describe, distinguish, and solve both conceptual and numerical problems involving interference (e.g., constructive, destructive, resonance, thin film), diffraction (e.g., around edges, single-slit, double-slit), and refraction (e.g., the use of Snell's law, critical angle calculation, thin lens equation, ray diagrams).

e. Describe, distinguish, and solve both conceptual and numerical problems involving reflection (with both plane and curved mirrors), Doppler effect, polarization, dispersion, and scattering.
f. Analyze systems where standing waves are present (e.g., close-ended air columns, open-ended air columns, wires under tension).

3.2 Understand electromagnetic radiation and applications of waves in information technologies and instrumentation.

a. Apply knowledge of the wave and particle models that explain the properties of electromagnetic radiation, including evidence supporting these models (e.g., black-body radiation, double-slit experiment).
b. Demonstrate knowledge of the effects of different frequencies of electromagnetic radiation (e.g., light, ultraviolet, X-rays, gamma rays) when absorbed by matter, including living cells.
c. Apply knowledge of the photoelectric effect, including the effects of varying frequencies of light on photoelectric materials.
d. Demonstrate knowledge of how energy and information are transferred by waves without mass transfer, the technological devices and applications associated with waves (e.g., cell phones, medical imaging, telescopes), and the advantages and disadvantages of digital transmission and storage.

Domain 4. Modern Physics

4.1 Understand quantum mechanics, the standard model of particles, and special relativity.

a. Analyze the four fundamental forces of nature, demonstrate knowledge of their ranges, and identify their force carriers.
b. Analyze the assumptions and relevance of the Bohr model of the atom.
c. Demonstrate knowledge of the basic principles of special relativity and their applications (e.g., Global Positioning System).
d. Demonstrate knowledge of the basic principles of quantum mechanics (e.g., Heisenberg uncertainty principle, wave-particle duality).

4.2 Understand nuclear processes.

a. Analyze mass-energy relationships in nuclear reactions and radioactive decay.
b. Compare and contrast alpha, beta, and gamma decay, and their effects on living matter.
c. Perform calculations involving half-life and binding energy.
d. Apply knowledge of the processes of nuclear fission and nuclear fusion.
e. Demonstrate the ability to balance nuclear reactions.