APPENDICES

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APPENDIX A

Survey of Perceptions towards the Use of Diagnostic Tests

DIRECTIONS

The purpose of this questionnaire is to assess your perceptions towards the use of diagnostic tests in the classroom. Your responses will be of great value to my research study: Implementing a Diagnostic Assessment Model Using Criterion-referenced Tests in a Private College.

The value of this questionnaire depends on the care with which you respond to each statement. Your answers will be treated with the strictest confidence, so feel free to answer all questions throughout thoughtfully and honestly. You will mark your answers on this booklet. There are 36 statements in this questionnaire. For each statement a five-point scale is provided for indicating whether you strongly disagree, disagree, uncertain, agree or strongly agree as the statement suggests.

You are to mark each statement by circling the rating point that represents your answer choice. To assist you in answering the questionnaire, the terms have been defined for the rating scale as follows:

SD - Strongly disagree
D - Disagree
U - Uncertain
A - Agree
SA - Strongly agree

Remember, you should answer each statement in accordance with what you think or feel. There are no 'right' or 'wrong' answers to these statements, and there is no time limit for this questionnaire. Work as quickly as you can without being careless, and do not spend too much time on any statement. Please do not omit any statements.

Thank-you.
Questionnaire to Assess Perceptions of Students towards Diagnostic Tests

<table>
<thead>
<tr>
<th>Age:</th>
<th>Sex:</th>
<th>Course:</th>
<th>Date:</th>
</tr>
</thead>
</table>

The following statements best describe diagnostic tests.  
*(Select the best response for each of the following statements)*

Response Key: SD-Strongly Disagree, D-Strongly Agree, U-Uncertain, A-Agree, SA-Strongly Agree

<table>
<thead>
<tr>
<th></th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I would like all tests to be diagnostic.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. If given the choice, I would probably chose a course that uses diagnostic tests for assessment.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. I wish I had diagnostic tests on other subjects in this course as well.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. I like diagnostic tests this semester, and I probably will be able to do better compared to the physics tests last semester.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. A diagnostic test is a systematic way of testing for mastery of learning objectives.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Mastery of a diagnostic physics test is a source of satisfaction.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. The feedback from diagnostic tests is a means to improve on my learning of physics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. A diagnostic test helps me in identifying my learning weaknesses.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. A diagnostic test is a very important type of test in providing feedback to students.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. Diagnostic tests should be given more emphases in my course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
11. When a diagnostic test shows my areas of weaknesses, I put more effort in studying these areas.

1 2 3 4 5

12. A major purpose of diagnostic tests is to help me learn more systematically.

1 2 3 4 5

13. Diagnostic tests serve a more useful purpose than does other tests that I sat for.

1 2 3 4 5

14. Learning can be improved by feedback from diagnostic tests.

1 2 3 4 5

15. Diagnostic test items relating closely to instructional objectives make studying for the test easier.

1 2 3 4 5

16. I wish diagnostic tests had been used in primary and secondary schools for assessment purpose.

1 2 3 4 5

17. The use of diagnostic tests this semester pleases me.

1 2 3 4 5

18. Since physics is so hard to understand, diagnostic testing of small units of instruction helps in my understanding.

1 2 3 4 5

19. I prefer the diagnostic tests in physics to the normal tests for other subjects in the course.

1 2 3 4 5

20. Diagnostic tests have been beneficial to me.

1 2 3 4 5

21. A student of average ability can perform better in tests on any subject if diagnostic tests are used.

1 2 3 4 5

22. Improvement in learning could be accomplished if teachers use diagnostic tests in the classroom.

1 2 3 4 5

23. I would like my teachers to use diagnostic tests in their subjects.

1 2 3 4 5
24. I would recommend that diagnostic tests be used for all subjects in this college. 

25. The main reason for using diagnostic tests is to make a subject easier to learn. 

26. The thrill of knowing what objectives I have mastered or not mastered is a motivating factor in diagnostic tests. 

27. If a student failed to answer a test item in a diagnostic test, all he has to do is to revise on the objectives of that item. 

28. A diagnostic test is one of the most important tools of obtaining feedback for both students and teachers. 

29. I would not know what I have learned without sitting for diagnostic tests. 

30. I do not mind having more diagnostic tests in physics. 

31. When I attend a course after I leave this college, I would prefer tests to be diagnostic. 

32. A subject should be organised into smaller units of assessment objectives before it is taught. 

33. Diagnostic physics tests this semester make me want to learn. 

34. I refer to the learning objectives of a module or unit when revising for a diagnostic test. 

35. Diagnostic test results provide me with a means to assess my own strengths and weaknesses. 

36. I like instructional objectives tested by diagnostic tests. These objectives allow me to study to my full potential.
APPENDIX B

Survey to Assess Group Differences in the Perceptions of the Diagnostic Test

DIRECTIONS

The purpose of this questionnaire is to assess your perceptions towards the use of diagnostic tests in the classroom. Your responses will be of great value to my research study: Implementing a Diagnostic Assessment Model in a Private College.

The value of this questionnaire depends on the care with which you respond to each statement. Your answers will be treated with the strictest confidence, so feel free to answer all questions thoughtfully and honestly. You will mark your answers on this booklet. The rating scale consists of a series of adjectives and their opposites listed on opposite sides of the page. A seven-point rating, ranging from 1 to 7, is inserted between these 18 bipolar adjectives. This seven-point rating is not shown.

You are to place an X on one of the seven lines placed between each pair of the eighteen subjects relating to diagnostic tests in the classroom. To assist you in answering the questionnaire, an example is shown below.

Bad  _____ _____ _____ X _____ Good

The response above is rated '6' on a scale of 1 to 7 points.

Remember, you should answer each statement in accordance with what you think or feel. There are no 'right' or 'wrong' answers to these statements, and there is no time limit for this questionnaire. Work as quickly as you can without being careless, and do not spend too much time on any statement. Please do not omit any statements.
Semantic Differential Scale to Assess Group Differences in the Perceptions of the Diagnostic Test

Place an X on one of the seven lines between each pair of the eighteen subjects relating to diagnostic tests in the classroom. Please respond quickly based on your first impressions.

| BAD       | _ | _ | _ | _ | _ | _ | _ | GOOD  |
| UNFAIR   | _ | _ | _ | _ | _ | _ | _ | FAIR  |
| PLEASANT | _ | _ | _ | _ | _ | _ | _ | UNPLEASANT |
| WORTHLESS | _ | _ | _ | _ | _ | _ | _ | VALUABLE |
| INFORMATIVE | _ | _ | _ | _ | _ | _ | _ | NON-INFORMATIVE |
| LIGHT    | _ | _ | _ | _ | _ | _ | _ | HEAVY |
| SOFT     | _ | _ | _ | _ | _ | _ | _ | TOUGH |
| STRONG  | _ | _ | _ | _ | _ | _ | _ | WEAK |
| SLOW     | _ | _ | _ | _ | _ | _ | _ | FAST |
| HOT      | _ | _ | _ | _ | _ | _ | _ | COLD |
| ACTIVE  | _ | _ | _ | _ | _ | _ | _ | PASSIVE |
| STATIC | _ | _ | _ | _ | _ | _ | _ | DYNAMIC |
| EASY    | _ | _ | _ | _ | _ | _ | _ | DIFFICULT |
| SIMPLE  | _ | _ | _ | _ | _ | _ | _ | COMPLEX |
| CLEAR | _ | _ | _ | _ | _ | _ | _ | CONFUSING |
| THREATENING | _ | _ | _ | _ | _ | _ | _ | NON-THREATENING |
| TENSE  | _ | _ | _ | _ | _ | _ | _ | RELAXING |
| FEARFUL | _ | _ | _ | _ | _ | _ | _ | NOT-FEARFUL |

Name:
APPENDIX C

Survey to Assess Perceptions towards Multiple-Choice versus Essay Type Diagnostic Tests

The purpose of this questionnaire is to assess your perceptions towards two different formats of the diagnostic test. Part A of the questionnaire is to assess your perceptions towards the multiple-choice format test while Part B assesses your perceptions towards the essay type format of the diagnostic test. Your responses will be of great value to my research study: Implementing a Diagnostic Assessment Model Using Criterion-referenced Tests in a Private College.

The value of this questionnaire depends on the care with which you respond to each statement. Your answers will be treated with the strictest confidence, so feel free to answer all questions thoughtfully and honestly. You will mark your answers on this booklet. Each part of the questionnaire consists of 14 five-point rating scale. Each scale is designed to gather data on your feelings towards one aspect of the test format.

You are to place an X on one of the five lines placed after each of the fourteen aspects relating to the diagnostic test format. To assist you in answering the questionnaire, an example is shown below.

<table>
<thead>
<tr>
<th>Not at all</th>
<th>A little</th>
<th>Uncertain</th>
<th>Quite a bit</th>
<th>Very</th>
</tr>
</thead>
</table>

1. Difficult

The response above is rated '4' on a scale of 1 to 5 points.

Remember, you should answer each statement in accordance with what you think or feel. There are no 'right' or 'wrong' answers to these statements, and there is no time limit for this questionnaire. Work as quickly as you can without being careless, and do not spend too much time on any statement. Please do not omit any statements.

Thank-you for your cooperation.
Questionnaire to Assess Students’ Perceptions towards Multiple-Choice Versus Essay Type Diagnostic Tests

PART A: Multiple-Choice Format

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little</th>
<th>Uncertain</th>
<th>Quite a bit</th>
<th>Very</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Difficulty</td>
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<tr>
<td>2. Complexity</td>
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<tr>
<td>3. Appropriateness</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>4. Clarity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5. Value or Worth</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6. Effectiveness</td>
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<td></td>
</tr>
<tr>
<td>7. Expectancy of Success</td>
<td></td>
<td></td>
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<tr>
<td>8. Degree of Interest Aroused</td>
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<tr>
<td>9. Degree of Anxiety Aroused</td>
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<tr>
<td>10. Comfortable Feeling</td>
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<tr>
<td>11. Fairness</td>
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<tr>
<td>12. Fear of Failure</td>
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<tr>
<td>13. Trickiness</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>14. Degree of Motivation</td>
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</tbody>
</table>

Please write your name below. Your responses will be kept confidential.

NAME:
### PART B: Essay-Type Format

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little</th>
<th>Uncertain</th>
<th>Quite a bit</th>
<th>Very</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Difficulty</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2. Complexity</td>
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<td>3. Appropriateness</td>
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<td>4. Clarity</td>
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<tr>
<td>5. Value or Worth</td>
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<tr>
<td>6. Effectiveness</td>
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<tr>
<td>7. Expectancy of Success</td>
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<tr>
<td>8. Degree of Interest Aroused</td>
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<tr>
<td>9. Degree of Anxiety Aroused</td>
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<tr>
<td>10. Comfortable Feeling</td>
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<tr>
<td>11. Fairness</td>
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<tr>
<td>12. Fear of Failure</td>
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<td></td>
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<tr>
<td>13. Trickiness</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>14. Degree of Motivation</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Please write your name below.

**NAME:**
APPENDIX D

Item Rating Form for Determining Content-Related Validity

Rater: ____________________________  Test: ____________________________

Please read carefully through the test specification. Next, please indicate how well you feel each item reflects the test specification. Judge a test item solely on the basis of the match between its content and the content defined by the test specification. Please use the four-point rating scale shown below:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>not relevant</td>
<td>somewhat relevant</td>
<td>quite relevant</td>
<td>very relevant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ITEM NUMBER</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>3</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>4</td>
<td>1 2 3 4</td>
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<td>1 2 3 4</td>
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<td>6</td>
<td>1 2 3 4</td>
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<td>7</td>
<td>1 2 3 4</td>
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<td>1 2 3 4</td>
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<td>9</td>
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<td>10</td>
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<td>19</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>20</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>
APPENDIX E

List of Formulae

1. Brennan Discrimination Index, $B$

$$B = \left( \frac{U}{n_1} - \frac{L}{n_2} \right)$$

in which $B = \text{Brennan's index}$
$n_1 = \text{number of students above mastery criterion}$
$n_2 = \text{number of students below mastery criterion}$
$U = \text{number of students in } n_1 \ \text{who gets item correct}$
$L = \text{number of students in } n_2 \ \text{who gets item correct}$

2. Item-total Correlation, $r_{XY}$

$$r_{XY} = \frac{\left( \sum \frac{XY}{N} \right) - (\bar{X})(\bar{Y})}{\sigma_X \sigma_Y}$$

in which $X = \text{scores on the item being analysed}$
$Y = \text{total scores on the test}$
$\bar{X} = \text{the mean for scores on the item being analysed}$
$\bar{Y} = \text{the mean of the total test scores}$
$\sigma_X = \text{the standard deviation of scores on the item being analysed}$
$\sigma_Y = \text{the standard deviation of the total test scores}$

3. Point-biserial Correlation Coefficient, $r_{pb}$

$$r_{pb} = \frac{(\bar{X}_1 - \bar{X}) \sqrt{p/1-p}}{\sigma_X}$$

in which $r_{pb} = \text{point-biserial correlation coefficient}$
$\bar{X} = \text{the mean on the test for all students}$
$\bar{X}_1 = \text{the mean on the test for only those students correct on item 1}$
$\sigma_X = \text{the standard deviation on the test}$
$p = \text{proportion of students correct on item 1}$
4. Pearson Product-moment Correlation Coefficient, $r_{XY}$

$$r_{XY} = \left( \frac{\sum XY}{N} \right) - \left( \bar{X} \right) \left( \bar{Y} \right)$$

$$\sigma_X \sigma_Y$$

in which

$\Sigma XY =$ sum of each X-score times its Y-score

$N =$ total number of pairs of scores

$\bar{X} =$ the mean of the X distribution

$\bar{Y} =$ the mean of the Y distribution

$\sigma_X =$ the standard deviation of the X distribution

$\sigma_Y =$ the standard deviation of the Y distribution

5. Split-half Reliability, $r_{XoXE}$

$$r_{XoXE} = \frac{\left( \Sigma X_o X_E \right) - (X_o)(X_E)}{\sigma_X \sigma_Y}$$

in which

$X_o =$ the odd-numbered items

$X_E =$ the even-numbered items

$\sigma_{Xo} =$ the standard deviation of the odd-numbered item scores

$\sigma_{XE} =$ the standard deviation of the even-numbered item scores

6. Cronbach's Coefficient Alpha, $r_\alpha$

$$r_\alpha = \frac{k}{k-1} \left( 1 - \sum \frac{\sigma_i^2}{\sigma_X^2} \right)$$

in which

$k =$ the number of test questions

$\sigma_X^2 =$ the test variance

$\sigma_i^2 =$ the variance on a specific test item (calculated for each item)

$\Sigma \sigma_i^2 =$ the sum of all test item variances
7. Kuder-Richardson 20 Formula

\[ r_{20} = \frac{k}{k-1} \left( 1 - \sum p_i q_i / \sigma_X^2 \right) \]

in which
- \( k \) = the number of test questions
- \( \sigma_X^2 \) = the test variance
- \( p_i \) = proportion of students answering an item correctly (one \( p \) value for each item)
- \( q_i \) = proportion of students answering an item incorrectly (equal to \( 1 - p \), one value for each item)
- \( \sum p_i q_i \) = the sum of each item's \( p \) value times its corresponding \( q \) value

8. Spearman-Brown Prophesy Formula

\[ r' = \frac{Nr}{1 + (n-1)r} \]

in which
- \( r' \) = reliability of the longer test
- \( r \) = reliability of the original test
- \( N \) = factor by which the test length has been increased, i.e., the ratio of the new test length to original test length

Note: \( N = 2 \) in split-half studies because the split-half procedure determines reliability from half-tests and the Spearman-Brown formula estimates the reliability of the complete test which is 2 times as long as the half-tests.

9. Standard Error of Measurement (SEM)

\[ SEM = (\sigma_X) \sqrt{1-r} \]

in which
- \( r \) = reliability coefficient for the test
- \( \sigma_X \) = the standard deviation of the test scores
10. Phi Coefficient, $\phi$

Matrix for computing $\phi$ coefficient for an item

<table>
<thead>
<tr>
<th></th>
<th>Pass</th>
<th>Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masters</td>
<td>$a$</td>
<td>$b$</td>
</tr>
<tr>
<td>Non-masters</td>
<td>$c$</td>
<td>$d$</td>
</tr>
<tr>
<td></td>
<td>$a + c$</td>
<td>$b + d$</td>
</tr>
</tbody>
</table>

$\phi = \frac{ad - bc}{\sqrt{(a+b)(a+c)(b+d)(c+d)}}$
APPENDIX F

Organisation of Syllabus into Modules, Units and Behavioural Objectives

Module 1: Wave Motion (3 units)  

<table>
<thead>
<tr>
<th>Unit</th>
<th>Instruction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Simple Harmonic Motion (S.H.M)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Unit 2: One-dimensional Progressive Waves</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Unit 3: Two-dimensional Waves – Light Waves</td>
<td>3 ½ weeks</td>
</tr>
</tbody>
</table>

Module 2: Quantum Physics (2 units)  

<table>
<thead>
<tr>
<th>Unit</th>
<th>Instruction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 4: Quantum Theory of Light – Photoclectric Effect</td>
<td>2 ½ weeks</td>
</tr>
<tr>
<td>Unit 5: X-rays &amp; Duality of Matter</td>
<td>2 ½ weeks</td>
</tr>
</tbody>
</table>

Module 3: Atomic Physics (1 unit)  

<table>
<thead>
<tr>
<th>Unit</th>
<th>Instruction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 6: Models of The Atom – Energy Levels</td>
<td>3 weeks</td>
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Module 4: Nuclear Physics (1 unit)  

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<th>Unit</th>
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<td>Unit 7: Nuclear Stability – Radioactivity</td>
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**Duration of Course:** 19 weeks

Note: Instructional time consists of 4 hours of Theory and 2 hours of Practical per week.
Module 1

Wave Motion

Unit 1: Simple Harmonic Motion

After completion of this unit, students should be able to do the following:

1.1 Define S.H.M stating the TWO conditions required.

1.2 Given a displacement, \( x \) versus time \( t \) graph for an S.H.M, to determine the amplitude, frequency and period.

1.3 Sketch the graphs of the form \( x = r \sin (\omega t + \phi) \) on the same set of axes.

1.4 Given an equation of the form \( x = r \sin (\omega t + \phi) \), to write down the amplitude, period, frequency, angular frequency and phase angle for the S.H.M.

1.5 Define amplitude, frequency, period and phase angle.

1.6 Given two graphs on the same set of axes, to determine the phase difference between the two S.H.M's represented by the graphs.

1.7 Recall that simple pendulum and mass-spring oscillators are examples of S.H.M.

1.8 Write down the formula for the period of a simple pendulum showing how the period depends on the length.

1.9 Write down the formula for the period of a mass-spring oscillator showing how the period depends on the mass and the force constant of the spring.

Unit 2: One-dimensional Progressive Waves

After completion of this unit, students should be able to do the following:

2.1 Define ‘transverse wave’ and ‘longitudinal wave’.

2.2 Sketch the displacement-distance (\( y-x \)) graph for a transverse wave and a longitudinal wave.
2.3 Sketch the displacement-time \((x-t)\) graph for a particle in the medium where a one dimensional wave passes.

2.4 Determine the wavelength and amplitude given a \((y-x)\) graph.

2.5 Determine the period and frequency of a wave from the \((x-t)\) graph.

2.6 Recall and apply the simple wave equation, \(v = f\lambda\).

2.7 To sketch the e-m wave showing \(B\) against \(x\) and \(E\) against \(x\) on the same graph.

2.8 To explain why an e-m wave is a transverse wave.

2.9 To appreciate that an e-m wave consists of oscillating electric and magnetic field vectors, not of material particles.

2.10 To recall that an e-m wave travels with the speed of light, \(c\).

2.11 To list down ALL the different types of e-m waves: gamma-rays, X-rays, ultraviolet, visible light, infra-red, microwaves and radio-waves.

2.12 To state the basic difference between the various types of e-m waves is the result of their different wavelength.

2.13 To draw a chart arranging e-m waves in order of decreasing wavelengths, including the orders of their magnitudes.

2.14 To calculate the time taken for an e-m wave signal from a radio station to reach a point a given distance away.

2.15 To sketch the displacement-time graphs on the same set of axes for two sinusoidal waves having the same wavelength and amplitude travelling in the same direction that are one quarter of a period out of phase.
Unit 3: Two-Dimensional Waves – Light Waves

On completion of this unit, students should be able to do the following:

3.1 State the Principle of Superposition.

3.2 State TWO conditions required for two sources of waves to be coherent.

3.3 Define the term 'constructive interference' and 'destructive interference'.

3.4 Recognise a geometrical construction of the interference of two dimensional waves from coherent sources.

3.5 Indicate on the interference pattern, the points of maxima and minima, namely antinodes and nodes respectively.

3.6 Explain, in terms of the path difference, why maximum and minimum occurs at a point.

3.7 Apply in simple calculations the conditions for constructive interference at a point, \( d \sin \theta = m \lambda \), \( m = 0, 1, 2, 3, \ldots \)

3.8 Apply in simple calculations, the conditions for destructive interference at a point, \( d \sin \theta = (n - \frac{1}{2}) \lambda \), \( n = 1, 2, 3, \ldots \)

3.9 Calculate the path difference of two waves at a point on a given interference pattern.

3.10 Apply the simple wave equation \( v = f \lambda \) to calculate the speed of water waves given the frequency and wavelength measured from an interference pattern.

3.11 Calculate the number of nodal and antinodal lines given the separation between sources and wavelength.

3.12 Describe the change in the interference pattern when the two sources are out of phase by \( \pi \) radians.
3.13 Recognise the setup and state the dimensions and functions of each component in Young’s double slit experiment.

3.14 Explain why the sources are coherent in Young’s double-slit experiment.

3.15 Sketch the interference pattern on the screen for interference of monochromatic light from the coherent sources.

3.16 Sketch the intensity distribution of the interference pattern on the screen.

3.17 Explain that the intensity distribution of the double slit interference pattern is the result of the intensity distribution of each single slit.

3.18 Solve simple problems involving the equations \( x_n = n\lambda D/d, n = 0, 1, 2, 3, \ldots \) for bright fringes and \( x_n = (n - \frac{1}{2})\lambda D/d, n = 1, 2, 3, \ldots \) for dark fringes.

3.19 Define ‘bandwidth’ of an interference pattern.

3.20 Apply the bandwidth formula \( w = \lambda D/d \) in simple calculations.

3.21 Use the condition \( \sin \theta < 1 \) to calculate the number of orders of maxima and minima in an interference pattern.

3.22 Describe the changes in the interference pattern and bandwidth for the following cases: (a) change the wavelength of the light source, (b) change the slits to screen distance, (c) change the slit separation, (d) use white light instead of monochromatic light, (e) perform the experiment in a different medium other than air, (f) slit width is reduced, (g) the two sources are out of phase by \( \pi \) radians.
Module 2

Quantum Physics

Unit 4: Quantum Theory of Light – The Photoelectric Effect

On completion of this unit, students should be able to do the following:

4.1 Recall that the photon energy, \( E \) is given by \( E = hf \) where \( h \) is Planck constant and \( f \) is the frequency of the light.

4.2 Recall that the momentum of a photon is given by \( p = \frac{h}{\lambda} \).

4.3 Calculate the energy and momentum of photons in various regions of the electromagnetic spectrum.

4.4 Define the 'photoelectric effect'.

4.5 Define the 'work function' for a metal.

4.6 Explain the significance of the threshold frequency \( f_o \) and threshold wavelength \( \lambda_o \).

4.7 Give the function of each component in the experimental method used to investigate the relationship between the maximum kinetic energy of the photoelectrons emitted and the frequency of the light incident on a metal surface.

4.8 Describe how Einstein used the photon theory of light and the conservation of energy to explain the photoelectric effect.

4.9 Interpret the equation \( K_{max} = hf - \Phi \) where \( K_{max} \) is the maximum kinetic energy of the emitted electrons.

4.10 Solve simple problems applying Einstein's photoelectric equation.
4.11 State the linear relationships (I) $K_{\text{max}}$ against $f$, and relate the slope and $x$-and $y$-intercepts to the equation $K_{\text{max}} = hf - \Phi$, (ii) Stopping potential $V_s$ against $f$ and $\frac{1}{\lambda}$ to determine (a) the threshold frequency or threshold wavelength, and (b) the work function, $\Phi$ for the metal.

4.12 Given a graph of $K_{\text{max}}$ against $f$, or $K_{\text{max}}$ against $\frac{1}{\lambda}$ to determine (a) the threshold frequency or threshold wavelength, and (b) the work function, $\Phi$ for the metal.

4.13 Given the threshold frequency of a metal and the wavelength of the light incident on the metal, to determine whether photoelectric effect occurs or not.

4.14 To explain why the intensity of light incident on a metal surface is directly proportional to the number of photons hitting the surface in one second.

4.15 To interpret the equation $P = Nh\nu f$ where $N$ is the number of photons incident on a metal surface per second and $P$ is the power in watts.

4.16 To list down two failures of the wave theory of light to explain the photoelectric effect.

4.17 To describe how the maximum kinetic energy of photoelectrons are affected by (a) changing the frequency of the light source, (b) use a different metal surface, (c) double the intensity of the light source, giving reasons to support the descriptions.

4.18 To describe how the graph of $K_{\text{max}}$ versus frequency, $f$ changes when (i) the metal is changed, (ii) the wavelength of the light is changed, (iii) the intensity of the light source is changed.

Unit 5: X-rays and Duality of Matter

5.1 Apply the work-energy theorem $eV = \frac{1}{2}mv^2$ as it applies to X-ray production.

5.2 Note that X-ray production is the reverse process of the photoelectric effect.
5.3 Differentiate between the origins of 'characteristic X-rays' and 'continuous X-rays'.

5.4 Sketch the X-ray spectrum showing intensity versus wavelength.

5.5 Explain the origins of the $K_\alpha$ and $K_\beta$ lines in the X-ray spectrum.

5.6 Interpret the equation $eV = hf_{\text{max}} = \frac{hc}{\lambda}$.

5.7 Solve simple problems involving the above equation.

5.8 Explain how (I) the accelerating voltage, and (ii) the metal target in the X-ray tube affect the X-ray spectrum.

5.9 Write down Bragg equation for X-ray diffraction.

5.10 Solve simple problems involving the above equation.

5.11 Explain that crystal acts as natural diffraction grating to study diffraction of X-rays because the inter-atomic spacing is of the same order as the wavelength of the X-rays.

5.12 Recall de Broglie wavelength for matter waves i.e. $\lambda = \frac{h}{mv}$.

5.13 Calculate the de Broglie wavelength for a given charged particle that is accelerated through a potential difference, eg. electron.

5.14 Explain why only sub-atomic particles such as electrons, protons and neutrons moving near to the speed of light exhibit wave behaviour light X-rays.

5.15 Describe how the Davisson and Germer experiment uses de Broglie wavelength and Bragg equation to demonstrate the wave nature of particles.

5.16 Calculate the accelerating voltage needed for a charged particle so that it has a de Broglie wavelength equivalent to the wavelength of a given X-ray.
Module 3

Atomic Physics

Unit 6: Models of The Atom – Energy Levels in an Atom

On completion of this unit students should be able to do the following:

6.1 State the meaning of the following: (a) ground state, (b) excited state, (c) excitation energy, (d) ionisation energy, (e) angular momentum is quantised.

6.2 Describe and explain what happens to a hydrogen atom when an electron of each of the following kinetic energies collide with the atom: less than 10.2 eV, 10.2 eV, 11 eV, 12.1 eV and 15 eV.

6.3 Describe and explain what happen to a hydrogen atom if a photon of the same energies as in 6.5 collides with the atom.

6.4 Calculate the wavelengths of the light emitted when an electron jumps from a higher excited state to the ground state or a lower excited state.

6.5 Given the energy level diagram for hydrogen, to calculate the shortest and longest wavelengths of the light emitted in each of the following series: (a) Lyman series, (b) Balmer series, and (c) Paschen series.

6.6 Recall which region of the electromagnetic spectrum does these series lie.

6.7 State, with the aid of a diagram, the number of possible wavelengths of light emitted when an electron jumps from to the ground state to the third excited state.

6.8 Explain the origin of the line emission spectra of hydrogen.

6.9 State the function of each component in the experimental setup of the Franck-Hertz experiment to confirm the existence of energy levels in an atom.

6.10 Interpret the current against accelerating voltage graph in the Franck-Hertz experiment and use it to find the first excitation energy of an atom.
6.11 To explain the dips in the current-voltage graph in the Franck-Hertz experiment.

Module 4

Nuclear Physics

Unit 7: Nuclear Stability - Radioactivity

On completion of this unit, students should be able to do the following:

7.1 Recall the two types of nuclear reactions - induced and spontaneous.

7.2 List the conservation laws that are obeyed in a nuclear reaction e.g. mass number, atomic number, energy, mass-energy and linear momentum.

7.3 Given a radioactive decay equation, to identify the daughter nucleus and product particle using the conservation of mass number and atomic number.

7.4 Explain why radioactive decay must be exothermic and not endothermic.

7.5 Explain what is meant by the 'random' nature of radioactive decay.

7.6 List the 4 types of radioactive radiation, giving their nuclear symbols.

7.7 Distinguish between the 4 types of radiation in terms of the following: (a) charge, (b) mass, (c) ionising power, (d) penetrative power, (e) range, (f) effect of magnetic and electric fields, and (g) energy.

7.8 Write and balance the nuclear equations for each of the four types of decay.

7.9 Use the conservation of linear momentum to find the ratio of the kinetic energies of the alpha particles and daughter nucleus in an alpha decay.

7.10 Explain the origin of $\beta^-$ and $\beta^+$ emission from the unstable parent nucleus.

7.11 Justify the emission of an antineutrino in beta minus decay using the laws of conservation of energy and linear momentum.
7.12 Explain why α - decay is monoenergetic while β - decays result in the emission of beta particles with a range of energies.

7.13 Calculate the energy released in a decay using Einstein's mass-energy equation, 
\[ \Delta E = (\Delta m) c^2. \]

7.14 Explain why the emission of γ-rays of discrete wavelengths suggests the existence of energy levels in a nucleus.

7.15 Use the graph of neutron number, \( N \) against proton number, \( Z \) for stable nuclei to predict the type of decay for a known unstable nucleus.

7.16 Write the radioactive decay law in the form of a differential equation

\[ \frac{dN}{dt} = -\lambda N, \] stating the meaning of each of the symbols used.

7.17 Solve the differential equation in 7.16 to obtain the decay law in the form

\[ N = N_o e^{-\lambda t}, \] stating the meaning of each symbol used.

7.18 Define 'half-life', \( t_{1/2} \) for a radioactive nuclide.

7.19 Solve simple problems involving the half-life, \( N = (1/2)^n N_o \) where \( N_o \) is the initial number of atoms and \( n \) is the number of half-lives.

7.20 Show, using the decay law in 7.17, that \( t_{1/2} = \frac{\ln 2}{\lambda} \)

7.21 Solve simple problems using the equations in 7.16, 7.17 and 7.20.

7.22 Given a graph of corrected count-rate(activity) against time, to determine (a) half-life,

(b) disintegration constant, \( \lambda \) and the number of nuclei present at any time \( t \).

7.23 Describe one application of radioisotopes e.g. apply the radioactive decay law to carbon-dating for determining the age of a fossil.
APPENDIX G

Semester Tests

**Semester 1**

Test 1: Units & Measurements, Kinematics, Dynamics

Test 2: Momentum, Impulse, Work, Energy & Power

Test 3: Circular Motion & Rotational Motion

Test 4: Electricity & Magnetism

**Semester 2**

Diagnostic Test 1: Simple Harmonic Motion

Diagnostic Test 2: Waves – Electromagnetic Waves

Diagnostic Test 3: Waves in Two Dimensions – Interference

Diagnostic Test 4: X-Rays & X-ray Diffraction

Diagnostic Test 5: Models of an Atom

Diagnostic Test 6: Nuclear Stability - Radioactivity
Physics Test 1

Topics: Units & Measurements, Kinematics, Dynamics
Time Allowed: 80 minutes

1. (a) Explain the difference between 'random error' and systematic error. (2 marks)
(b) Write down the dimensions for (i) velocity (ii) energy or work. (2 marks)
(c) A student proposed that a body of mass m moving with a velocity \( v \) possess a certain amount of energy given by the equation \( E = km^a v^b \). Using dimensional analysis, find the value of a and b. (4 marks)

2. (a) Define 'uniform acceleration' (1 mark)
(b) A boat, starting from rest is uniformly accelerated to 90 ms\(^{-1}\) in 10.0 s.
(i) Draw a velocity-time(v-t) graph for the first 10.0 s. (2 marks)
(ii) Use your graph to determine (a) acceleration, and (b) the distance travelled. (4 marks)

3. (a) A hockey player is standing on his skates on a frozen pond when an opposing player moving with uniform velocity of 12 ms\(^{-1}\) skates by with the puck. After 3.0 s, the first player makes up his mind to chase his opponent. If he accelerates uniformly at 4.0 ms\(^{-1}\),
(i) how long does it take him to catch his opponent? (4 marks)
(ii) how far has he travelled in this time? (Assume the player with the puck remains in motion at constant velocity.) (2 marks)
(b) Sketch velocity-time graphs for the two players on the same set of axes. (2 marks)

4. A ball is tossed vertically upward at a speed of 20 ms\(^{-1}\) from the edge of a building 30 m tall.
(a) How high does the ball rise? (2 marks). If the ball just misses the edge of the building on the way down,(b) how long does it take to reach the ground? (2 marks), (c) What is its speed just before it hits the ground? (2 marks)

5. (a) State Newton's three laws of motion. (3 marks)
(b) The engine on a 0.20 kg model airplane exerts a forward tractive force on the plane of 10 N, while the air exerts a resistive force of 7.5 N on the plane. (i) What is the acceleration of the plane along its direction of motion? (ii) What is the distance moved by the plane in 5.0 s, assuming it starts from rest? (4 marks)

6. Two movers attempt to move a 50 kg piece of equipment by exerting forces of 200N north and 300N east. (a) What is the resultant force acting on the piece of equipment, assuming friction can be ignored? (b) What are the magnitude and direction of the acceleration of the object? (6 marks)

7. (a) A ball is held in a person's hand. (i) Draw a free-body diagram for the ball, (ii) If the ball is dropped, redraw the free-body diagram for the ball. (2 marks)
(b) Identify the action-reaction pairs in the following situations: (i) A snowball hits a girl in the back, (ii) A horse pulling a cart with a cable. (Ignore the earth). (2 marks)
(c) What is wrong with the statement, "Since the car is at rest, there are no forces acting on it?" How would you correct this statement? (3 marks)
(b) Two blocks on a frictionless horizontal surface are connected by a light string, as in the figure below.

\[ a \text{ ms}^{-2} \]

\[ m_1 \quad m_2 \]

Given \( m_1 = 10 \text{ kg}, m_2 = 20 \text{ kg} \) and \( F = 50 \text{ N} \),

(i) draw free-body diagrams for each block,
(ii) determine the acceleration of the system,
(iii) determine the tension in the string. (6 marks)

8. Two objects are connected by a light inextensible string that passes over a frictionless pulley as in the figure below. Given the frictional force exerted on the 4.0 kg object is 12N, (a) draw a free-body diagram for the system, (b) find the acceleration of the system, and (c) find the tension in the string. (5 marks)

\[ a \text{ ms}^{-2} \]

\[ 4 \text{ kg} \]

\[ a \text{ ms}^{-2} \]

\[ 7 \text{ kg} \]
Physics Test 2

Topics: Momentum, Impulse, Work, Energy & Power
Time Allowed: 80 minutes

1. (a) Write down the dimensions for linear momentum. (1 mark)
   (b) A child bounces a tennis ball on the floor. The impulse delivered by the floor to the ball is 2.00 Ns during the 1/800 s of contact. What is the magnitude of the average force exerted on the ball by the floor? (2 marks)

2. (a) State the law of conservation of linear momentum. (1 mark)
   (b) Explain how linear momentum is conserved when a ball bounces from a floor. (2 marks)
   (c) A 60.0 kg astronaut is on a space walk away from the space shuttle when her tether line breaks. She is able to throw her 10.0 kg oxygen tank away from the shuttle with a speed of 12.0 ms\(^{-1}\) to propel herself back to the shuttle. If she starts from rest relative to the shuttle, determine his speed of recoil. (2 marks)

3. (a) Distinguish between an 'elastic collision' and an 'inelastic collision'. (2 marks)
   (b) Is it possible to have a collision in which all of the kinetic energy is lost? If yes, give an example. (2 marks)
   (c) A 1200 kg car travelling initially with speed of 25.0 ms\(^{-1}\) in an easterly direction crashes into the rear end of a 9000 kg truck moving in the same direction at 20.0 ms\(^{-1}\). The velocity of the car immediately after the collision is 18.0 ms\(^{-1}\) to the east. (i) What is the velocity of the truck immediately after the collision? (3 marks) (ii) How much kinetic energy is lost in the collision? Account for this loss in energy. (3 marks)

4. (a) A 0.30 kg puck, initially at rest on a horizontal, frictionless surface is struck by a 0.20 kg puck moving initially along the x-axis with a speed of 2.0 ms\(^{-1}\). After the collision, the 0.20 kg puck has a speed of 1.0 ms\(^{-1}\) at an angle of 53\(^\circ\) to the positive x-axis as shown in the figure below. Using graphical or component methods, (i) determine the speed and direction of the 0.30 kg puck after the collision. (4 marks) (ii) find the magnitude of the impulse exerted on the 0.30 kg puck. (2 marks)

   ![Diagram of puck collision]

5. (a) State the work-energy theorem. (1 mark)
(b) A mechanic pushes a 2500 kg car from rest to a final speed \( v \) and does 5000 J of work in the process. During this time the car moves 25.0 m. Neglecting friction between car and road, (i) what is the final speed \( v \) of the car? (2 marks) (ii) what is the horizontal force exerted on the car? (2 marks)

6. (a) State the law of conservation of energy. (1 mark)
(b) A bead slides with friction around a loop-the-loop of radius 1.5 m. (Refer figure below). If the bead is released from a height \( h = 3.0 \) m, what is the speed of the bead at point A? (2 marks)

(c) A child's toy consists of a piece of plastic attached to an elastic spring of force constant \( k \) Nm\(^{-1}\). The spring is compressed 2.0 cm and the toy is released from rest. If the mass of the toy is 100 g and it rises to a maximum height of 60 cm, estimate the value of \( k \). (3 marks)

7. (a) Can gravitational potential energy of a given mass be negative. Explain. (2 marks)
(b) A parachutist of mass 50.0 kg jumps out of an airplane at a height of 1000 m. Taking \( g = 10 \text{ m s}^{-2} \), (i) find the speed just before reaching the ground assuming there is not air friction, (ii) if air friction is present and the speed is \( 5.00 \text{ ms}^{-1} \) just before landing, find how much energy was lost to air friction during this jump. (3 marks)

8. (a) Give one example of a conservative force and one example of a non-conservative force. (1 mark)
(b) A 2.00 kg block situated on a rough incline is connected to an elastic spring of negligible mass having a spring constant of 100 Nm\(^{-1}\). The block is released from rest when the spring is unstretched, and the pulley is frictionless. The block moves 20.0 cm down the incline before coming to rest.
(i) Find the loss in gravitational potential energy of the block. (2 marks)
(ii) Find the elastic potential energy stored in the spring when it is extended by 20.0 cm. (1 mark)
(iii) Is your answer to (i) and (ii) equal? If not, what is the difference? (1 mark)
(iv) Hence, find the work done against friction by the block in moving down the rough incline. (3 marks)
Physics Test 3

Topics: Circular Motion & Rotational Motion
Time Allowed: 90 minutes

1. (a) What is meant by 'centripetal acceleration' and 'tangential acceleration' for a particle that is undergoing uniform circular motion. (2 marks)

   (b) Write down the centripetal force exerted on a particle of mass m moving with constant speed v in a circle of radius r. (1 mark)

2. Timothy drives a Proton around a curve of radius 20 m at a constant speed of 10 ms\(^{-1}\).

   (a) What is the magnitude of the acceleration of the car? (1 mark)

   (b) If the car has a mass of 900 kg and Timothy's mass is 75 kg, what is the resultant force exerted on the car and driver? (1 mark)

   (c) In what direction does this resultant force act? (1 mark)

3. A 150 kg car is travelling at 16 ms\(^{-1}\) north at the point X on a circular section of the track which has a radius of 64 m (See figure below). At X, the car has a tangential acceleration of 30 ms\(^{-1}\). Find

   (a) the centripetal acceleration of the car at X. (1 mark)

   (b) the resultant acceleration of the car at X. (3 marks)

   (c) the resultant force exerted on the car. (1 mark)

4. A car of mass 4.0 kg moves without friction on the track as shown in the figure below. Initially its speed at A is 10 ms\(^{-1}\).
(a) Using the law of conservation of energy, find its speed at B, which lies on the arc of a circle of radius 2.0 m. (2 marks)
(b) Draw a free-body diagram of the car at B. (2 marks)
(c) Hence, determine the normal force exerted on the car by the track at B. (2 marks)

5. (a) Define 'uniform angular acceleration' of a rigid body rotating about a fixed axis. (1 mark)
(b) A flywheel initially at rest is given a uniform angular acceleration such that it rotates through an angular displacement of 450 radians in the first 9.00 s. Find (i) the magnitude of the angular acceleration. (2 marks), (ii) the angular velocity of the body after 9.00 s. (2 marks)

6. (a) Define 'moment of inertia' of a rigid body and 'torque'. (2 marks)
(b) A wheel in the shape of a uniform solid disc has a mass of 10 kg and a radius of 0.25 m. A string is wound around its circumference and pulled off tangentially by a constant force of 20 N so that the wheel rotates freely about an axis through the centre of the wheel. See figure below. Given that the moment of inertia of a uniform solid disc about an axis through its centre is given by \( I = \frac{1}{2} mr^2 \), find (i) the moment of inertia of the wheel. (1 mark), (ii) the torque applied to the wheel. (2 marks), (iii) the angular acceleration of the wheel. (2 marks), and (iv) the angular displacement of the wheel after 2.00s. (2 marks)

7. (a) State the law of conservation of angular momentum. (1 mark)
(b) Explain how this law is applied to an ice-skater or a diver. (2 marks)
(c) A student sits on a pivoted while holding a pair of weights as in the figure below. The stool is free to rotate about a vertical axis with negligible friction. The total moment of inertia of the student, weights and stool is 2.25 kgm\(^2\). The student is set in rotation with an initial angular speed of 5.0 rads\(^-1\) with the weights outstretched. As he rotates, he suddenly pulls the weights inward so that the new moment of inertia of the system becomes 1.80 kgm\(^2\). Find (i) the new angular speed of the system. (2 marks), (ii) the initial and final rotational kinetic energies of the system. (2 marks)

From your answer in (ii), is there a loss or gain in kinetic energy? (1 mark). Account for this loss or gain. (1 mark)

8. (a) A rolling body possess both translational and rotational kinetic energies. Write down, in terms of the angular speed \( \omega \), the total kinetic energy of a uniform solid disc of mass \( m \)
and radius \( r \) that is rolling without slipping on a horizontal surface with a speed \( v \) and an angular speed \( \omega \). You are given the moment of inertia of the disc as \( I = \frac{1}{2} mr^2 \) (2 marks)

(b) A steel ball bearing of radius 0.70 cm is rolling along a table at 40 cm\( s^{-1} \) when it starts to roll up a smooth incline. What is the total kinetic energy of the ball before rolling up the incline? (2 marks)

(c) Using the law of conservation of energy, find how high above the table level does the ball rise before stopping. (2 marks) Given moment of inertia of a solid sphere is \( \frac{2}{5} mr^2 \) about an axis through its centre.

(d) A uniform solid sphere and a uniform solid disc of the same mass \( m \) and radius \( r \) roll from rest down a smooth incline from the same point. Find (i) the speeds \( v_d \) and \( v_s \) of the disc and sphere respectively at the bottom of the incline. (3 marks), (ii) the ratio \( v_d : v_s \). (1 mark)
Physics Test 4

Topics: Electricity & Magnetism
Time Allowed: 90 minutes

1. (a) State Coulomb's law of electrostatics. (1 mark)

(b) A 4.5 \( \mu C \) point charge is located 3.2 m from a -2.8 \( \mu C \) point charge. Find the magnitude of the force exerted by one charge on the other. (2 marks)

2. Three point charges are arranged as shown in the figure below. Find the magnitude and direction of the electrostatic force on the 6 \( \mu C \) charge. (4 marks)

3. (a) Define the 'electric field strength' at a point. (1 mark)

(b) In the figure above, determine

(i) the magnitude and direction of the electric field strength at P due to the +2.5 \( \mu C \) charge. (2 marks)

(ii) the magnitude and direction of the electric field strength at P due to the +6.0 \( \mu C \) charge. (2 marks)

(iii) the value of x given that the resultant electric field at P is zero. (2 marks)

4. (a) Sketch the electric field lines surrounding (i) an isolated positive point charge, +Q coulomb, (ii) an isolated negative point charge, -Q coulomb, and (iii) a pair of opposite equal point charges +Q and -Q placed close together. (3 marks)

(b) Sketch the magnetic field lines surrounding (i) a bar magnet, (ii) a long straight wire carrying a current, (iii) a solenoid carrying a current. (3 marks)
5. (a) A uniform electric field is directed along the positive x-axis and has a strength of 4.0 \( \times 10^{-1} \) NC\(^{-1}\). Find (i) the electric force exerted on a proton by this field. (1 mark), (ii) the acceleration of the proton. (1 mark), and (iii) the time required for the proton to reach a speed of 1.0 \( \times 10^{-6} \) ms\(^{-1}\) assuming it starts from rest. (2 marks)

(b) An electron is projected with an initial speed of 2.0 \( \times 10^{4} \) ms\(^{-1}\) perpendicularly to a uniform electric field set up between a pair of parallel, oppositely charged metal plates. If the separation between the plates is 2.0 cm, the length of the plates is 10 cm and the potential difference between them is 1000V, determine

(i) the magnitude of the electric field strength between the plates. (1 mark)
(ii) the magnitude of the acceleration of the electron. (1 mark)
(iii) the time taken for the electron to pass through the field. (2 marks)
(iv) the speed and direction of the electron as it leaves the field. (4 marks)

6. (a) Define the electrical potential difference between two points. (1 mark)

(b) Find the work done to move a 6.0 \( \mu \)C charge between two points for which the potential difference is 40V. (2 marks)
(c) Show that the units of NC\(^{-1}\) and Vm\(^{-1}\) are equivalent. (2 marks)
(d) Find the speed of an electron that has been accelerated through a potential difference of 2.0 \( \times 10^{3} \) V. Given electron mass, \( m = 9.11 \times 10^{-31} \) kg, \( e = -1.6 \times 10^{-19} \) C. (4 marks)

7. (a) Define magnetic field strength. (1 mark)

(b) A wire 2.0 m in length carries a current of 4.0 A in a uniform magnetic field of magnitude 0.05T. Calculate the magnitude of the magnetic force on the wire if the angle between the magnetic field and the direction of the current in the wire is (i) 60\(^{\circ}\), and (ii) 90\(^{\circ}\). (3 marks)

(c) A singly charged positive ion has a mass of 2.0 \( \times 10^{-26} \) kg. It is accelerated to a speed of 1.0 \( \times 10^{6} \) ms\(^{-1}\) before entering a magnetic field of strength 0.50 T along a direction perpendicular to the field. Calculate (i) the magnetic force exerted on the ion. (1 mark), (ii) the radius of the circular path followed by the ion in the field. (2 marks), and (iii) the time taken for one revolution. (1 mark)

8. (a) Find the magnetic field strength at a distance of 10 cm from a long, straight wire carrying a current of 5.0 A. (1 mark)

(b) Two long parallel conductors carry currents \( I_1 = 4 \) A and \( I_2 = 2 \) A, both directed into the page as shown in the figure below. The conductors are separated by a distance of 10 cm. Determine the magnitude and direction of the resultant magnetic field strength at the point P located 6.0 cm from \( I_1 \) and 8.0 cm from \( I_2 \). (4 marks)
Diagnostic Test 1

Unit: Simple Harmonic Motion
Time Allowed: 45 minutes

1. Define (a) periodic motion giving TWO examples. (2 marks)

2. Define (a) amplitude, (b) frequency and (c) angular frequency for an S.H.M. (3 marks)

3. The graph below shows how the displacement, $x$ varies with time, $t$ for a mass-spring oscillating system.

```
<table>
<thead>
<tr>
<th>x/cm</th>
<th>-1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
```

Find (a) amplitude, (b) period and (c) frequency. (3 marks)

4. (a) Given that the displacement, $x$ of a particle varies with time, $t$ as $x = 5.0 \sin \frac{2\pi t}{3}$ metre, find (i) the amplitude, $r$ (ii) the period, $T$ (iii) the frequency, $f$ in hertz and (iv) the angular frequency in $\text{rads}^{-1}$. (4 marks)

(b) Sketch the graph of $x$ against $t$ for the above motion. (1 mark)

5. Given that a particle exhibiting SHM has displacement $x$ varies with time $t$ according to

$$x = 2.0 \sin \left( 2t + \pi/2 \right) \text{ metres}$$

(a) Write down the phase angle. (1 mark)

(b) Sketch a graph of $x$ against $t$. (1 mark)

(c) What is the phase difference between the above motion and the motion given by $x = 2.0 \sin 2t$? (1 mark)

(d) Which of these SHM leads the other? (1 mark)
6. (a) Write down the period, $T$ and frequency, $f$ of oscillation of a mass-spring oscillator of mass $m$ attached to an elastic string with force constant $k$. (2 marks)

(b) If the spring is replaced by another of higher stiffness, does the period, $T$ increase or decrease? (1 mark)

7. State TWO basic requirements a system must satisfy if it is to undergo SHM. (2 marks)

8. (a) Write down the period, $T$ for a simple pendulum of length $L$. (1 mark)

(b) If the length of the simple pendulum is doubled, by what factor is the period increased? (1 mark)

(c) How will the period, $T$ change if the simple pendulum is taken to the Moon? Is it increased or decreased? Support your answer. (2 marks)

9. (a) Sketch on the same graph the displacement, $x$ against time, $t$ graphs for TWO SHM that are out of phase by $\pi/4$ (or $45^\circ$). (3 marks)

(b) Indicate on the graphs, which LEADS and which LAGS. (1 mark)
Diagnostic Test 2

Unit: Waves-Electromagnetic Waves
Time Allowed: 45 minutes

1. Define ‘transverse wave’ (1 mark). Give an example (1 mark).

2. Define ‘longitudinal wave’ (1 mark). Give an example (1 mark)

3. Sketch the displacement-distance graph (y-x) graph for a transverse wave of amplitude 2.0 cm and wavelength 3.0 cm. (1 mark)

4. The wave in Figure 1 below is moving rightwards with a speed of 20 cm s^{-1}. Find (a) the wavelength, and (b) frequency (2 marks)

   ![Displacement vs Distance Graph](image)

5. The displacement, x in metres for a particle in a medium where a transverse wave passes varies with time t in seconds according to the equation:

   \[ x = 2.0 \sin \left( \frac{2\pi}{3} t \right) \]

(a) Find the period. (1 mark)
(b) Sketch the graph of \( x \) against \( t \) (1 mark)
(c) Sketch on the same graph \( x = 4.0 \sin \left( \frac{2\pi}{3} t + \frac{\pi}{3} \right) \) (1 mark)

6. Explain why sound waves is a longitudinal wave while e-m wave is a transverse wave. (2 marks)

7. What is the basic difference between electromagnetic waves such as microwaves, radio waves and visible light? (1 mark)

8. What is the frequency of an e-m wave that has a wavelength of 4.0 m given that the speed of e-m waves is \( 3.0 \times 10^8 \) ms^{-1}. (1 mark)

9. A radar pulse returns to the receiver after a total travel time of \( 4.0 \times 10^{-4} \) s. How far away is the object that reflected the wave? Given speed of e-m waves is \( 3.0 \times 10^8 \) ms^{-1}. (1 mark)
10. When light (or other e-m waves) travels across a given region in space, what is it that oscillates? (1 mark)

11. Sketch the electric field $E$ against distance $x$ and magnetic field $B$ against distance $x$ from the source on the same graph. (1 mark)

12. Arrange the following e-m waves in order of increasing wavelengths: visible light, infra-red, ultra-violet, microwaves, radio-waves, X-rays, $\gamma$-rays. (1 mark)

13. Two sinusoidal waves having the same wavelength and amplitude and travelling in the same direction are one quarter of a period out of phase. Sketch the displacement-time graphs for the two waves using the same set of axes. (2 marks)
Diagnostic Test 3

Unit: Waves in Two Dimension - Interference
Time Allowed: 60 minutes

1. (a) State TWO conditions required for two sources of waves to be coherent.(2)
   (b) Define constructive interference and destructive interference of waves.(2)
   (c) State the Principle of Superposition of waves.(1)

2. (a) The diagram below shows the interference pattern for two point sources of water waves in a ripple tank.

   \[ S_1 \]
   *

   *

   \[ S_2 \]

   (i) Draw on the above diagram, the first order antinodal lines and the first order nodal lines.(2marks)
   (ii) Mark a point, P on the pattern in which constructive interference(i.e. antinode) occurs.(1mark)
   (iii) Mark a point Q on the pattern in which destructive interference(i.e. node) occurs.(1mark)
   (iv) Using a ruler, find the wavelength of the water waves represented in the diagram.(1mark)
   (v) Given the frequency, \( f \) of the waves is 20 Hz and using your answer to part (d), calculate the speed of the waves.(2 marks)

(b) The diagram below shows the interference pattern of coherent water waves of wavelength \( \lambda \) from two point sources, \( S_1 \) and \( S_2 \).

   (i) Find the path difference, in terms of \( \lambda \), for the points (a) \( R \) and (b) \( X \)
   (ii) Is there a maximum at \( R \)? (3 marks)
3. (a) Young's experiment is performed with monochromatic light of wavelength $\lambda$ using the apparatus as shown below. The point C on the screen is equidistant from slits $S_1$ and $S_2$.

\[ \lambda \]

\[ S_1 \]

\[ d \]

\[ S_2 \]

\[ D \]

\[ C \]

\[ P \]

(i) Explain why the sources are coherent. (1 mark)

(ii) $P$ is a point on the screen such that $S_1P - S_2P = \frac{1}{2} \lambda$. Do you expect to see a bright fringe or dark fringe at $P$? (1 mark)

(iii) If the distance between the two slits is $d = 1.0 \text{ mm}$, distance from slits to screen $D = 2.0 \text{ m}$ and $\lambda = 6.0 \times 10^{-7} \text{ m}$, find the distance $x$ in metres. (2 marks)

(b) Yellow light of wavelength 589.3 nm falls on a double slit of separation, $d = 0.400 \text{ mm}$. If the screen is $D = 150 \text{ cm}$ from the slits, find

(i) the bandwidth, $\omega$ (1 mark)

(ii) the distance of the 3rd order bright fringe from the zeroth order bright fringe. (1 mark)

4. (a) The slits in a Young's double slit experiment are $1.3 \times 10^{-4} \text{ m}$ apart. If light of wavelength $\lambda = 633 \text{ nm}$ is used, find

(i) the angular deviation of the 2nd order maximum from the zeroth order maximum; (1 mark)

(ii) the angular deviation of the 1st order minimum from the zeroth order maximum; (1 mark)

(iii) how many orders of maxima, including the zeroth order maxima, can be observed on the screen? (1 mark)

(iv) Hence, sketch the fringe pattern on the screen. (1 mark)

(v) Sketch and explain the intensity distribution of the interference pattern (1 mark)

(b) What change occurs in the bandwidth of the interference pattern in Young's double slit experiment if

(i) blue light is replaced by red light, (1 mark)

(ii) the distance between the two slits is halved, (1 mark)

(iii) white light is used instead of monochromatic light, (1 mark)

(iv) the two sources are out of phase by $\pi$ radians. (1 mark)
Diagnostic Test 4

Unit: Quantum Theory of Light – The Photoelectric Effect
Time Allowed: 45 minutes

1. Photoelectric effect is the effect where
   
   A. electrons are emitted from a metal surface that is heated
   B. electrons are emitted from a metal that is illuminated by light
   C. photons are emitted from a metal surface
   D. protons are emitted from a metal surface

2. If ultra-violet light of wavelength 300 nm incident on a metal does not cause photoelectric effect, which of the following actions may possibly cause photo-emission of electrons from the same metal?
   
   A. Shine violet light of wavelength 400 nm
   B. Allow radio waves of wavelength 1.0 m to fall on a metal surface
   C. Use microwaves of wavelength 2.0 cm instead
   D. Allow gamma rays of wavelength 1.0 nm to fall on a metal surface

3. The work function, $\Phi$ for a metal is
   
   A. the minimum amount of energy needed to free an electron from a metal surface
   B. equal to the maximum kinetic energy of a photoelectron emitted
   C. the number of electrons emitted per second from a metal surface
   D. the amount of heat required to melt a metal

4. The work function of a metal is 2.3 eV. This means that
   
   A. at least 2.3 eV of energy is required to free an electron from a metal surface
   B. electrons are emitted with 2.3 eV of kinetic energy
   C. 2.3 eV of energy is absorbed by the metal in one second
   D. 2.3 eV of energy is required to melt the metal

5. The threshold frequency of a metal is $5.0 \times 10^{14}$ Hz. This means that
   
   A. light of frequency greater or equal to $5.0 \times 10^{14}$ Hz will cause photoelectric effect
   B. light of frequency less than $5.0 \times 10^{14}$ Hz will cause photoelectric effect
   C. only light of frequency $5.0 \times 10^{14}$ Hz will cause photoelectric effect
   D. photoelectric effect will occur only if more than $5.0 \times 10^{14}$ J of energy is absorbed by the metal
6. Light of wavelength $5.0 \times 10^{-7}$ m is incident on a metal with a threshold frequency of $7.0 \times 10^{14}$ Hz. Which of the following statements is true?

A. photoelectric effect occurs  
B. photoelectric effect does not occur  
C. sometimes it occurs and sometimes it does not  
D. electrons of kinetic energy $2.0 \times 10^{-7}$ J are emitted

7. Light of frequency $5.0 \times 10^{14}$ Hz is incident on a metal surface. A photon in this light has an energy equal to

A. $3.3 \times 10^{-19}$ J  
B. $6.6 \times 10^{-19}$ J  
C. $3.3 \times 10^{-20}$ J  
D. $6.6 \times 10^{-20}$ J

8. Which of the following is TRUE for the momentum $p$ of a photon of light with frequency $f$ and wavelength $\lambda$.

A. $p = \frac{h}{\lambda}$  
B. $p = \frac{hc}{\lambda}$  
C. $p = \frac{h}{f}$  
D. $p = \frac{hc}{f}$

9. A 100W lamp emits light of frequency $f = 5.0 \times 10^{14}$ Hz. How many photons are emitted in one second?

A. $3.0 \times 10^{20}$  
B. $3.3 \times 10^{20}$  
C. $5.0 \times 10^{12}$  
D. $5.0 \times 10^{16}$

10. In order to calculate the number of photons emitted per second from a monochromatic light source of a certain power output, it would be necessary to know

A. Planck constant and speed of light  
B. wavelength of the light  
C. Planck constant, wavelength of the light and speed of light  
D. Planck constant and wavelength of light

11. Which one of the following graphs best represents the relationship between photon energy $E$ and the frequency $f$ of light?

A.  
B.  
C.  
D.  

![Graphs A, B, C, D showing different representations of the relationship between photon energy and frequency.]
12. Which of the following equations is NOT true?

A. \( K_{\text{max}} = hf - \Phi \)  
B. \( K_{\text{max}} = \frac{hc}{\lambda} - \Phi \)  
C. \( K_{\text{max}} = hf_0 \)  
D. \( K_{\text{max}} = h(f-f_0) \)

13. Identify the equation below which is NOT true?

A. \( K_{\text{max}} = eV_s \)  
B. \( \Phi = hf_0 \)  
C. \( K_{\text{max}} = hf_0 \)  
D. \( K_{\text{max}} = h(f-f_0) \)

14. Radiation of frequency \( 9.0 \times 10^{14} \) Hz falls on a metal surface with a threshold frequency of \( 4.0 \times 10^{14} \) Hz. Given Planck constant is \( 6.6 \times 10^{-34} \) Js, the maximum kinetic energy of the electrons emitted is

A. \( 3.3 \times 10^{19} \) J  
B. \( 1.3 \times 10^{20} \) J  
C. \( 3.3 \times 10^{20} \) J  
D. \( 1.3 \times 10^{19} \) J

15. Which of the following graphs represents the photon energy \( E \) against wavelength \( \lambda \)?

A.  
B.  
C.  
D.  

16. Evidence for a particle theory of light is provided by

A. interference  
B. photo-emission of electrons  
C. diffraction  
D. refraction

17. Which of the following is NOT evidence for a particle theory of light?

A. instantaneous emission of electrons from a metal surface when light shines on it  
B. a metal has a threshold frequency  
C. light undergoing interference and diffraction  
D. light undergoing reflection

18. Light of wavelength 375 nm is incident upon a surface which has a work function of 2.0 eV. The maximum kinetic energy of the ejected electrons, in eV, is

A. \( 2.1 \times 10^{-19} \)  
B. 2.1  
C. 4.2  
D. \( 4.2 \times 10^{-19} \)
19. The maximum kinetic energy of photoelectrons emitted from a metal surface incident by monochromatic light of frequency $f$ is measured for different values of $f$. The graph of $K_{\text{max}}$ against $f$ is shown below.

![Graph showing $K_{\text{max}}$ vs. $f$]

From the graph, the threshold frequency is

A. $2 \times 10^{14}$ Hz  
B. $3 \times 10^{14}$ Hz  
C. $6 \times 10^{14}$ Hz  
D. $1.5 \times 10^{14}$ Hz

20. Use the graph in question 19 to determine the value of Planck constant, $h$.

A. $2 \times 10^{-20}$ Js  
B. $3.0 \times 10^{14}$ Js  
C. $6.5 \times 10^{-34}$ Js  
D. $3.0 \times 10^{-14}$ Js

21. Which of the following changes will NOT affect the value of the maximum kinetic energy of the electrons emitted from a metal surface?

A. change the wavelength of the light source  
B. change the intensity of the light source  
C. change the metal  
D. change the light source from blue to violet

22. The graph G below shows how $K_{\text{max}}$ varies with frequency $f$ in a photoelectric experiment.

![Graph showing $K_{\text{max}}$ vs. $f$]
If the metal is changed to one with lower work function, which of the following graphs is possible?

A. P  B. Q  C. R  D. G

23. In an experiment to study how the maximum kinetic energy of electrons emitted from a metal surface varies with frequency $f$ of the incident light as shown in the diagram below. Which of the following statements is NOT true?

A. The galvanometer reading drops when the sliding contact S is shifted to the right
B. The galvanometer reading rises when S is shifted to the left
C. The galvanometer reading increases when the intensity of the light increases
D. The galvanometer remains unchanged when S moves to the left or right

24. The same circuit as in question 23 is used to study how the maximum kinetic energy $K_{\text{max}}$ varies with frequency $f$ of the light incident on a metal surface. When the sliding contact S is in the position shown, the galvanometer reading is zero and voltmeter reading is 1.5 V. Which of the following statements is TRUE?

A. The maximum kinetic energy of the photoelectrons is 1.5 eV
B. The photon in the light has an energy of 1.5 eV
C. The work function of the metal is 1.5 eV
D. The galvanometer shows a reading if S is shifted rightwards
Diagnostic Test 5

Unit: X-rays & X-ray Diffraction
Time Allowed: 45 minutes

1. X-rays are
   A. particles   B. e-m waves   C. mechanical waves   D. visible light

2. An electron is accelerated through a potential difference of 100 kV in an X-ray tube. The kinetic energy, in joules, is
   A. 100000   B. 1.6 \times 10^{-19}   C. 1.6 \times 10^{-14}   D. 100

3. The electron is accelerated in question 2 hits a heavy metal target and X-ray photons are emitted. The minimum wavelength of the X-ray photons produced are
   A. 1.24 \times 10^{-11} m   B. 1.24 \times 10^{-10} m   C. 1.24 \times 10^{-12} m   D. 1.24 \times 10^{-7} m

4. Which of the following diagrams best shows correctly the X-ray spectrum? (I = intensity)
   A. ![Diagram A]  
   B. ![Diagram B]  
   C. ![Diagram C]  
   D. ![Diagram D]

5. When the potential difference between the cathode and the anode in an X-ray tube is increased, which of the following statements is correct?
   A. The characteristic X-rays emitted are different
   B. The minimum wavelength of the X-rays emitted is decreased
   C. The minimum wavelength of the X-rays emitted is increased
   D. The kinetic energy of the electrons hitting the target is decreased

6. An ordinary X-ray tube might operate 40,000 V with a current of 10 mA hitting the target. The electrical power, in watts, is
   A. 40   B. 400   C. 4000   D. 400000
7. In question 6 above, if all the electron kinetic energy is emitted as an X-ray photon, the maximum frequency of the X-rays emitted is approximately

A. $9.7 \times 10^{18}$ Hz  B. $4.0 \times 10^5$ Hz  C. $9.7 \times 10^{15}$ Hz  D. $4.0 \times 10^{18}$ Hz

8. The wavelength of the $K_\beta$ line in the characteristic X-ray spectrum of molybdenum is $6.3 \times 10^{-11}$ m. This X-ray is incident on a crystal of atomic spacing $2.8 \times 10^{-10}$ m. The glancing angle in the first order maximum is given by

A. $\sin \theta = 0.1125$  B. $\sin \theta = 0.225$  C. $\sin \theta = 0.45$  D. $\sin \theta = 0.90$

9. X-rays are incident normally on a crystal as shown in Figure 1. A strong first order diffracted beam is observed as shown.

![Figure 1](image)

The glancing angle is

A. $30^\circ$  B. $60^\circ$  C. $15^\circ$  D. $45^\circ$

10. For question 9, find the wavelength, in nm, of the X-rays if the inter-atomic spacing is $0.8 \times 10^{-10}$ m.

A. 6.9  B. 0.69  C. 0.8  D. 8.0

11. When an accelerated electron knocks out an electron from the L-shell of an atom, an electron from the M-shell jumps in to fill the vacancy. This gives, in the X-ray spectrum, the

A. $K_\alpha$  B. $K_\beta$  C. $L_\alpha$  D. $L_\beta$

12. The following values are found for the X-ray spectrum emitted by gold target: $K_\beta$ line = 0.018 nm, $L_\alpha$ line = 0.13 nm. From these values, the energy difference between the K and the L shells is

A. 59.5 keV  B. 59.5 eV  C. 59.5 MeV  D. 95.2 keV
13. Characteristic X-rays are emitted if a high mass number metal such as tungsten is used as the target in an X-ray tube because

A. the bombarding electron knocks out a valence electron in the L-shell of the atom  
B. the bombarding electron knocks out an electron in the K-shell of the tungsten atom  
C. the bombarding electron is decelerated by the metal target  
D. an electron in a higher energy shell jumps to a lower energy shell

14. In the X-ray spectrum shown in Figure 2 below, X represents

A. $K_\alpha$ line  
B. $K_\gamma$ line  
C. $L_\alpha$ line  
D. $L_\beta$ line

15. When X-rays are incident on a laboratory single slit, no diffraction pattern can be detected. This is possibly due to

A. the slit width being too large compared to X-ray wavelengths  
B. the slit width of the grating being too small compared to X-ray wavelengths  
C. the single slit absorbs the X-rays  
D. experimental error

16. The de Broglie wavelength for an electron moving with speed $1.0 \times 10^5 \text{ m s}^{-1}$ is

A. $7.3 \times 10^{-7} \text{ m}$  
B. $7.3 \times 10^{-9} \text{ m}$  
C. $7.3 \times 10^{-10} \text{ m}$  
D. $7.3 \times 10^{-11} \text{ m}$

17. The de Broglie wavelength, in nm, for an electron of kinetic energy $50 \text{ eV}$ is

A. $0.17$  
B. $1.7$  
C. $0.17 \times 10^{-10}$  
D. $1.7 \times 10^{-10}$

18. In Davisson and Germer experiment, a beam of electrons is accelerated across a potential difference and incident normally on a crystal. Strong first order diffraction is recorded in the direction as shown. If the inter-atomic spacing of the crystal is $1.0 \times 10^{-10} \text{ m}$, the de Broglie wavelength of the electron waves is

A. $1.73 \times 10^{-10} \text{ m}$  
B. $1.0 \times 10^{-10} \text{ m}$  
C. $8.66 \times 10^{-11} \text{ m}$  
D. $5.0 \times 10^{-11} \text{ m}$
19. For the question 18 above, the de Broglie wavelength, $\lambda$, for the particle may be expressed as

A. $\lambda = \frac{h}{2mk}$  
B. $\lambda = \sqrt{2hmK}$  
C. $\frac{h}{\sqrt{2mk}}$  
D. $\sqrt{\frac{h}{2mk}}$

20. Wave behaviour of objects in our daily lives are not obvious to us but subatomic particles moving near to the speed of light exhibit wave behaviour. This is because

A. the de Broglie wavelength of subatomic particle waves are close to the wavelengths of X-rays
B. the de Broglie wavelength of subatomic particle waves are several metres long
C. the size of the objects in our daily lives are too large
D. the de Broglie wavelength of the objects in our daily lives are close to the wavelength of X-rays
DIAGNOSTIC TEST 6

Unit: Models of An Atom
Time: 45 minutes

For questions 1-10, refer to Figure 1 below which shows some of the energy levels of the hydrogen atom.

\[
\begin{align*}
N &= \infty & & 0 \text{ eV} \\
N &= 4 \\
N &= 3 & & -1.5 \text{ eV} \\
N &= 2 & & -3.4 \text{ eV} \\
N &= 1 & & -13.6 \text{ eV}
\end{align*}
\]

1. The ionisation energy, in joules, of the hydrogen atom is
   A. 10.2      B. 12.1      C. 13.6      D. 1.5

2. The three electron transitions shown corresponds to light emission in the Balmer series. These light are
   A. visible      B. ultra-violet      C. infra-red      D. X-rays

3. The longest wavelength, in nm, in the Balmer series is
   A. 654      B. 122      C. 456      D. 221

4. The shortest wavelength, in nm, in the Lyman series of lines is
   A. 0.91      B. 9.1      C. 91      D. 910

5. The energy, in eV, required to excite the hydrogen atom in its ground state to the second excited state is
   A. 10.2      B. 12.1      C. 1.9      D. 13.6
6. The atom absorbs a quantum of energy and jumps to the third excited state from the ground state. The maximum possible number of wavelengths of the light emitted is

A. 3  B. 4  C. 5  D. 6

7. An atom of hydrogen in its ground state collides with an electron of kinetic energy 10.2 eV. Which of the following statements is NOT true?

A. the electron may suffer an elastic collision with the atom
B. the electron may suffer an inelastic collision with the atom
C. the electron may suffer a perfectly inelastic collision with the atom
D. the atom may become excited

8. Photons of energy 10.5 eV collides with a hydrogen atom in its ground state.

A. The atom is ionised.
B. The atom is excited
C. The photon collides elastically with the atom
D. The photon collides inelastically with the atom.

9. Electrons of kinetic energy 11 eV collide with hydrogen atoms in their ground state. Which of the following statements is TRUE?

A. The atom is ionised
B. The atom is excited to the second excited state
C. Light photons of energy 10.2 eV are emitted by the atom
D. Electrons of kinetic energy 10.2 eV are left after collision with the atoms

10. A photon of energy 15 eV is incident on a hydrogen atom. Which of the following statements are NOT true?

A. The atom may be ionised
B. The atom may be excited to any excited state due to inelastic collisions
C. The atom may remain in the ground state
D. The photon suffers an inelastic collision with the hydrogen atom

11. When sodium atoms in their ground states are excited, the emitted wavelength observed is 589 nm. This result agrees with a value for the first excitation energy of

A. 2.1 eV  B. 2.3 eV  C. 1.2 eV  D. 3.2 eV
12. Figure 2 below shows three of the energy levels in an atom.

\[ \begin{array}{c|c}
3 & 10 \text{ eV} \\
2 & 5 \text{ eV} \\
1 & 0 \text{ eV} \\
\end{array} \]

Figure 2

An electron jumping from level 2 to level 1 results in the emission of a photon of blue light. An electron jump from level 3 to level 1 could result in the emission of a photon of

A. red light  B. green light  C. ultra-violet light  D. X-rays

13. The results of the Franck-Hertz experiment is as shown in Figure 3 below.

\[ \begin{array}{c}
\text{I / } \mu\text{A} \\
\text{Grid potential / V} \\
0 & 4 & 8 \\
\end{array} \]

Figure 3

The first excitation energy, in eV, of the atom is

A. 2  B. 4  C. 6  D. 8

14. The figure below shows the experimental setup of Franck-Hertz experiment. What is the function of the grid G?
15. Referring to the energy level diagram for hydrogen in Question 1, when the voltage across the cathode and grid, G is 12V it is expected that the hydrogen gas atoms in their ground state will absorb and emit photons of energies, in eV, of

A. 10.2  
B. 12.0  
C. 10.2 and 12.0  
D. 1.8

16. There is a dip in the graph at Q because an electron

A. suffers a perfectly elastic collision with an atom  
B. collides inelastically with an atom  
C. suffers a perfectly inelastic collision with an atom  
D. does not collide with any atom
Diagnostic Test 7

Unit: Nuclear Stability - Radioactivity
Time Allowed: 30 minutes

1. Which of the following statements concerning alpha particles is NOT true?

A. They are stopped by an aluminium plate.
B. They cause scintillations on impact with a zinc sulphide screen.
C. They travel at the speed of light.
D. They are deflected in a magnetic field.

2. An engineer wishes to use a radioisotope to trace a crack in a pipe buried about a metre below the ground. Which one of the following isotopes should be chosen?

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Half-life</th>
</tr>
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<tbody>
<tr>
<td>A. alpha</td>
<td>a few hours</td>
</tr>
<tr>
<td>B. beta</td>
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</tr>
<tr>
<td>C. gamma</td>
<td>several years</td>
</tr>
<tr>
<td>D. gamma</td>
<td>a few hours</td>
</tr>
</tbody>
</table>

3. A radioactive nuclide has a half-life for 2 days. The ratio (number of atoms decayed): (number of atoms remaining undecayed) 4 days after the preparation of a new sample is

A. 1/4  B. 1/3  C. 3  D. 4

4. Gamma-rays of discrete wavelengths are emitted by an ‘excited’ nucleus. They

A. can be deflected by electric fields.
B. can be deflected by magnetic fields.
C. Do not ionise air molecules.
D. suggest the existence of energy levels in a nucleus.

5. An isotope has a half-life of 8 years. After a period of 24 years, the fraction of the isotope remaining is

A. 2/3  B. ¼  C. 1/3  D. 2/3
6. When the nucleus of a radioisotope decays with the emission of a $\beta^-$ particle,

A. its atomic number increases by one.
B. there is no change in the atomic number.
C. its neutron number increases by one.
D. its neutron number does not change.

7. The half-life of a radioisotope Y is 80 hours. If its initial activity is 12 Bq, its activity in Bq, after 240 hours will be

A. 0.08  B. 0.46  C. 1.50  D. 3.0

8. A radioactive nuclide Q which has $n$ neutrons and $p$ protons in its nucleus, decays be a series of emissions to form a stable element. If two alpha particles and one beta minus particle are emitted during the transition from Q to R, the element R may be represented by

A. $^n_4R_{p-4}$  B. $^n_4R_{p-3}$  C. $^{p+n-9}_4R_{p-4}$  D. $^{p+n-8}_4R_{p-3}$

9. $^{214}\text{Po}$ may decay into $^{210}\text{Po}$ by emitting an $\alpha$ - particle followed by

A. a $\beta^-$ particle and a gamma ray photon.
B. two $\beta^-$ particles.
C. an $\alpha$ - particle and a $\beta^-$ particle
D. a $\gamma$ - ray photon.

10. A nucleus $^aX_b$ decays by emitting an $\alpha$ - particle and a quantum of gamma radiation. The new nucleus of element Y could be written

A. $^{a-2}X_{b-2}$  B. $^{a-4}X_{b-2}$  C. $^{a-4}Y_{b-3}$  D. $^{a-5}Y_{b-2}$

11. A newly prepared sample of a radioactive material X starts to decay into a daughter product Y which is itself radioactive. Assuming that the half-lives of X and Y are much the same, which one of the following graphs best represents the variation of the activity A of the daughter product Y with time t?

A.  

B.  

C.  

D.
12. A radioactive nuclide $X$ decays to give a daughter product which is not radioactive. The measured activity $A$, at various times $t$ is given in the table. The activity in $s^{-1}$, after 9 hours is

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<thead>
<tr>
<th></th>
<th>$A (s^{-1})$</th>
<th>$t$ (hour)</th>
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<tr>
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<td>B</td>
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<td>C</td>
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<td>D</td>
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<td></td>
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13. Which of the following statements is NOT true?

A. Alpha particle emission is monoenergetic.
B. Beta minus particles are emitted with a range of kinetic energies.
C. A radioactive decay is an endothermic reaction because it is a spontaneous reaction.
D. Beta minus particle emission is accompanied by an antineutrino.

14. Which of the following statements about $\beta^-$ particles emission is correct?

A. The particles may take on a range of energies because there are only two products in beta decay.
B. The energy released during the decay is shared among the daughter nucleus, beta particle and neutrino.
C. The maximum possible kinetic energy of a beta particle emitted is equal to the energy released in the decay.
D. Beta particles emitted are mono-energetic to conserve energy and momentum.

15. Which of the following statements is correct?

A. Beta plus decay is accompanied by a neutrino.
B. Beta plus decay of a nucleus results in a decrease in neutron number.
C. Beta plus decay results in an increase of atomic number.
D. Beta plus decay is accompanied by an antineutrino.

16. Suppose that you start with 0.001 gram of a pure radioactive substance and a few hours later determine that only 0.00025 gram of the substance remains. How much energy, in joules, have been released in the form of kinetic energies? ($c = 3.0 \times 10^8 \text{ ms}^{-1}$)

A. $6.75 \times 10^{15}$  
B. $2.25 \times 10^{15}$  
C. $9.0 \times 10^{15}$  
D. 0

17. The graph below shows a neutron number $N$ against proton number $Z$ graph for stable nuclei. Which of the following radiation is most likely to be emitted by a radioactive isotope if it was position at point P?
A. alpha particle      B. beta-minus particle      C. beta-plus particle      D. gamma ray

18. Use the conservation of linear momentum to determine the speed of an alpha particle that is emitted from a $^{238}\text{U}_{92}$ nucleus which recoils with a speed of 0.01 ms$^{-1}$.

A. $1.7 \times 10^{-4}$ ms$^{-1}$      B. $0.6$ ms$^{-1}$      C. $1.7 \times 10^{-3}$ ms$^{-1}$      D. $8.4 \times 10^{-5}$ ms$^{-1}$

19. Which of the following nuclear decays is possible?

A. $^{40}\text{Ca}_{20} ightarrow ^{40}\text{K}_{19} + ^{0}\text{e}_{1} + {\bar{\nu}}$
B. $^{144}\text{Nd}_{60} ightarrow ^{144}\text{Ce}_{58} + ^{4}\text{He}_{2}$
C. $^{12}\text{B}_{5} ightarrow ^{12}\text{C}_{6} + ^{0}\text{e}_{1} + {\bar{\nu}}$
D. $^{14}\text{C}_{6} ightarrow ^{14}\text{N}_{7} + ^{0}\text{e}_{1} + {\bar{\nu}}$

20. Living matter reaches an equilibrium in which the Carbon-14 it contains produces a corrected count-rate of 15 counts per minute for each gram of its carbon content. 1 gram of carbon extracted from an old piece of wood gives a corrected count-rate of 5 counts per minute. If the half-life of carbon is 5700 years, which one of the following is the best estimate of the age of the wood in years?

A. 1900      B. 3600      C. 11400      D. 9000

21. Radioactive decay is said to be 'random' event. This means that

A. every nucleus has an equal chance of decay at any instant of time.
B. a nucleus will decay naturally without the help of any external agent.
C. the rate of decay of a radioactive substance varies with time follows a bell shaped curve.
D. the radiation comes out in all directions.
22. Radioactive decay is a 'spontaneous' event. This means that

A. every nucleus has an equal chance of decay at any instant of time.
B. a nucleus will decay naturally without the help of any external agent.
C. energy is absorbed in a decay.
D. light emission accompanies a decay.

23. The table shows the count-rate recorded at a point in a laboratory at various times, with and without a source in position.

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<th>Time(days)</th>
<th>Count-rate</th>
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<tr>
<td>30</td>
<td>30</td>
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<tr>
<td>90</td>
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</tr>
</tbody>
</table>

The half-life of the source is

A. 10 days   B. 15 days   C. 20 days   D. 30 days
## APPENDIX H

Test Specifications and Item Ratings for Diagnostic Tests 1-7

### Diagnostic Test 1

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Key: K - Knowledge; C - Comprehension; AP - Application; AN - Analysis, SY-Synthesis
Judges' ratings: not relevant, 1; somewhat relevant, 2; quite relevant, 3; very relevant, 4

### Diagnostic Test 2

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## APPENDIX I

Test Difficulty Ratings for First Semester Tests and Second Semester Tests

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Judges' ratings: not difficult, 1; somewhat difficult, 2; quite difficult, 3; very difficult, 4

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Judges' ratings: not difficult, 1; somewhat difficult, 2; quite difficult, 3; very difficult, 4