Exam 01: Chapters 01—02

Instructions
Put your name on this test paper. When you complete the exam, the test paper must be submitted. This exam paper will be
returned to you when it is graded.

You may use your calculator and the formula sheet provided. You may not use your phone or any additional reference
materials. If you need scratch paper, sheets will be provided for you.

Make sure that your phone is switched off. It should be put away, and nowhere visible on your desk. If your phone rings
during the exam, you will be required to turn in your exam and leave the room. You will not be allowed to return and
complete any unfinished portions of the exam. You may not use any type of mobile device as a calculator.

๏ There is exactly one correct answer for each question.
๏ Each question is worth 2.5 points.
๏ There is no partial credit.

Formulas and Constants

Average value: \( x_{av} = \frac{x_1 + x_2 + x_3}{3} \)

Volume of a Cube: \( V = l^3 \)

Density: \( \rho = \frac{m}{V} \)

Pythagorean Theorem: \( a^2 + b^2 = c^2 \)

Average speed: \( \text{speed} = \frac{\text{distance}}{\text{time}} \)

Velocity: \( v = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} \)

Acceleration: \( a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} \)

Acceleration due to Earth's gravity: \( g = 9.8 \text{ m/s}^2 \)

Newton #2:

Weight: \( w = mg \)

Impulse \( J \):

\[ J = F \Delta t \]

Linear Momentum Vector:

\[ \overrightarrow{p} = m \overrightarrow{v} \]

Linear Momentum Magnitude:

\[ p = m v \]

Impulse-Momentum:

\[ F \Delta t = m \Delta v \]

\[ m v_i + F \Delta t = m v_f \]

Conservation of Momentum:

\[ p_i = p_f \]

\[ p_i = (p_A + p_B)_i \]

\[ p_f = (p_A + p_B)_f \]

Law of Gravity:

\[ F = G \frac{m_1 m_2}{r^2} \]

\[ G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \]

Scoring
Each question is worth 2.5 points.

Points: \[ \frac{\text{Your Points}}{150} \]
1. What is science?
   A) A rigid set of unchanging rules.
   B) A static collection of unchanging facts.
   C) A search for order and explanation of our physical surroundings.
   D) A method for gathering, categorizing, analyzing, and using information to explain the physical universe.
   E) Both A and B, but not C and D.
   F) Both C and D, but not A and B.

2. Ben-Hur, Titanic, and LOTR: Return of the King are the three movies which have earned the most Academy Awards (11 Oscars each). Why were we even discussing this in a physical science class?
   A) This is an example of a measurement which does not objectively quantify a property.
   B) These are three movies that happen to show the laws of physics incredibly accurately; there is no “cartoon” or fake physics in these particular films.
   C) The number of Oscars earned by a movie is an objective measurement of the quality of the film. It’s a scientific fact that these three movies are the best movies in the history of cinema.

3. If I say (as I did in class), "Titanic is 195!", how do you make sense of this statement?
   A) You can't make sense out of nonsense.
   B) Take the statement at face value, because it’s offered by a person in a position of authority.
   C) Reject the statement out of hand, because it’s offered without context.

4. In the English (or Imperial) system of units, length can be measured in yards. What is the referent for this measurement?
   A) A yard is the approximate average length of a human stride.
   B) A yard is literally derived from the average length of a human foot.
   C) The average length from the street to the back fence of a typical suburban house lot is a yard.
   D) Half the length of the typical lanyard cord (like the kind for ID badges) is a demi-yard, or just a yard for short.

5. Who uses the metric system (or Système Internationale)?
   A) Everyone; this is the agreed upon standard system for all of the countries in the world. Well, except for the US, Liberia, and Myanmar.
   B) Hardly anyone; only the Unites States, Liberia, and Myanmar still use this system of measurement.
   C) No one; this system of units fell out of favor in the late 1700s, and has not been used since.
   D) A mystery. The system dates all the way back to the ancient Greeks, and no one knows how it developed.

6. Metric (Système Internationale) units are based on
   A) the body measurements of Louis XVI, the king of France in the late 1700s.
   B) the decimal system: units are easily divided or multiplied by factors of 10 to convert (i.e., 100cm = 1m).
   C) the hexadecimal system: units are all multiples of powers of 16, which is actually 2^4, 2^2, or 2^1.
   D) a mystery. The system dates all the way back to the ancient Greeks, and no one knows how it developed.

7. True or false: The kilogram (unit of mass) is a derived unit.

8. Which of the following is a fundamental unit?
   A) length
   B) velocity
   C) acceleration
   D) momentum
   E) These are all examples of fundamental units!

9. How long is one metric second?
   A) A metric second is approximately 1/10 of an English (or Imperial) second.
   B) A metric second is approximately 1.1 times longer than an English (or Imperial) second.
   C) A metric second cannot be measured, so it cannot be compared to an English (or Imperial) second.
   D) Trick question! A second is a second. There is no difference between a “metric” or an “English” second!

10. If you are measuring the time for google to complete a search, what units would be the most appropriate?
   A) nanometers = 10^-9m
   B) milliseonds = 10^-3s
   C) centimeters = 10^-2m
   D) kilograms = 10^3g
   E) megayears = 10^15years

11. A cross-sectional data set consists of
   A) one piece of information collected one time from one subject (or experiment).
   B) one piece of information collected one time from a large number of subjects (or experiments).
   C) the same piece of information collected from the same subjects (or experiments), repeated over time.
   D) information collected from subjects who share the same demographic properties (for example, age or birthday).

12. When you calculate a ratio, what are you actually doing?
   A) Comparing. A ratio, or fraction, just compares two quantities.
   B) Graphing. Calculating a ratio is the same thing as constructing a pie chart.
   C) Judging. By constructing a ratio, you are judging which of the quantities is actually better.
   D) Math. The calculation of anything is just math, and does not have any relationship to the actual physical world.

<table>
<thead>
<tr>
<th>Trial</th>
<th>diameter $d$ (cm)</th>
<th>circumference $c$ (cm)</th>
<th>ratio $c/d$ (unitless)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>31.5</td>
<td>3.15</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>93.9</td>
<td>3.13</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>157</td>
<td>3.14</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>219.8</td>
<td>3.14</td>
</tr>
</tbody>
</table>

13. Complete the Trial 3 row of the table above by calculating the ratio of circumference to diameter, $\frac{c}{d}$. Answer numerically, with two decimal places (and no units).

$$\frac{c}{d} = \frac{157}{50} = 3.14$$

14. For Trials 1–3, calculate the average value for the ratio $\frac{c}{d}$. Record this average (with two decimal places) as the ratio for Trial 4.

$$a_{avg} = \frac{3.15 + 3.13 + 3.14}{3} = 3.14$$
15. Using the average ratio, predict the circumference of a circle with diameter \( d = 70 \text{ cm} \). Answer numerically, rounding your answer to the nearest integer (no decimal places).

\[
c = (\pi \times d) = (3.14) (70) = 220
\]

16. True or false: For any circle you decide to measure, the ratio \( \frac{c}{d} \) will increase linearly as the diameter increases.

17. A cube of iron has sides with length \( l = 3 \text{ cm} \). When measured on a balance, its mass is \( m = 212.2 \text{ g} \). Calculate the density \( \rho \) of this cube.

\[
\rho = \frac{212.2 \text{ g}}{(3 \text{ cm})^3} = \frac{212.2 \text{ g}}{27 \text{ cm}^3} = 7.86 \text{ g/cm}^3
\]

A) \( \rho = 2.89 \text{ g/cm}^3 \) D) \( \rho = 15.7 \text{ g/cm}^3 \)
B) \( \rho = 7.86 \text{ g/cm}^3 \) E) \( \rho = 31.4 \text{ g/cm}^3 \)
C) \( \rho = 11.2 \text{ g/cm}^3 \) F) \( \rho = 126 \text{ g/cm}^3 \)

18. The force of gravity follows an inverse-square law. Let’s say you decrease the distance between two masses, from \( r_1 = 2 \text{ m} \) to \( r_2 = 1 \text{ m} \). What happens to the gravitational force between the masses as a result?

A) Half the distance, \( \frac{1}{2} \) the force: \( F_2 = \frac{1}{2} F_1 \)
B) Half the distance, \( \frac{1}{4} \) the force: \( F_2 = \frac{1}{4} F_1 \)
C) Half the distance, \( 2 \times \) the force: \( F_2 = 2 F_1 \)
D) Half the distance, \( 4 \times \) the force: \( F_2 = 4 F_1 \)
E) Half the distance, no change in the force. \( F_2 = F_1 \)

19. Why do we care about this inverse-square behavior?

A) We don’t. It’s a pointless math trick.
B) This behavior shows up all over physics, so understanding it for gravity means understanding it when we see it the next time.
C) This behavior is unique to gravity, and science is always interested in unique or unusual things.

20. The steps of the scientific method

A) are linear. Each step in the process must be followed in order, or you cannot expect to achieve reproducible results.
B) are exhausting. There are so many steps involved that no one actually understands them or follows them.
C) are random. Scientific progress almost always occurs randomly, when a scientist makes a discovery by accident while looking for something else.
D) are iterative. When science gets done in the real world, the process of inquiry, experimentation, and revision may repeat itself many times.
E) are imaginary. Scientists don’t actually have a process they follow. Like artists, they create scientific theories with their imagination. The results are typically untested, because they are usually untestable!

21. A law of nature is best defined as

A) an untestable conjecture.
B) an educated and testable guess that explains a phenomenon.
C) a partially–tested set of ideas that explains some part of nature.
D) a discarded set of ideas that explains some part of nature falsely or incorrectly.
E) a well–tested set of ideas that explains some part of nature, and which everyone has accepted as true.

22. An hypothesis is best defined as

A) an untestable conjecture.
B) an educated and testable guess that explains a phenomenon.
C) a partially–tested set of ideas that explains some part of nature.
D) a discarded set of ideas that explains some part of nature falsely or incorrectly.
E) a well–tested set of ideas that explain some part of nature, and which everyone has accepted as true.

23. Why do we call it “Einstein’s Theory of Relativity?”

A) Because it’s only a theory, and like all theories, nobody can really say if it’s right or wrong.
B) Because it has been tested repeatedly for over a hundred years, and never shown to be false.
C) Because Einstein was brilliant, and almost everything he said is automatically true.
D) Because it’s an untested idea. Once someone figures out a way to test it, it can become an hypothesis (if it holds up to experiment).

24. When presented with experimental evidence which contradicts or disproves his hypothesis, a scientist must

A) always throw away the entire hypothesis and start over from scratch.
B) continue to support his hypothesis without modifying it. Experiments are meaningless.
C) resign from his research group. Scientists who can’t prove their hypotheses are no scientists at all.
D) examine both the evidence and the hypothesis. The experiment may need to be redesigned, or the hypothesis may need to be revised—or maybe both.

25. Pride and Prejudice is the very best book. Great Expectations is absolutely the worst book ever. This is an example of

A) a fun fact!
B) a personal opinion.
C) a proven scientific theory.
D) a testable hypothesis.

26. People get very unlucky and more accident-prone than normal on Friday the 13th. This is an example of

A) a fun fact!
B) an unbiased opinion.
C) a proven scientific theory.
D) a testable hypothesis.

27. The earth is a spherically shaped planet which orbits the sun once every 365.25 days. This is an example of

A) a vicious conspiracy!
B) an uninformed opinion.
C) a proven scientific theory.
D) an untested hypothesis.

28. The distance traveled by an object

A) is always the same as the object’s displacement.
B) is never the same as the object’s displacement.
C) might be greater than the object’s displacement.
D) might be less than the object’s displacement.
The keys shown above are initially at rest on the table at point A. You slide them from A to B to C, and leave them again at rest at point C.

29. True or false: The displacement of the keys is greater than the distance traveled.

30. True or false: The displacement of the keys is 5ft.

31. True or false: It is possible for an object to travel zero distance, but have a non-zero displacement.

32. Velocity is an example of a vector. What exactly is a vector?
   A) Vector is a unit, like meters or seconds. Vector just happens to be the name of the metric unit of force.
   B) Vector is another way of saying very, very large. A vector quantity must be written in scientific notation.
   C) A vector is a physical quantity for which both a size (or magnitude) and a direction are meaningful and relevant.
   D) A vector is a physical constant. A random number (like 5) is not a vector, but pi (3.14) is a vector because it has meaning.

33. Which of the following is not a vector quantity?
   A) Time
   B) Displacement
   C) Velocity
   D) Force
   E) Momentum

Car A drives due east at 30 mph (13.4 m/s). Car B drives due west, also at 30 mph. Both cars maintain a constant speed as they drive. Answer Questions 34–38 using this data.

34. The cars have
   A) the same speed, but different velocities.
   B) the same direction, but different speed.
   C) the same direction, but different velocities.
   D) the same velocity: speed and direction both match.

35. Expressed mathematically, Car A has velocity $v_A = +13.4 \frac{m}{s}$.
   What, then, is the velocity of Car B?
   A) $v_B = +0 \frac{m}{s}$
   B) $v_B = -0 \frac{m}{s}$
   C) $v_B = +13.4 \frac{m}{s}$
   D) $v_B = -13.4 \frac{m}{s}$

36. Which car is accelerating?
   A) Car A.
   B) Car B.
   C) Neither car. Both vehicles have constant velocity.

37. Car A now begins to drive around a curve, carefully keeping its speed at 30 mph (13.4 m/s). Is Car A accelerating?
   A) No; constant speed means zero acceleration.
   B) Yes; even if the speed remains constant, the changing direction means non-zero acceleration.

38. There’s a STOP sign up ahead, and Car A hits the brakes. It comes to a complete stop after 4 seconds. What was the vehicle’s acceleration?
   A) $a_A = \frac{0 - 13.4 \frac{m}{s}}{4s} = -3.35 \frac{m}{s^2}$
   B) $a_A = \frac{-13.4 \frac{m}{s}}{4s} = 3.35 \frac{m}{s^2}$
   C) Zero. Car A did not accelerate.

39. The graph above shows the velocity of a car as a function of time. Use the definition of acceleration $a = \frac{\Delta v}{\Delta t}$ to calculate the acceleration of the car during Interval A.
   A) $a_A = 0 \frac{m}{s^2}$
   B) $a_A = 0.25 \frac{m}{s^2}$
   C) $a_A = 1 \frac{m}{s^2}$
   D) $a_A = 2 \frac{m}{s^2}$
   E) $a_A = 4 \frac{m}{s^2}$
   F) $a_A = 8 \frac{m}{s^2}$

40. What is the acceleration during Interval C? Answer numerically and include the proper sign.
   $a_A = \frac{v_f - v_i}{t_f - t_i} = \frac{4 - 8}{10 - 6} = -1 \frac{m}{s^2}$

41. Over which interval above is the object slowing down?
   A) Interval A
   B) Interval B
   C) Interval C

42. True or false: The force of gravity on the penny is greater.

43. True or false: The acceleration of both objects is equal.

44. What does an object’s inertia (measured by mass) tell you?
   A) The size of the object. The greater the inertia, the larger the size.
   B) The weight of the object. The greater the inertia, the less weight the object has.
   C) The density of the object. The greater the inertia, the higher the density of the object.
   D) The resistance to change. The greater the inertia, the more an object resists a change in its motion.

45. True or false: According to Newton’s First Law of Motion, the instant you stop applying a force to an object, it stops moving.

46. According to Newton’s First Law of Motion, objects at rest
   A) will remain at rest, unless acted upon by an unbalanced force.
   B) will begin to move spontaneously, as motion is the natural state for all mass.
   C) cannot be made to move; there are no circumstances under which stationary objects can change their state of motion. Once you’re stuck, you’re stuck.
   D) cannot experience forces. That’s why they are at rest, because it is not possible to exert any force upon them. Not even The Force.
47. You watch as a hockey puck slides across the ice, traveling several meters before coming to rest. According to Newton’s First Law,
   A) objects without mass cannot move, so the puck must have zero mass.
   B) objects in motion want to be at rest, so the puck naturally stops moving.
   C) objects in motion want to remain in motion, so some force must have acted upon the puck to stop it moving.

48. You notice that when you apply a horizontal force to an object with mass \( m_1 = 4\text{kg} \), its acceleration is \( a_1 = 1\text{m/s}^2 \). According to Newton’s Second Law of Motion, if you apply the exact same horizontal force to a second object with \( m_2 = 8\text{kg} \), how much will it accelerate?
   A) If the forces are the same, the acceleration of each object must also be exactly the same, regardless of their different masses: \( a_2 = a_1 = 1\text{m/s}^2 \).
   B) If Object 2 has twice the mass, the same force will provide twice the acceleration: \( a_2 = 2a_1 = 2\text{m/s}^2 \).
   C) If Object 2 has twice the mass, applying the same force will only give half the acceleration: \( a_2 = \frac{1}{2}a_1 = 0.5\text{m/s}^2 \).
   D) There is no relationship between the forces and the accelerations, so there is no way to predict what will happen.

49. Calculate the acceleration of the lawnmower if your friend pushes it with a horizontal force \( F = 65\text{N} \). The mass of the mower is \( m = 25\text{kg} \). Answer numerically with one decimal place.
   \[
   a = \frac{F}{m} = \frac{65\text{N}}{25\text{kg}} = 2.6\text{m/s}^2
   \]

50. The Earth has an acceleration due to gravity \( g = 9.8\text{m/s}^2 \). However, on Mars the value for \( g = 3.71\text{m/s}^2 \). On Earth, a 100kg mass weighs
   \[
   w = mg = (100\text{kg}) (9.8\text{m/s}^2) = 980\text{N}
   \]
   How much does a 50kg mass weigh on Mars? Answer numerically, rounding to the nearest integer.
   \[
   w = mg = (50\text{kg}) (3.71\text{m/s}^2) = 186\text{N}
   \]

51. Two separate forces are acting on the same object.
   A) This might be an example of Newton #3, but only if the forces act in the same direction.
   B) This might be an example of Newton #3, but only if the two forces act in opposite directions.
   C) This is always an example of Newton #3. Any two forces acting on the same object form an action-reaction pair.
   D) This is never an example of Newton #3, because an action-reaction force pair always acts on two different objects.

52. Which of the following is an example of a Newton’s Third Law action-reaction force pair?
   A) The tension in a rope and the weight of the object it supports.
   B) The force of gravity on a skydiver and the air resistance on him as he falls.
   C) The force of gravity on a block and the frictional force on it as it slides down a rough incline.
   D) The force on an insect due to the windshield, and the force on the windshield due to the insect that just hit it.
   E) These are all excellent examples of Newton #3!

53. Tiny (the elephant) applies \( 150\text{N} \) of force to Ike (the dude in the wig). How much force does Ike apply to Tiny?
   A) Exactly 0N.
   B) Maybe 50N.
   C) About 75N.
   D) Exactly 100N.
   E) Exactly 150N.
   F) No way to tell!

54. If Ike has a mass of \( 60\text{kg} \), then that \( 150\text{N} \) push gives him an acceleration \( a_1 = 2.50\text{m/s}^2 \). Tiny, though, has a whopping mass \( m = 500\text{kg} \). What is the magnitude \( a \) of Tiny’s acceleration? Answer numerically, rounding to three decimal places.
   \[
   a = \frac{F}{m} = \frac{150\text{N}}{500\text{kg}} = 0.300\text{m/s}^2
   \]

55. Billiard balls having identical mass are shown above in a long-exposure photograph. Of the balls labeled A through E, which has the largest momentum? Ball E

56. Compare the momentum vectors for Ball B and Ball C.
   A) Both vectors have the same magnitude and direction.
   B) The magnitudes of both are almost identical, but the vector directions are different.
   C) The magnitudes of the vectors are very different, but the directions are identical.
   D) The magnitudes of the vectors are very different, and their directions are different as well.
   E) There cannot be a comparison, because Ball B has momentum, but Ball C does not.
57. Object A has momentum $= +p$, while Object B has momentum $= -p$. From this information, you know that both
   A) are both at rest.
   B) have the same mass.
   C) have the same speed.
   D) are traveling in the same direction.
   E) are traveling in opposite directions.

A car with mass $m_A = 3000$ kg is traveling east with a speed $v_A = +5$ m/s. A second car ($m_B = 2000$ kg) travels west, with a speed $v_B = -4$ m/s. Unfortunately, car B runs head-on into the car A.

\[ P_{total} = P_A + P_B \]
\[ P_{total} = m_A v_A + m_B v_B \]
\[ P_{total} = (3000 \text{ kg})(5 \text{ m/s}) + (2000 \text{ kg})(-4 \text{ m/s}) \]
\[ P_{total} = 15000 \frac{kg \cdot m}{s} - 8000 \frac{kg \cdot m}{s} = 7000 \frac{kg \cdot m}{s} \]

58. What is the total system momentum ($p_f = car_A + car_B$) at the instant just before the collision?
   A) $p_f = 0$ kg m/s.
   B) $p_f = 5000$ kg m/s.
   C) $p_f = 7000$ kg m/s.
   D) $p_f = 8000$ kg m/s.
   E) $p_f = 15000$ kg m/s.
   F) $p_f = 23000$ kg m/s.

59. What is the total system momentum ($p_f = car_A + car_B$) at the instant just after the collision?
   A) Zero: $p_f = 0$.
   B) Less than the initial momentum: $p_f < p_i$.
   C) Equal to the initial momentum: $p_f = p_i$.
   D) Greater than the initial momentum: $p_f > p_i$.

60. True or false: After the collision, the momentum of car A (by itself) will be unchanged. However much momentum it had prior to the collision, it will have exactly the same amount afterwards.