CHAPTER 1—PHYSICS AND THE LIFE SCIENCES

MULTIPLE CHOICE

1. The principle of Occam's Razor is a principle of reasoning; what does it say we should generally do?
   a. Prefer simpler or more parsimonious explanations to the more complicated ones.
   b. Reason from detailed particular observations to general or universal principles.
   c. Accept nothing as true without compelling empirical or mathematical evidence of its truth.
   d. Reason from general or universal principles to particular results.

   ANS: A
   RAT: The principle is often inaccurately summarized as "the simplest explanation is most likely the correct one." Rather, the principle generally recommends that, when faced with competing hypotheses that are equal in other respects, one should select the one that makes the fewest new assumptions.
   PTS: 1
   REF: p. 4
   BLM: Remember

2. When creating of a model to explain a certain physical concept, what are observations and collected data most useful for?
   a. making predictions
   b. proving that the model is correct without a doubt
   c. testing predictions made by the model
   d. generating catalogues

   ANS: C
   RAT: Observations are used in testing predictions of a model.
   PTS: 1
   REF: p. 4
   BLM: Higher Order

3. How many significant figures are in 20 006?
   a. 2
   b. 3
   c. 4
   d. 5

   ANS: D
   RAT: all zeroes are significant here
   PTS: 1
   REF: p. 5
   BLM: Higher Order

4. How many significant figures are in 0.0235?
   a. 2
   b. 3
   c. 4
   d. 5

   ANS: B
   RAT: leading zeroes are not significant
   PTS: 1
   REF: p. 5
   BLM: Higher Order

5. When would the measurement of weight with a scale be precise but not accurate?
   a. If it is precise it has to be accurate.
   b. The scale does not read zero at zero.
   c. The zero is not consistently set for all measurements.
   d. If it is precise it cannot be accurate.

   ANS: B
   RAT: Accuracy measures the degree of closeness of measurements to the true value, whereas precision is the degree of variation of measurements among themselves, when the underlying true quantity is unchanging.
   PTS: 1
   REF: p. 5
   BLM: Higher Order

6. Which of the following is the value for $(6.28 \div 0.21 \times 1125)$, with the correct number of significant figures?
   a. 34000
   b. 33640
   c. 33643
   d. 33642.871428

   ANS: A
   RAT: The result has the same number of significant figures as the least accurate number used in calculation.
   PTS: 1
   REF: p. 5
   BLM: Higher Order

7. Which of the following numbers has the highest precision?
   a. 12.534
   b. $6 \times 10^{-8}\ m^3$
   c. $2.38675 \times 10^{9}\ m^3$
   d. 1.200008

   ANS: B
   RAT: The smallest power of ten quoted in a result should represent the precision of the result.
   PTS: 1
   REF: p. 5
   BLM: Higher Order

8. Which of the following numbers has the highest accuracy?
   a. 12.534
   b. 6×10^{-8} m^3
   c. 2.38675×10^{9} m^3
   d. 1.200008

   ANS: D
   RAT: The number of significant figures should represent the accuracy of the result.
   PTS: 1
   REF: p. 5
   BLM: Higher Order

9. Which of the following is the value for the product of $(1.362 \times 10^{5}) \cdot (8.5 \times 10^{6})$, with the correct number of significant figures?
   a. 1.1577×10^{12}
   b. 1.158×10^{12}
   c. 1.16×10^{12}
   d. 1.2×10^{12}

   ANS: D
   RAT: The result has the same number of significant figures as the least accurate number used in calculation.
   PTS: 1
   REF: p. 7
   BLM: Higher Order

10. To convert a quantity from m/s^2 to $km/hr/s$, what must you do?
    a. Multiply by 1000 and divide by 60.
    b. Multiply by 1000 and divide by 3600.
    c. Multiply by 60 and divide by 1000.
    d. Multiply by 3600 and divide by 1000.

    ANS: D
    RAT: $m/s^2 = (m/s)/s = [(1/1000)\ km / (1/3600)\ h]/s = 3600/1000\ [(km/h)/s]$
    PTS: 1
    REF: p. 8
    BLM: Higher Order

11. Total lung capacity of a male, on average, is about 6 litres of air. What would this be, expressed in cubic metres?
    a. 6 m^3
    b. 6×10^{-3} m^3
    c. 6×10^{-6} m^3
    d. This cannot be done. The dimensions are different.

    ANS: B
    RAT: $6 \times (10^{-1})^3$ m^3 = 6×10^{-3} m^3
    PTS: 1
    REF: p. 8
    BLM: Higher Order

12. The largest blue whale ever measured weighed around 420 000 pounds (lb.). The SI unit for weight is the Newton (N), and one pound (1 lb.)? 6~ 4.5 N. Which of the following values represents the mass of the whale in SI units?
Note: weight = mass × g, where g = 9.8 m/s^2.
a. 1.9×10^5 *g*
b. 1.9×10^5 kg
c. 1.9×10^7 *g*
d. 1.9×10^7 kg

ANS: B
RAT: (420 000 × 4.5) N / 9.8 m/s^2 = 1.9×10^5 kg
PTS: 1
REF: p. 9
BLM: Higher Order

13. Which of the following is a fundamental unit in the SI?
a. kilometre (km)
b. kilogram (kg)
c. gram (g)
d. Newton (N)

ANS: B
RAT: metre is a fundamental SI unit, not kilometre, kilogram not gram
PTS: 1
REF: p. 9
BLM: Remember

14. Which of the following relationships is dimensionally consistent? In these equations, *a* is acceleration, *v* is velocity, *t* is time, and *x* is distance.
a. $a = v / t^2$
b. $a = v / x^2$
c. $a = v^2 / t$
d. $a = v^2 / x$

ANS: D
RAT: $m / s^2 = m^2 / s^2 m$
PTS: 1
REF: p. 11
BLM: Higher Order

15. Which of the following relationships is dimensionally consistent? In these equations, a is acceleration, v is velocity, t is time and x is distance.
    a. $x = v^2 / a$
    b. $x = at / v$
    c. $x = v / t$
    d. $x = a^2 / v$

    ANS: A
    RAT: $m = m^2 s^2 / m s^2$
    PTS: 1
    REF: p. 11
    BLM: Higher Order

16. In the expression $v_f^2 = v_0^2 + P x$, where x has units metre (m), and v_f and v_0 have units m/s, what are the units for P?
    a. m/s
    b. m
    c. m/s^2
    d. no units

    ANS: C
    RAT: $m^2 s^2$ is (m) (m/s^2)
    PTS: 1
    REF: p. 11
    BLM: Higher Order

17. Flow rate of a fluid is expressed as a velocity of fluid multiplied by the cross sectional area of the pipe (v A). Assume that the pipe is a blood vessel with circular cross sectional area, calculated as $A = \pi r^2$, where r is a radius. In a continuous flow rate, where $v_1A_1 = v_2A_2$, calculate the change of the velocity of blood if a blood vessel with radius r_1 reduced its radius by the factor of 2, to $r_2 = r_1 / 2$.
    a. $v_2=(1 / 4)v_1$
    b. $v_2=2v_1$
    c. $v_2=4v_1$
    d. $v_2=(1 / 2)v_1$

    ANS: C
    RAT: $v_1A_1 = v_2A_2 \rightarrow v_1 \pi r_1^2 = v_2 \pi r_2^2 \rightarrow v_1 \pi r_1^2 = v_2 \pi (r_1/2)^2 \rightarrow v_1 \cancel{\pi} \cancel{r_1^2} = v_2 \cancel{\pi} \cancel{r_1^2} (1/4) \rightarrow v_2=4v_1$
    PTS: 1
    REF: p. 12
    BLM: Higher Order

18. Exploring proportions in the human body, you can notice that the span of your arms is equal to your body height. If a child has height of 1.3 m, and an adult 1.74 m, approximately by what factor is the adult's arm length longer than that of the child?
    a. 1.34
    b. 1.55
    c. 1.79
    d. 2.40

    ANS: A
    RAT: proportion 1.74 m / 1.3 m = 1.34
    PTS: 1
    REF: p. 12
    BLM: Higher Order

19. If an adult has 3 times the weight of a child, the adult's foot will be twice as long and twice as wide as the child's foot. What is the ratio of force per unit area (pressure *P*) exerted on the feet of the child, compared to the force exerted on the adult's feet?
    a. 1/3
    b. 3/4
    c. 4/3
    d. 3

    ANS: C
    RAT: $P_{child} = W_{child} / Area_{child\text{-}foot}$, $P_{adult} = W_{adult} / Area_{adult\text{-}foot}$
    $P_{child} / P_{adult} = W_{child}\ Area_{adult\text{-}foot} / Area_{child\text{-}foot}\ W_{adult}$
    $P_{child} / P_{adult} = W_{child}\ 4Area_{child\text{-}foot} / Area_{child\text{-}foot}\ 3$
    W_{child} $P_{child} / P_{adult} = 4/3$

    PTS: 1
    REF: p. 12
    BLM: Higher Order

20. The thickness of human hair is around 100 micrometres (□m). If a width of a DNA molecule is around 10 nanometres (nm), how many DNA molecules can fit across a hair strand?
    a. 10^2
    b. 10^3
    c. 10^4
    d. 10^5

    ANS: C
    RAT: hair 100 μm = 10^{-4} m , DNA 10 nm = 10^{-8} m, 10^{-4} m /10^{-8} m = 10^4 m
    PTS: 1
    REF: p. 16
    BLM: Higher Order

TRUE/FALSE

1. In creating of a model which would explain a certain physical concept, observations and collected data are most useful for proving that the model is a true representation of a concept.

   ANS: F
   RAT: Observations are testing predictions of a model.
   PTS: 1
   REF: p. 4
   BLM: Higher Order

2. The calculator can hold only a few significant digits. When adding a set of positive numbers of widely varying magnitude on a calculator, in order to get the most accurate result one should start at the largest number and add successively smaller ones.

   ANS: F
   RAT: One should start at the smallest number and add successively larger numbers. The calculator can hold only a few significant digits, so adding a small number to a larger one will result in losing the least significant digits, while adding several small numbers may accumulate to a larger number with more significant digits, so that rounding off to the appropriate number of significant figures would provide a more accurate result.
   PTS: 1
   REF: p. 4
   BLM: Higher Order

3. A precise measurement is not necessarily an accurate one.

   ANS: T
   RAT: Example: scale can be very precise but not set to zero, so it does not show accurate weight.
   PTS: 1
   REF: p. 5
   BLM: Higher Order

4. When adding or subtracting numbers, the result has the same precision as the least precise number used in the calculation.

   ANS: T
   RAT: When adding or subtracting numbers, the result has the same precision as the least precise number used in the calculation.
   PTS: 1
   REF: p. 5
   BLM: Remember

5. Numbers 20 and 20.0 have the same number of significant figures.

   ANS: F
   RAT: No, in 20, only 2 is significant, trailing zero is not, in 20.0 both zeros are significant because of decimal point.
   PTS: 1
   REF: p. 5
   BLM: Higher Order

6. Numbers 0.025 and 25 have the same number of significant figures.

   ANS: T
   RAT: leading zeros are not significant
   PTS: 1
   REF: p. 5
   BLM: Higher Order

7. The smallest power of ten quoted in a result should represent the precision of the result.

   ANS: T
   RAT: The smallest power of ten quoted in a result should represent the precision of the result.
   PTS: 1
   REF: p. 5
   BLM: Remember

8. The smallest power of ten quoted in a result should represent the accuracy of the result.

   ANS: F
   RAT: No, the number of significant figures should represent the accuracy of the result. The smallest power of ten quoted in a result should represent the precision of the result.
   PTS: 1
   REF: p. 5
   BLM: Remember

9. The Earth's equator, with a circumference around 40 000 km, is longer than the total length of capillaries in human body, $6x10^9$cm.

   ANS: F
   RAT: 6×10^9cm = 60 000 km
   PTS: 1
   REF: p. 9
   BLM: Higher Order

10. Nerve fibres conduct impulses with a speed of 72 m/s in rats, which is faster than the 72 km/h speed of conduction in squids.

    ANS: T
    RAT: 72 km/h = 20 m/s which is less than 72 m/s.
    PTS: 1
    REF: p. 9
    BLM: Higher Order

ESSAY

1. When choosing between two models which explain a physical principle with equal success, but which differ in complexity of explanation, how do we choose the more plausible model?

   ANS:
   The principle of Occam's Razor is a principle of reasoning which asserts that in general we should prefer the simpler explanation with fewer assumptions to the more complicated one.
   RAT: The principle is often inaccurately summarized as "the simplest explanation is most likely the correct one." Rather, the principle generally recommends that, when faced with competing hypotheses that are equal in other respects, one should select the one that makes the fewest new assumptions.
   PTS: 1
   REF: p. 4
   BLM: Remember

2. You are measuring your weight on a scale. You know that the scale is extremely precise. However, you notice that your weight measured on this scale is not accurate. How could a precise scale show an inaccurate result?

   ANS:
   The scale is not positioned properly for the measurement. Its reading when empty was not set to zero.
   RAT: Accuracy measures the degree of closeness of measurements to the true value, whereas precision is the degree of variation of measurements among themselves, when the underlying true quantity is unchanging.
   PTS: 1
   REF: p. 5
   BLM: Higher Order

3. Calculate both the sum and the difference between the following two numbers: 1.04×10^{-5} m and 7.7×10^{-7} m. Express your results with correct units, number of significant figures, and scientific notation.

   ANS:
   the sum is 1.12×10^{-5} m, the difference is 9.6×10^{-6} m
   RAT: 1.117×10^{-5} m has 2 decimal points significant, 0.963×10^{-5} m converted to scientific notation 9.6×10^{-6} m
   PTS: 1
   REF: p. 6
   BLM: Higher Order

4. Radioactive decay is described with the following law: $N = N_0 \times 2^{-\lambda t}$, where N is the number of nuclei, N_0 is the original number of nuclei at the start of the process, t is time needed for N_0 to decay to N, and λ is a radioactive constant of a particular element. What are the units of λ? If the radioactive constant of another element is larger, does that element require a shorter or longer time to perform the same decay?

   ANS:
   1/s, shorter time
   RAT: N is a number, no units, t is time, unit second, λ has to have unit 1/s
   PTS: 1
   REF: p. 8
   BLM: Higher Order

5. The speed of light is 3×10^8 m/s. The distance between Earth and the Sun is roughly 150 million kilometres. How long does it take for light to travel from the Sun to the Earth? Express the result in seconds, minutes, hours, and days. Which unit is most appropriate?

   ANS:
   500 seconds, 8.3 minutes, 0.14 hours, 0.0058 days
   RAT: time = distance / speed
   PTS: 1
   REF: p. 9
   BLM: Higher Order

6. Some astrologers claim that the gravitational influence of Mars can affect a child during birth. Gravitational force is linearly proportional to the masses of two bodies and decreases with the square of the distance between those bodies. Compare the influence of Mars (at a distance is 7.8×10^7 km from the Earth), and a 70 kg doctor at a distance of 0.1m, on a 3 kg baby. The mass of Mars is 6.42×10^{23} kg, and the universal gravitational constant is $G = 6.67300 \times 10^{-11}$ m^3 kg^{-1} s^{-2}.

   ANS:
   doctor has 66 times larger gravitational influence on the baby than Mars
   RAT: $F = G\, m_1\, m_2 / d^2$
   PTS: 1
   REF: p. 9
   BLM: Higher Order

7. A cylindrical water tank holds 650 litres of water. The volume of a cylinder is given by $V = \pi r^2 h$ (r is radius, h is height). How much water (in litres) could the tank hold if the radius was doubled and the height reduced to half?

   ANS:
   $V_{new} = \pi r^2 h$ $4/2 = 2$ $V_{old} = 650$ L $\times 2 = 1300$ L
   RAT: proportion
   PTS: 1
   REF: p. 15
   BLM: Higher Order

8. Mass of the human brain and body are related as: $\text{mass}_{\text{brain}}$ is proportional to $(\text{mass}_{\text{body}})^{0.68}$. Find the brain mass of the dolphin:
   a) if we assume that the dolphin is as intelligent as a human, and
   b) if we assume that it is as intelligent as a chimpanzee. Compare your results to the real value from the table and draw a conclusion about its intelligence ranking.

   ANS:
   Bottlenose dolphin is less intelligent than a human, but more than a chimpanzee.
   RAT: Bottlenose dolphin's $\text{mass}_{\text{brain}}$
   a) $\text{mass}_{\text{brain}} = \text{mass}_{\text{brain human}} (\text{body mass}_{\text{dolphin}} / \text{body mass}_{\text{human}})^{0.68} = 2498$ g
   b) $\text{mass}_{\text{brain}} = \text{mass}_{\text{brain chimp}} (\text{body mass}_{\text{dolphin}} / \text{body mass}_{\text{chimp}})^{0.68} = 928$ g
   PTS: 1
   REF: p. 15
   BLM: Higher Order

9. Estimate the number of hairs on your head, if you counted 50 hairs on a 5mm × 5mm area. State your assumptions.

   ANS:
   around 120000
   RAT: if head has radius approximately 10 cm= 100 mm, area $A=4\pi r^2 = 120\,000$ mm^2, if $\frac{1}{2}$ of head is covered by hair, area covered by hair is 60000 mm^2, with 50 hairs/ 25 mm^2, total number of hairs is 60000 mm^2 × 50 hairs/ 25 mm^2 = 120 000 hairs
   PTS: 1
   REF: p. 16
   BLM: Higher Order

10. Average human heartbeat is 75/minute. How many heartbeats has a 20-year-old student had since birth?

    ANS:
    around 4×10^7 a year, around 8×10^8 in 20 years
    RAT: conversion of units 75/minute = 75 × 365 × 24 × 60/year, times 20
    PTS: 1
    REF: p. 16
    BLM: Higher Order

