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Chapter 2

1. Aristotle classified motion into two kinds: *natural motion* and *violent motion*.
2. Aristotle believed forces were necessary for motion. It was Galileo who later refuted this idea and established the concept of inertia.
3. Galileo discredited Aristotle's ideas that heavy objects fall faster than light ones, and that a force is necessary to maintain motion.
4. Experiment. In conducting experiments, Galileo ushered in the age of modern science.
5. The property is called inertia.
6. Weight depends on gravity, while mass does not.
7. Your weight would be greater on the Earth because of its stronger force of gravity. Mass, however, is the same everywhere.
8. Newtons for weight; kilograms for mass.
9. One kg would weigh less on the Moon.
10. Neither; any amount of water has the same density.
11. The net force on the box is 10 N to the right.
12. The description of a vector quantity needs both magnitude and direction.
13. The force is tension.
14. Tension will be 20 N.
15. $F = 0$ means that the vector sum of all the forces that act on an object in equilibrium equals zero. The forces cancel.
16. The support force acts at a right angle to the surface. Normal is another term for "right angle."
17. The same. You actually read the support force by the scale, which is the same as your weight when the scale is stationary.
18. The bowling ball on the lane moves without a change in speed and is therefore in equilibrium. The ball rolling down the hill changes its speed and is therefore not in equilibrium.

19. Since the crate slides in equilibrium (constant velocity), we know that the friction must be equal and opposite to our push. That way the forces cancel and the crate slides without changing velocity.

20. The direction of friction is opposite to the direction of motion.

21. To the left.

22. Yes, opposite to your push, just enough so that $\Sigma F = 0$.

23. Speed is magnitude (how much) and velocity is speed with direction (how much and which way).

24. Velocity involves both magnitude (speed) and direction. Speed involves only magnitude.

25. The speedometer shows instantaneous speed.

26. You can be at rest relative to the Earth, but moving at 100,000 km/h relative to the Sun.

27. Acceleration = change in velocity/unit of time; $a = \Delta v/\Delta t$.

28. 10 m/s^2, or more precisely, 9.8 m/s^2.

29. The unit of time appears once for the unit of velocity, and again for the time during which the velocity changes.

30. The speed decreases by 10 m/s each second.

31. Synovial fluid is a lubricant. It protects the bones against the wearing effects of friction. The bones rub against the lubricating synovial fluid instead of against each other.

32. Descriptions will vary: Possible examples include: physics-air resistance; chemistry-lubricants; biology-fingerprints; earth science-earthquakes; astronomy-meteors

33. Friction is one of the causes of earthquakes because it prevents rock from moving when pushed. As a result, elastic strain builds up in the rock. More about this in Chapter 22.

34. Your speed is zero at the top of your jump.

35. Length of legs and strength of muscles affects jumping ability.

36. The more massive and larger cans tend to roll farther.

37. Answers will vary. The speeds are calculated by measuring the distance and the time to cover that distance.

38. Average speed = (30 m)/(2 s) = 15 m/s.

39. Average speed = (1.0 m)/(0.5 s) = 2 m/s.

40. Acceleration = (10 m/s)/(2 s) = 5 m/s^2.

41. Acceleration = (100 km/h)/(10 s) = 10 km/h·s.

42. Acceleration = (40 m/s)/(4 s) = 10 m/s^2.

43. C, B, A.

44. C, A, B, D.

45. (a) B, A, C, D. (b) B, A, C, D

46. (a) None, all same, zero. (b) C, B, A.

47. (a) 30 N + 20 N = 50 N. (b) 30 N – 20 N = 10 N, in the direction of the 30-N force.

48. (a) Net force is zero (because velocity is constant!). (b) Friction = 100 N.

49. From $F = 0$, friction equals weight, mg, = (100 kg)(10 m/s^2) = 1000 N (or 980 N using g = 9.8 m/s^2).

50. From v $\frac{d}{t}$, t $\frac{d}{v}$.

We convert 3 m to 3000 mm, and $t = \frac{3000\text{ mm}}{1.5\text{ mm/year}}$ = 2000 years.

51. $a = \frac{\text{change in velocity}}{\text{time interval}} = \frac{90\text{ km/h}}{10\text{s}}$ = -9 km/h·s.

(The vehicle decelerates at 9 km/h•s.) Convert to m/s^2 by multiplying by 1000 m/km and h/3600 s, whereupon acceleration = $-2.5\ m/s^2$.

52.

Time (*in seconds*)	Velocity (*in meters/second*)	Distance (*in meters*)
6	60	180
7	70	245
8	80	320
9	90	405
10	100	500

53. Since it starts going up at 40 m/s and loses 10 m/s each second, its time going up is 4 seconds. Its time returning is also 4 seconds, so it's in the air for a total of 8 seconds. Distance up (or down) is $1/2\ gt^2 = 5\ 4^2 = 80$ m. Or from $d = vt$, where average velocity is $(40 + 0)/2 = 20$ m/s, and time is 4 seconds, we also get $d = 20$ m/s 4 s = 80 m.

54. (a) The velocity of the ball at the top of its vertical trajectory is instantaneously zero.
(b) One second before reaching its top, its velocity is 10 m/s.
(c) The amount of change in velocity is 10 m/s during this 1-second interval (or any other 1-second interval).
(d) One second after reaching its top its velocity is 10 m/s—equal in magnitude but oppositely directed to its value 1 second before reaching the top.
(e) The amount of change in velocity during this (or any) 1-second interval is 10 m/s.
(f) In 2 seconds, the amount of change in velocity, from 10 m/s up to 10 m/s down, is 20 m/s (not zero!).
(g) The acceleration of the ball is $10\ m/s^2$ before reaching the top, when reaching the top, and after reaching the top. In all cases acceleration is downward, toward Earth's center.

55. The Leaning Tower experiment discredited the idea that heavy things fall proportionally faster. The incline plane experiments discredited the idea that a force is needed for motion.

56. Inertia is measured by mass.

57. A dieter loses mass. To lose weight, the person could go to the top of a mountain where the force of gravity is less. But the amount of matter and therefore the mass would be the same.

58. The density of lead, mass/volume is $11.3\ g/cm^3$. The density of aluminum is $(5.4\ g)/(2\ cm^3) = 2.7\ g/cm^3$, whatever the amount. Two grams of a metal has the same density as one gram of the same metal.

59. The density of aluminum is $(5.4\ g)/(2\ cm^3) = 2.7\ g/cm^3$. Density is a ratio of weight or mass per volume, and this ratio is greater for any amount of lead than for any amount of aluminum. So 5 kg of lead has a greater density than 10 g of aluminum.

60. Maximum, 25 N + 15 N = 40 N. Minimum, 25 N – 15 N = 10 N.

61. From $\boldsymbol{F} = 0$, the upward forces are 400 N, and the downward forces are 250 N + weight of the staging. So the staging must weigh 150 N.

62. From $F = 0$, the upward forces are 400 N + tension in right scale. This sum must equal the downward forces of 250 N + 300 N + 300 N. Arithmetic shows the reading on the right scale is 450 N.

63. Yes, the forces are equal and opposite and cancel to zero, thus putting the person in equilibrium. But the two forces don't make up an action-reaction pair. This is because they both act on the same object. The reaction to the downward pull of gravity (the world pulling down on the person) is the person pulling up on the world.

64. No, we cannot, for there may well be forces that cancel to zero. We can say no net force acts on it.

65. No, because the force of gravity acts on the object. Its motion is undergoing change, as a moment later should be evident a moment later.

66. If the crate speeds up, then your force is greater than the force of friction.

67. The impact speed is 2 km/h.

68. Not very successful, for Harry's speed will be zero relative to the land.

69. More than 2 hours, because you cannot maintain an average speed of 60 miles/hour without exceeding the speed limit. You begin at zero, and end at zero, so even if there's no slowing down along the way you'll have to exceed 60 mi/h to average 60 mi/h. So the trip will take you more than 2 hours.

70. An increase of 10 m/s during each second of fall.

71. The distance increases as the square of the time, so each successive distance covered is greater than the preceding distance covered.

72. Both hit the ground with the same speed (but not in the same time).

73. Acceleration is 10 m/s^2, constant, all the way down. (Velocity, however, is 50 m/s at 5 seconds, and 100 m/s at 10 seconds.)

74. Aristotle would likely say the ball slows to reach its natural state. Galileo would say the ball is encountering friction, an unbalanced force that slows it.

75. An object cannot be in equilibrium if only one force acts on it, for there would then be a non-zero net force. It would undergo a change in its motion.

76. Each scale shows half her weight.

77. In the left figure, Harry is supported by two strands of rope that share his weight (like the little girl in Exercise 76). So each strand supports only 250 N, less than the breaking point. The total force upward supplied by ropes equals the weight acting downward, which gives a net force of zero and no acceleration. In the right figure, Harry is now supported by only one strand, which for Harry's well-being requires that the tension be 500 N. Since this is greater than the breaking point of the rope, the rope breaks. The net force on Harry is then only his weight, giving him a downward acceleration of *g*. The sudden return to zero velocity changes his vacation plans.

78. The ball slows by 10 m/s each second, and gains 10 m/s when descending. The time up equals the time down if air resistance is nil.

79. Ball B will finish first because its average speed along the lower part of the track as well as on the downward and upward slopes is greater than the average speed of the ball along track A.

80. (a) Average speed is greater for the ball on track B. (b) The instantaneous speed at the ends of the tracks is the same because the speed gained on the down-ramp for B is equal to the speed lost on the up-ramp side. (Many people get the wrong answer for the previous

question because they assume that because the balls end up with the same speed that they roll for the same time. Not so.)