The twenty-first annual SLAPT Physics Contest
Southern Illinois University Edwardsville
April 29, 2006

Senior Physics Test

$g=9.8\ m/s^2$ $c=3 \times 10^8\ m/s$ $G=6.7 \times 10^{-11}\ Nm^2/kg^2$

$e=1.6 \times 10^{-19}\ C$ $m_{electron}=9.11 \times 10^{-31}\ kg$ $k = \frac{1}{4\pi\varepsilon_o} = 9 \times 10^9 \frac{Nm^2}{C^2}$

Absolute zero: 0 K or 273°C

Please answer the following questions on the supplied answer sheet. You may write on this test booklet, but only the answer sheet will be scored.

1 Is it possible for an object moving in one dimension to have its instantaneous velocity and instantaneous acceleration with an opposite sign at some instant of time?
(a) Yes
(b) No

2 A car is traveling north at 21.9 m/s. After 12 s, its velocity is 14.1 m/s in the same direction. Find the magnitude and direction of the car's average acceleration.
(a) 0.65 m/s^2 south
(b) 0.65 m/s^2 north
(c) 3.0 m/s^2 south
(d) 3.0 m/s^2 north

3. A boy throws a rock with an initial velocity of 4.15 m/s at 30.0^O above the horizontal. How long does it take for the rock to reach the maximum height of its trajectory?
(a) 0.212 s
(b) 0.374 s
(c) 0.415 s
(d) 0.585 s

4. What is the x-component of the velocity for a ball with a speed of 40 m/s, moving at an angle 30^O above the horizontal?
(a) 0 m/s
(b) 20.0 m/s
(c) 34.6 m/s
(d) 40.0 m/s

5. The sum of two vectors is zero. What can you conclude about the two vectors?
(a) They point in the same direction
(b) They are perpendicular
(c) They point in opposite directions
(d) One has twice the magnitude of the other

6. What is the mass of an object that experiences a gravitational force of 489 N near the Earth's surface?
(a) 10.0 kg
(b) 20.0 kg
(c) 49.9 kg
(d) 69.9 kg

7. A new roller coaster contains a loop-the-loop in which the car and the rider are completely upside down. If the radius of the loop is 17.9 m, with what minimum speed must the car traverse the loop so that the rider does not fall out while upside down at the top? Assume the rider is not strapped to the car.

(a) 10.0 m/s
(b) 13.2 m/s
(c) 14.5 m/s
(d) 14.9 m/s^2

8. Is the normal force on a body always equal in magnitude to its weight?
(a) Yes, no matter where you are in the universe
(b) Yes, so long as the object is on the Earth
(c) No

9. Consider a horse pulling a buggy, and making the buggy accelerate forwards. How does the magnitude of the force that horse exerts on the buggy compare to the magnitude of the force that the buggy exerts on the horse?
(a) The magnitude of the force that the horse exerts on the buggy is greater.
(b) The magnitude of the force that the buggy exerts on the horse is greater.
(c) They are equal in magnitude
(d) There is not enough information to say.

10. Calculate the kinetic energy of a 0.300 kg baseball thrown at a velocity of 28 m/s.
(a) 118 J
(b) 177 J
(c) 207 J
(d) 236 J

11. A child pulls on a wagon with a force of 75 N. If the wagon moves a total of 42 m in 3.8 min, what is the average power generated by the child?
(a) 14 W
(b) 17 W
(c) 18 W
(d) 21 W

12. Two satellites, A and B, of the same mass, are going around the Earth in concentric orbits. The distance of satellite B from Earth's center is twice that of satellite A. What is the ratio of the tangential speed of B to that of A?
(a) 1/2
(b) $1/\sqrt{2}$
(c) 1
(d) $\sqrt{2}$
(e) 2

13. Suppose rain falls vertically into an open cart rolling along a straight horizontal track with negligible friction. As a result of the accumulating water, the speed of the cart
(a) Increases
(b) Does not change
(c) Decreases

14. An object initially at rest explodes into two fragments of masses 2.0 kg and 4.6 kg that move in opposite directions. If the speed of the first fragment is 1.0 m/s, find the internal energy of the explosion.
(a) 1.4 J
(b) 1.4 kJ
(c) 3.3 J
(d) 3.3 kJ

15. Consider two carts, of masses m and 2m, at rest on an air track. If you push first one cart for 3 s and then the other for the same length of time, exerting equal force on each, the momentum of the light cart is

(a) Four times the momentum of the heavy cart
(b) Two times the momentum of the heavy cart
(c) The same as the momentum of the heavy cart
(d) Half the momentum of the heavy cart
(e) One-fourth the momentum of the heavy cart

16. A figure skater stands on one spot on the ice (assumed frictionless) and spins around with her arms extended. When she pulls in her arms, her angular momentum is conserved. Her rotational kinetic energy
(a) Increases
(b) Remains the same
(c) Decreases

17. A frictional force of 750 N acts tangentially on a tire at the point where the tire touches the road. If the force gives rise to a torque of 225 N*m, what is the diameter of the wheel?
(a) 0.300 m
(b) 0.522 m
(c) 0.600 m
(d) 6.67 m

18. If the frequency of a harmonic oscillator doubles, while its amplitude remains the same, how much does the maximum value of acceleration change?
(a) 2
(b) 4
(c) $\sqrt{2}$
(d) $2/\pi$
(e) It does not change

19. If the frequency of a violin string is to be increased by 20%, what change in tension must be applied?
(a) 4.5%
(b) 10%
(c) 20%
(d) 44%

20. Crests of an ocean wave pass a pier every 9.0 s. If the waves are moving at 5.6 m/s, what is the wavelength of the ocean waves?
(a) 8 m
(b) 43 m
(c) 50 m
(d) 58 m

21. Visible light is an electromagnetic wave that travels at $3.00 * 10^8$ m/s in a vacuum. What is the frequency of a visible light wave with a wavelength of 519 nm?
(a) $1.45 * 10^{15}$ Hz
(b) $4.34 * 10^{14}$ Hz
(c) $5.78 * 10^{14}$ Hz
(d) $7.51 * 10^{13}$ Hz

22. Transverse waves propagate at 43.2 m/s in a string that is subjected to a tension of 60.5 N. If the string is 16.1 m long, what is its mass?
(a) 0.219 kg
(b) 0.371 kg
(c) 0.522 kg
(d) 0.606 kg

23. A transverse wave propagates along a string. The particles in the string move
(a) Perpendicular to the direction of propagation
(b) Parallel to the direction of propagation
(c) Depends on the initial disturbance

24. If a source of sound is moving towards you, how does that motion affect the wavelength of the sound waves that you observe?
(a) It increases it
(b) It decreases it
(c) It does not affect it

25. A 0.663 m string is clamped at both ends. If the lowest standing wave frequency in the string is 326 Hz, what is the wave speed?
(a) 432 m/s
(b) 536 m/s
(c) 657 m/s
(d) 216 m/s

26. If you triple your distance from a sound source, the ratio of the new intensity that you hear to the old intensity that you heard will be
(a) 1/9
(b) 1/3
(c) $1/\sqrt{3}$
(d) 1
(e) 3

27. Imagine holding two identical bricks underwater. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is
(a) larger than the force required to hold brick A in place
(b) equal to the force required to hold brick A in place
(c) smaller than the force required to hold brick A in place

28. If a piece of metal has a hole in it and the metal is heated, how does the area of the hole change?
(a) It increases
(b) It remains the same
(c) It decreases

29. An ideal gas is in a closed container. It is pressure is 141 Pa initially, and its temperature is 20.0^{O} C, what is its pressure after its temperature is raised to 60.0^{O} C?
(a) 47 Pa
(b) 124 Pa
(c) 160 Pa
(d) 423 Pa

30. A fluid in an insulated, flexible bottle is heated by a high resistance wire and expands. If 17 kJ of heat is applied to the system and it does 9 kJ of work, how much does the internal energy change?
(a) –8 kJ
(b) 8 kJ
(c) 26 kJ
(d) 153 kJ

31. Two identical containers are each filled with 10 moles of gas. The two containers are at the same temperature, yet the internal energies of the two gasses differ. How can this be?
(a) The molecules of the two gasses have different masses
(b) The molecules of the two gasses have different numbers of degrees of freedom
(c) This could be explained by either (a) or (b)
(d) Neither (a) nor (b) could explain this

32. Which of the following is not true? The electric force
(a) decreases with the inverse of the square of the distance between two charged particles
(b) between an electron and a proton is much stronger than the gravitational force between them
(c) between two protons separated by a distance d is larger in magnitude than that between two electrons separated by the same distance d
(d) may be either attractive or repulsive

33. Three point charges are positioned on the x-axis. If the charges and corresponding positions are +32 μC at x=0, +20 μC at x=40 cm, and –60 μC at x=60 cm, what is the magnitude of the electrostatic force on the +32 μC charge?
(a) 12 N
(b) 36 N
(c) 48 N
(d) 50 N
(e) 84 N

34. An electron enters a region of uniform electric field (E=50 N/C) with an initial velocity of 40 km/s directed the same as the electric field. What is the speed of the electron 1.5 ns after entering this region?
(a) 18 km/s
(b) 27 km/s
(c) 42 km/s
(d) 53 km./s
(e) 62 km/s

35. A charge q is placed a distance r from the origin, and a charge 2q is placed a distance 2r. There is a charge Q at the origin. If all charges are positive, which charge is at the higher potential?
(a) q
(b) 2q
(c) The two charges have the same potential

36. A solid spherical conductor is given a net nonzero charge. The electrostatic potential of the conductor is
(a) largest at the center
(b) largest on the surface
(c) largest somewhere between the center and the surface
(d) constant throughout the volume

37. A particle of charge 5.0 μC is released from rest at a point x=10 cm. If a 5.0 μC charge is held fixed at the origin, what is the kinetic energy of the particle after it has moved 90 cm?
(a) 1.2 J
(b) 1.6 J
(c) 1.8 J
(d) 2.0 J
(e) 2.4 J

38. A 15 μF capacitor and a 25 μF capacitor are connected in parallel, and this combination is charged to a potential difference of 60 V. How much energy is then stored in this capacitor combination?
(a) 17 mJ
(b) 32 mJ
(c) 45 mJ
(d) 50 mJ
(e) 72 mJ

39. Consider two identical resistors wired in series (one behind the other). If there is an electric current through the combination, the current in the second resistor is
(a) greater than the current through the first resistor
(b) equal to the current through the first resistor
(c) half the current through the first resistor
(d) less than the current through the first resistor, but not necessarily half as much

40. Two resistors with differing resistances are connected first in series and then in parallel. Which combination has the larger net resistance?
(a) The pair in series
(b) The pair in parallel
(c) The two combinations have the same net resistance
(d) There is not enough information to decide between these choices

41. What maximum power can be generated from an 18 V emf using any combination of a 6.0 Ω resistor and a 9.0 Ω resistor?
(a) 22 W
(b) 54 W
(c) 71 W
(d) 80 W
(e) 90 W

42. What is the magnetic force on a 2.0 m length of straight wire carrying a current of 30 A in a region where a uniform magnetic field has a magnitude of 55 mT and is directed at an angle of 20^{O} away from the wire?
(a) 1.1 N
(b) 1.3 N
(c) 1.5 N
(d) 1.7 N
(e) 3.1 N

43. A light ray is incident on the surface of water (n=1.33) at an angle of 60^{O} relative to the normal to the surface. The angle of the refracted wave is
(a) 20^{O}
(b) 30^{O}
(c) 40^{O}
(d) 60^{O}
(e) 80^{O}

44. A light ray whose frequency is 6×10^{14} Hz in vacuum is incident on water (n=1.33). The wavelength of the light after it enters the water is
(a) 266 nm
(b) 376 nm
(c) 500 nm
(d) 665 nm
(e) 798 nm

45. A layer of water (n=1.33) floats on a container of carbon tetrachloride (n=1.46). What is the critical angle at the interface?
(a) 43^{O}
(b) 58^{O}
(c) 66^{O}
(d) 78^{O}
(e) 88^{O}

46. As seen in air by a person looking down on the surface, the image of an object beneath the surface formed by light rays leaving a flat refracting surface of a pool of water is
(a) real and closer to the viewer than the object
(b) virtual and closer to the viewer than the object
(c) real and farther from the viewer than the object
(d) virtual and farther from the viewer than the object
(e) virtual and the same distance from the viewer as the object

47. In an interference pattern, the wavelength and frequency are
(a) the same in both the regions of constructive interference and the regions of destructive interference
(b) greater in regions of constructive interference than in regions of destructive interference
(c) smaller in regions of constructive interference than in regions of destructive interference
(d) unchanged in regions of constructive interference but greater in regions of constructive interference
(e) unchanged in regions of constructive interference but smaller in regions of constructive interference

48. Rutherford's experiment, in which he fired alpha particles of 7.7 MeV kinetic energy at a thin gold foil, showed that nuclei were very much smaller than the size of an atom because
(a) some alpha particles passed through the foil undeflected
(b) some alpha particles were deflected backwards
(c) some alpha particles were captured by the gold nuclei
(d) the alpha particles could not get closer than 10^{-10} m to the gold nuclei
(e) the alpha particles split into deuterium nuclei when they encountered the gold nuclei

49. The half-life of a muon is 2.2 μs as measured in a stationary reference frame. What will be the half-life of the muon if it is moving with a speed of 0.8 c?
(a) 1.32 μs
(b) 2.75 μs
(c) 3.67 μs
(d) 8.13 μs
(e) 15.8 μs

50. Energy is released during a nuclear reaction due to a conversion between mass and energy. The initial and final amounts of mass are different. If a total of 1 gram of mass is "lost," how much energy is released?
(a) 90×10^{10} J
(b) 90×10^{12} J
(c) 90×10^{14} J
(d) 90×10^{15} J
(e) 90×10^{16} J

Tie-breaker question

The following question will only be used to break ties between contestants with identical scores on the multiple-choice section. For this section you must show your work clearly.

A child sits at the top of a frictionless sphere of radius R. She starts to slide down. Find the angle on the sphere at which she loses contact with the sphere. The sphere is fixed in place, and does not move during her slide down.