THE TWENTY-FOURTH ANNUAL SLAPT PHYSICS CONTEST
SOUTHERN ILLINOIS UNIVERSITY EDWARDSVILLE
APRIL 25, 2009
9 – 11 AM

COMPREHENSIVE PHYSICS TEST

$g = 9.8$ m/s/s $1cm^3$ = milliliter $R = 8.314$ J/mol/K

$e = 1.6 \times 10^{-19}$ C The Coulomb constant, $k = 8.99 \times 10^9$ N·m^2/C^2

$c = 3.0 \times 10^8$ m/s The value of Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K

Please answer the following questions on the supplied answer sheet. You may write on this test booklet and keep it for your records. Only the answer sheets will be scored

Your Answer Sheet must have your name, your school, and the word SENIOR

The cash prizes for this exam will be:
First Prize of $150, Second Prize of $75, and Third Prize of $25.

Certificates of Honorable Mention will be presented to the next highest scoring twenty percent of the contestants, and certificates to the top three scoring schools.

Award Ceremony at 12:30 in this room

1) If the fastest you can safely drive is 65 mi/h, what is the longest time you can stop for dinner if you must travel 541 mi in 9.6 h total?
    a. 1.0 hr
    b. 1.3 hr
    c. 1.4 hr
    d. No time to stop

2) Acceleration is sometimes expressed in multiples of *g*, where g = 9.8 m/s^2 is the acceleration due to the earth's gravity. In a car crash, the car's velocity may go from 26 m/s to 0 m/s in 0.15 s. How many *g*'s are experienced, on average, by the driver?
    a. 13 g
    b. 18 g
    c. 22 g
    d. 23 g

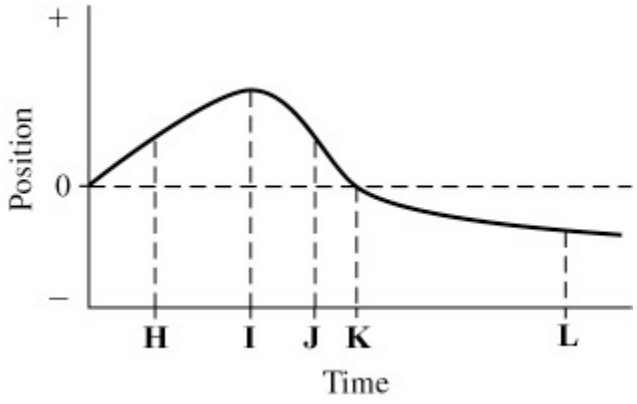
3) A car accelerates from 10.0 m/s to 30 m/s at a rate of 3.0 m/s^2. How far does it travel while accelerating?
    a. 80 m
    b. 117 m
    c. 133 m
    d. 226 m

4) Human reaction times are worsened by alcohol. How much farther would a drunk driver's car travel before he hits the brakes than a sober driver's car? Assume both cars are initially traveling at 49.0 mi/h, the sober driver takes .33 s and the drunk driver takes 1.0 s to hit the brakes in a crisis.
    a. 34 ft
    b. 40 ft
    c. 45 ft
    d. 48 ft

5) The position of an object is given by $x = bt^3 - ct^2 + dt$. What is the instantaneous acceleration of the object when t = 0.7 s? Assume b = 4.1 m/s^3, c = 2.2 m/s^2 and d = 1.7 m/s
    a. –13 m/s
    b. 2.2 m/s
    c. 13 m/s
    d. 1.5 m/s

6) At the same moment, one rock is dropped and one is thrown downward with an initial velocity of 10 m/s from the top of a 300 m building. How much earlier does the thrown rock strike the ground?
   a. 0.95 s
   b. 1.05 s
   c. 2.10 s
   d. They land at the same time

7) The plot below shows the position of an object as a function of time. The letters H-L represent particular moments of time. At which moment in time is the speed of the object the highest?

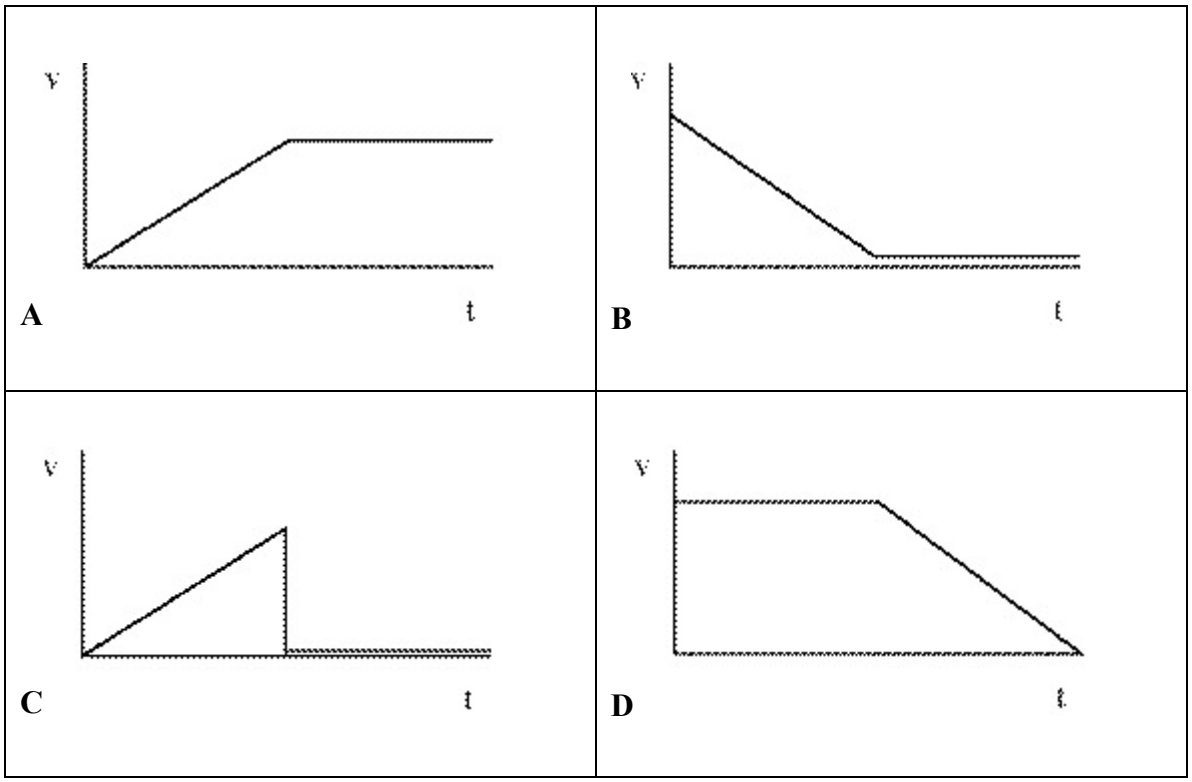


   a. H
   b. I
   c. J
   d. K

8) The position of an object as a function of time is given by $\vec{r} = bt^3\,\hat{i} + ct\,\hat{j}$. If b = 2.1 m/s^3 and c = 1.7 m/s , what is the force on a 2.0 kg object when t = 1.8 s?
   a. 54 $\hat{i}$ N
   b. 38 $\hat{i}$ N
   c. 45 $\hat{i}$ +12 N $\hat{j}$
   d. 45 $\hat{i}$ N

9) A trolley starts from rest and runs down a sloping track section onto a second level section as shown. Friction is negligible.

Which velocity–time graph below best represents the trolley's motion on both sections?

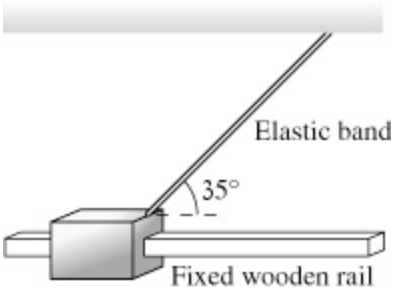


10) Suppose you are playing hockey on a new-age ice surface in which there is no friction between the ice and the hockey puck. You wind up and hit the puck as hard as you can. Just after the puck loses contact with your stick, the puck
    a. Will start to slow down
    b. Will slow down a little then move at a constant rate
    c. Will not slow down or speed up
    d. Will speed up a little, then move at a constant rate

11) Kieran takes off down a 50 m high, 10° slope on his jet–powered skis. The skis have a thrust of 280 N. The combined mass of skis and Kieran is 50kg (the fuel mass is negligible). Kieran's speed at the bottom is 40 m/s. What is the coefficient of kinetic friction of his skis on snow?

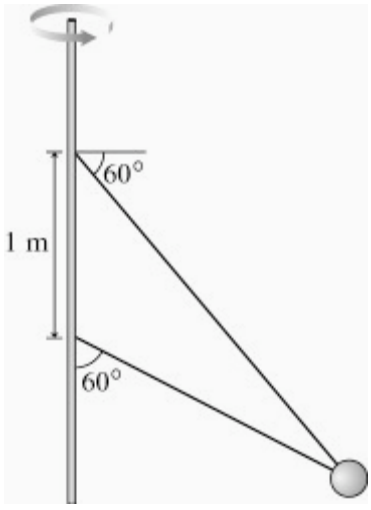
a. 0.23
b. 0.29
c. 0.47
d. 0.58

12) A device has a 100 g wooden shuttle that is pulled along a square wooden rail by an elastic band. The shuttle is released when the elastic band has 9.0 N tension at a 35° angle. What is the magnitude of the initial acceleration of the shuttle?



a. 52 m /s /s
b. 68 m /s /s
c. 74 m /s /s
d. 90 m /s /s

13) The figure shows two wires tied to a 3.3 kg sphere which revolves in a horizontal circle at constant speed. At this particular speed the tension is the same in both wires. What is the tension?



a. 20 N
b. 22 N
c. 24 N
d. 26 N

14) Two vehicles approach a right angle intersection and then collide. After the collision, they become entangled. If their mass ratios were 1: 5 and their respective speeds as they approached were 16 m/s and 17 m/s, find the final velocity of the wreck
   a. 14.4 m/s at 79°
   b. 16.9 m/s at 79°
   c. 17.3 m/s at 79°
   d. 19.2 m/s at 79°

15) A block starts from rest at the top of a 31.0° inclined plane and encounters a spring, of constant 3.4 k N/m, rigidly attached to the plane. If the block's mass is 33.0 kg and it compresses the spring by 37.0 cm, find the distance the block travelled before it encountered the spring
   a. 1.0 m
   b. 1.37 m
   c. 1.74 m
   d. 1.82 m

16) A 2.3 kg object moving at 7.3 m/s collides inelastically with a 4.0 kg object which is initially at rest. What percentage of the initial kinetic energy of the system is lost during the collision.
   a. 47 %
   b. 50 %
   c. 58%
   d. 63%

17) A force $\vec{F} = 12\,\mathbf{i} - 10\,\mathbf{j}$ N acts on an object. How much work does this force do as the object moves from the origin to the point $\vec{r} = 13\,\hat{\mathrm{i}} + 11\,\hat{\mathrm{j}}$ m?
   a. 12 J
   b. 37 J
   c. 46 J
   d. 62 J

18) A solid disk of radius 1.60 m and mass 2.30 kg rolls without slipping to the bottom of an inclined plane. If the angular velocity of the disk is 5.35 rad/s at the bottom, what is the height of the inclined plane
   a. 5.61 m
   b. 4.94 m
   c. 4.21 m
   d. 3.73 m

19) A hollow steel ball of diameter 3 m barely floats in water. What is the wall thickness of the ball? (ρ_{Fe} = 7.87 g/cm^3)
   a. 1.3 cm
   b. 4.2 cm
   c. 6.6 cm
   d. 37 cm

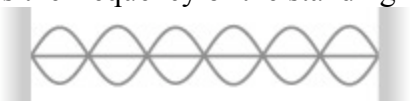
20) A gamma ray (a pulse of electromagnetic energy) has a frequency of 2.42×10^{20} Hz. What is the ratio of its wavelength to the radius of the nucleus which produced it (radius = 5.0×10^{-13} cm)?
   a. 0.0015
   b. 39.4
   c. 248
   d. 1.21 x 10^8

21) Find the speed of an ocean wave whose displacement is given by $y = 3.7 \cos(2.2x - 5.6t)$ where x and y are in meters and t is in seconds
   a. 2.2 m/s
   b. 2.5 m/s
   c. 3.7 m/s
   d. 20.7 m/s

22) A motor drives a mechanism that produces simple harmonic motion at one end of a stretched cable such that the oscillation amplitude is 25.1 cm. What is the wave amplitude when the power of the motor is increased by 25.1%? Assume that the frequency oscillation and tension in the wire are unchanged.
   a. 25.3 cm
   b. 25.8 cm
   c. 28.1 cm
   d. 33.7 cm

23) The siren of an ambulance wails at 1395 Hz when the ambulance is stationary. What frequency will you hear after this ambulance passes you while traveling at 33.60 m/s? The speed of sound under the prevailing conditions is 343.0 m/s.
   a. 1052 Hz
   b. 1271 Hz
   c. 1395 Hz
   d. 1547 Hz

24) A string, 2.0 meters in length, is fixed at both ends and tightened until the wave speed is 78 m/s What is the frequency of the standing wave shown in the figure



a. 120 Hz
b. 230 Hz
c. 350 Hz
d. 470 Hz

25) Two motors in a factory are running at slightly different rates. One runs at 825 rpm and the other at 786 rpm. You hear the sound intensity increase and then decrease periodically due to wave interference. How long does it take between successive instances of the sound intensity increasing?

a. 1.54 s
b. 1.63 s
c. 1.66 s
d. 1.79 s

26) What is the phase difference between (a) the displacement and the potential energy and (b) the displacement and the kinetic energy at a fixed point of a harmonic wave on a string?

a. (a) 0 (b) 0
b. (a) $\pi/2$ (b) 0
c. (a) 0 (b) $\pi/2$
d. (a) $\pi/2$ (b) $\pi/2$

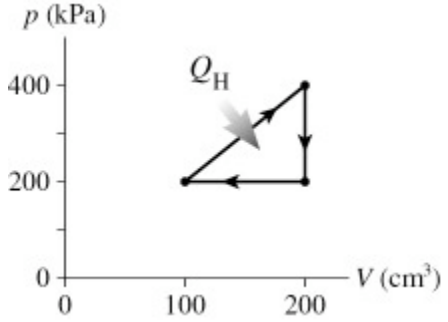
27) The velocity of a longitudinal sound wave in an ideal gas is given by $v = \sqrt{\gamma P/\rho}$, where γ is the ratio of the specific heat at constant pressure to that at constant volume, P is the pressure, and ρ is the mass density. Assuming an ideal gas with $\gamma = 1.4$ and $\rho = 1.4$ g/L at standard temperature and pressure, find the wavelength for a 2700 Hz sound wave

a. 0.00 m
b. 0.12 m
c. 8.33 m
d. 2 cm

28) A cork bobs on the surface of the water making an oscillation every 3.0 s, with an amplitude of 1.0 m. Another cork 18.0 m away is observed to bob exactly 180° out of phase with the first cork. What is the velocity of the water waves?

a. 2.0 m/s
b. 4.0 m/s
c. 18 m/s
d. 25 m/s

29) The figure shows a cycle for a heat engine for which QH=35 J. What is the thermal efficiency



a. 15%
b. 23%
c. 25%
d. 29%

30) Eleven molecules have speeds 16, 17, 18, . . . , 26 m/s. Calculate v_{rms}

a. 21.2 m/s
b. 21.5 m/s
c. 21.7 m/s
d. 22.0 m/s

31) What is the average kinetic energy of an ideal gas at 842 K?

a. 5.81×10^{-21} J
b. 1.74×10^{-20} J
c. 3.93×10^{-19} J
d. 1.18×10^{-17} J

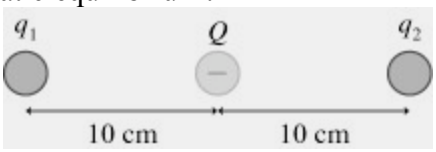
32) An ideal gas in a balloon is kept in thermal equilibrium with its constant–temperature surroundings. How much work is done by the gas if the pressure is slowly reduced and the balloon expands to 6.0 times its original size? The balloon initially has a pressure of 645.0 Pa and has a volume of 0.10 m^3

a. –330 J
b. 120 J
c. 330 J
d. 390 J

33) Suppose a van de Graaff generator builds a negative static charge, and a grounded conductor is placed near enough to it so that a 9.0 μC of negative charge arcs to the conductor. Estimate the number of electrons involved?

a. 5.6×10^{13}
b. 5.4×10^{11}
c. 5.0×10^{9}
d. 9.0

34) In the figure below the charge in the middle is Q = -3.1 nC. For what charge q1 will charge q2 be in static equilibrium?

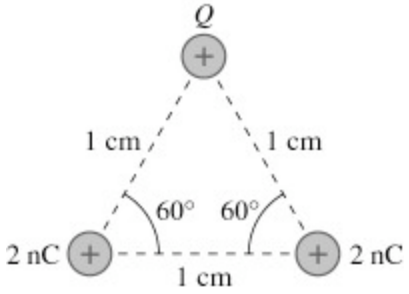


a. 25 nC
b. 6.2 nC
c. 3.1 nC
d. 12 nC

35) A small sphere with a mass of 441.0 g is moving along the *y*-axis when it encounters an electric field of 5.0 $\hat{i}$ N/C. If the sphere suddenly accelerates 13.0 $\hat{i}$ m/s^2, what is the charge that it carries?

a. –1900 C
b. –1.9 C
c. 1900 C
d. 1.9 C

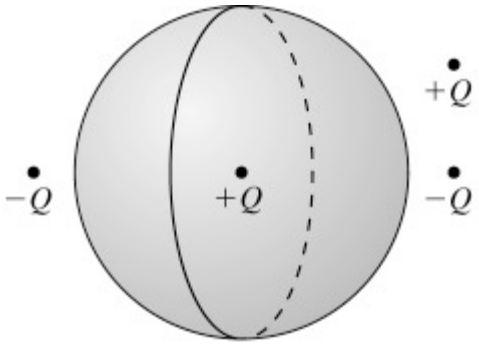
36) In the figure Q = 5.8 nC and all other quantities are exact. What is the magnitude of the force on the charge Q?



a. 0.9 mN
b. 1.0 mN
c. 1.2 mN
d. 1.8 mN

37) The electric field 1.5 cm from a small object points toward the object with a strength of 180,000 N/C. What is the object's charge?
a. –4.5nC
b. 4.5 nC
c. –5.0 nC
d. 5 nC

38) A particle with a charge +Q is inside a spherical Gaussian surface, and three other charges (one with a charge +Q and two with a charge -Q) are outside the Gaussian surface, as shown.



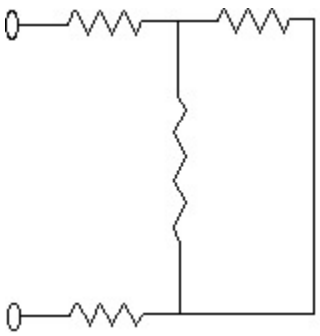
The net electric flux through the surface is:
a. Greater than zero
b. Less than Zero
c. Equal to zero

39) A copper wire of length *L* and radius *b* is attached to another copper wire of length *L* and radius 2*b*, forming one long wire of length 2*L*. This long wire is attached to a battery, and a current is flowing through it. Relative to the electric field within the wire of radius *b*, the magnitude of the electric field within the wire of radius 2*b* is
a. Two times weaker
b. Two times stronger
c. Four times weaker
d. Four times stronger

40) A device experiences a voltage drop of 4.0 V across it while a current of 4.0 mA flows through it. How much power does it dissipate?

a. 16 mW
b. 64 mW
c. 4.0 kW
d. 1.0 kW

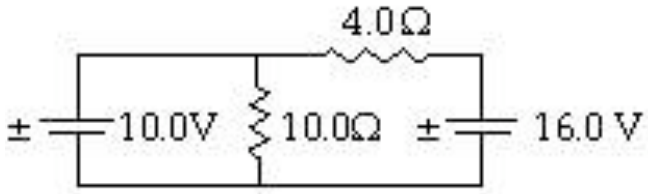
41) Each of the resistors in the circuit shown have a resistance of 160.0 Ω. What is the equivalent resistance of the circuit?



a. 400 Ω
b. 640 Ω
c. 480 Ω
d. 160 Ω

42) Refer to the figure. What is the current through the 4.0 Ω resistor?

a. 1.1 A
b. 1.5 A
c. 4.0 A
d. 0.43A



43) A very long wire generates a magnetic field of 0.0050×10^{-4} T at a distance of 3.0 mm. What is the magnitude of the current?

a. 24,000 mA
b. 3300 mA
c. 7.5 mA
d. 1.7 mA

44) A 2-slit arrangement with 60.3 μm separation between the slits is illuminated with 482.0 nm light. Assuming that a viewing screen is located 2.14 m from the slits, find the distance from the first dark fringe on one side of the central maximum to the second dark fringe on the other side.
    a. 68.4 mm
    b. 51.3 mm
    c. 34.2 mm
    d. 24.1 mm

45) You look through a glass cube normal to a face. What maximum angle can you rotate the cube and still see through the opposite face if $n = 1.28$
    a. 130 °
    b. 95.3 °
    c. 64.8°
    d. 50.9°

46) The speed of light in a material is 0.50 *c*. What is the critical angle of a light ray at the interface between the material and a vacuum
    a. 21°
    b. 24°
    c. 27°
    d. 30°

47) A refracting telescope has an objective focal length of 320 cm and an angular magnification of 75. The telescope is initially focused on a star. The telescope is then refocused on a mountain top, 10 km distant. The final telescopic image is at infinity in both cases. The change made, in the separation between the objective and the eyepiece, due to the refocusing, in mm, is closest to
    a. –2mm
    b. –1 mm
    c. 0 mm
    d. 1 mm

48) An ancient rock is found to contain ^{40}Ar gas, indicating that 77% of the ^{40}K in the rock has decayed since the rock solidified. Any argon would have boiled out of liquid rock. How long ago did the rock solidify? The half–life of ^{40}K is 1.25 billion years.
    a. 0.3 billion years
    b. 1.8 billion years
    c. 2.6 billion years
    d. 3.2 billion years

49) What is the basic difference between Schrodinger's equation and Newton's 2nd law?
    a. Newton's 2nd can be used to predict exactly where a particle will be at any given time , whereas solutions to Schrodinger's equation only give probabilities.
    b. Newton's 2nd law is only valid for big objects (like balls) and the Schrodinger equation is only valid for small objects (like atoms and electrons).
    c. Energy is conserved in Newton's 2nd law, but not in Scrhodinger's Equation

50) An electron and a proton are both moving such that their kinetic energy is roughly 100 eV. How do the speeds of the particles compare?
    a. The proton is moving about 30 times faster than the electron
    b. The electron and proton are moving about the same speed
    c. The electron is moving about 1000 times faster than the proton
    d. The electron is moving about 30 times faster than the proton.