PHYSICSBOWL - APRIL 23, 2003

40 QUESTIONS–45 MINUTES

This contest is sponsored by the **American Association of Physics Teachers**, **Texas Instruments Incorporated** and **Frey Scientific** to generate interest in physics and to recognize outstanding high school physics students and their teachers.

This competition is held in 15 regions, each with two divisions. Division I is for students in a first-year physics course; Division II is for students in an advanced or second-year physics course. A school's score in each division is the sum of the four highest student scores in that division. A school may compete in either or both divisions.

NOTE: one award per student

If your exam is a photocopy or previously opened, your school is in violation of US copyright law and the contest rules.

INSTRUCTIONS

Answer sheet: Write and bubble-in the appropriate information on your answer sheet. You should fill in your name, sex, grade, and School ID Number and 2 special codes. In the block labeled "IDENTIFICATION NUMBER," write in and encode the nine-digit school identification number that your teacher will give you. You will also need to fill in TWO SPECIAL CODES to identify which level of physics you are taking (column A) and the region you are from (columns F and G). Failure to properly fill in all the above information on your answer sheet will mean your score will not be counted towards the school's team overall score and you will become ineligible for individual recognition. Your answer sheet will be machine graded. Be sure to use a #2 pencil, fill the bubbles completely, and make no stray marks on the answer sheet.

Questions: The test is composed of 50 questions however students will be required to answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the number of the question on the test.

Division I students will answer only questions 1-40.
Division II students will answer only questions 11-50. Numbers 1-10 on the answer sheet should remain blank for all Division II students.

Calculator: A hand-held calculator may be used. However, any memory must be cleared of data and programs. Calculators may not be shared.

Formulas and constants: The formulas and constants provided with these instructions may be used.

Time limit: 45 minutes.

Score: Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared, from the end of the test forward, until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner, and you should consider them carefully.

Good Luck!

Do Not Open This Booklet Until You Are Told to Begin.

You should use the following values in determining the answers on this test. If you use other values in calculating answers, you may obtain values which do not exactly match answer selections found on this test. You will then need to choose the answer on the test closest to your value.

acceleration due to gravity	g	=	10 m/s^2
gravitational constant	G	=	6.7 x 10^{-11} N m^2/kg^2
specific heat of water	c_w	=	1.0 kcal/kg K = 4.2 x 10^3 J/kg K
atomic mass unit	1 u	=	1.7 x 10^{-27} kg = 9.3 x 10^2 MeV/c^2
electron volt	1 eV	=	1.6 x 10^{-19} J
rest mass of electron	m_e	=	9.1 x 10^{-31} kg
rest mass of proton	m_p	=	1.7 x 10^{-27} kg
electronic charge	e	=	1.6 x 10^{-19} C
Coulomb's constant	k	=	9.0 x 10^9 N m^2/C^2
permittivity constant	$Â_o$	=	8.9 x 10^{-12} C^2/N m^2
permeability constant	μ_0	=	4ð x 10^{-7} Ŧ m/A
speed of sound in air (20 C)	v_s	=	340 m/s
speed of light in vacuum	c	=	3.0 x 10^8 m/s
Planck's Constant	h	=	6.6 x 10^{-34} J s = 4.14 x 10^{-15} eV s

American Association of Physics Teachers

PHYSICSBOWL

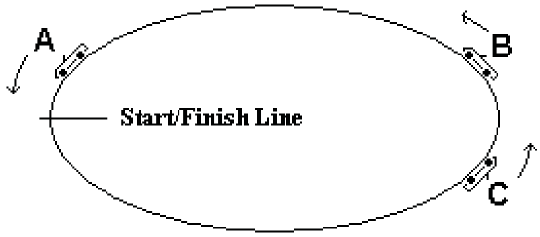
$x = v_0 t + \frac{1}{2} a t^2$	$v_f = v_0 + at$	$\bar{v} = \frac{\Delta x}{\Delta t}$
$v_f^2 = v_0^2 + 2a\Delta x$	$v_{0x} = v_0 \cos\theta$	$v_{0y} = v_0 \sin\theta$
$a_c = \frac{v^2}{r}$	$\sum F = ma$	$F_g = mg$
$F_g = G\frac{m_1 m_2}{r^2}$	$p = mv$	$W = Fs\cos\theta = F_{\parallel}s = Fs_{\parallel}$
$E_k = \frac{1}{2} mv^2$	$E_p = mgh$	$E_p = \frac{1}{2} kx^2$
$P = \frac{W}{\Delta t} = Fv\cos\theta = F_{\parallel}v$	$\tau = RF\sin\theta = RF_{\perp} = R_{\perp}F$	$\sum \tau = I\alpha$
$n = \frac{c}{v}$	$v = f\lambda$	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$y = y_m \cos(kx - \omega t)$	$f = \frac{n}{2l}\sqrt{\frac{T}{\rho}}$	$f' = f\left(\frac{v}{v \pm v_s}\right)$
$n\lambda = d\frac{x_n}{L} = d\sin\theta_n$	$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$	$m = -\frac{d_i}{d_o}$
$Q = mc\Delta T$	$Q = mL$	$\Delta U = Q - W$
$pV = nRT$	$W = p\Delta V$	$F_e = k\frac{q_1 q_2}{r^2}$
$E = \frac{F}{q}$	$V = \frac{W}{q}$	$V = k\frac{q}{r}$
$V = Ed$	$Q = CV$	$V = RI$
$P = VI$	$F = qvB\sin\theta = qvB_{\perp}$	$F = ILB\sin\theta = ILB_{\perp}$
$B = \frac{\mu_0 I}{2\pi r}$	$B = \mu_0 nI$	$emf = BLv$
$E = mc^2$	$E = hf$	$p = \frac{h}{\lambda}$

Nuclear notation: ${}^{A}_{Z}X$ where A is the atomic mass number and Z is the nuclear charge.

ATTENTION: All Division I students, START HERE.
All Division II students, skip the first ten questions, begin on question 11.

THE NEXT THREE QUESTIONS REFER TO THE FOLLOWING SCENARIO

The diagram below is a snapshot of three cars all moving counterclockwise during a one lap race on an elliptical track.



1. Which car has had the lowest average speed during the race so far?
   A) car A
   B) car B
   C) car C
   D) all three cars have had the same average speed
   E) cannot be determined with information provided

2. Which car at the moment of the snapshot **MUST** have a net force acting on it?
   A) car A
   B) car B
   C) car C
   D) all three cars have net forces acting on them
   E) cannot be determined with information provided

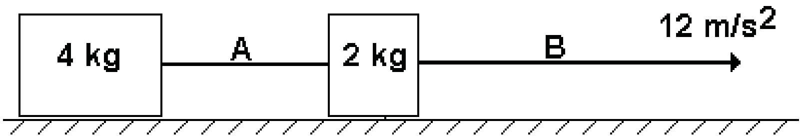
3. Which car can finish the race without changing its present momentum?
   A) car A
   B) car B
   C) car C
   D) none of the three cars can finish the race with its present momentum
   E) cannot be determined with information provided

4. When an object falls freely in a vacuum near the surface of the earth
   A) the velocity can not exceed 10 m/s^2
   B) the terminal velocity will be greater than when dropped in air
   C) the velocity will increase but the acceleration will be zero
   D) the acceleration will constantly increase
   E) the acceleration will remain constant

5. Two arrows are launched at the same time with the same speed. Arrow A at an angle greater than 45 degrees, and arrow B at an angle less than 45 degrees. Both land at the same spot on the ground. Which arrow arrives first?
   A) arrow A arrives first.
   B) arrow B arrives first.
   C) they both arrive together.
   D) it depends on the elevation where the arrows are launched.
   E) it depends on the elevation where the arrows land.

THE NEXT THREE QUESTIONS REFER TO THE FOLLOWING SCENARIO

A 2 kg mass and a 4 kg mass on a horizontal frictionless surface are connected by a massless string A. They are pulled horizontally across the surface by a second string B with a constant acceleration of 12 m/s^2.



6. What is the magnitude of the force of string B on the 2 kg mass?
   A) 72 N B) 48 N C) 24 N D) 6 N E) 3 N

7. What is the magnitude of the force of string A on the 4 kg mass?
   A) 72 N B) 48 N C) 24 N D) 6 N E) 3 N

8. What is the magnitude of the net force on the 2 kg mass?
   A) 72 N B) 48 N C) 24 N D) 6 N E) 3 N

9. How much current flows through a 4 ohm resistor that is dissipating 36 watts of power?
   A) 2.25 amps B) 3.0 amps C) 4.24 amps D) 9.0 amps E) 144 amps

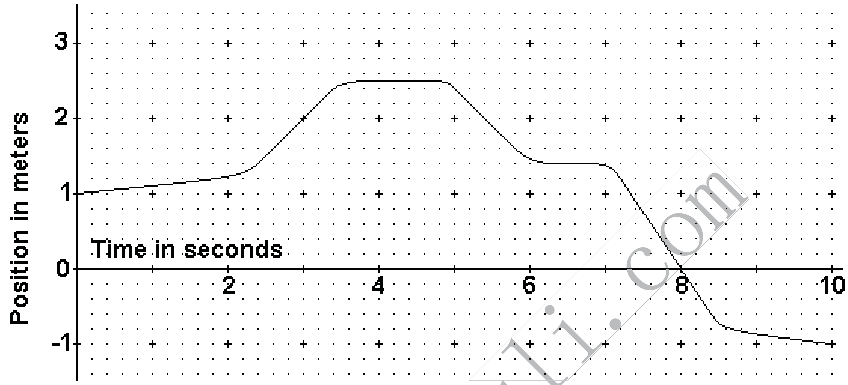
10. A ball is thrown into the air at an angle θ as measured from the horizontal with a velocity v. The horizontal velocity of the ball will be directly proportional to which of the following
    A) the angle θ
    B) the sine of the angle θ
    C) the cosine of the angle θ
    D) the tangent of the angle θ
    E) the value of the gravitational acceleration

<u>ATTENTION</u>: All Division I students, turn page and continue through question 40.

ATTENTION: All Division I students, continue through question 40.
All Division II students, START HERE. Numbers 1-10 on you answer sheet should remain blank. Your first answer should be number 11.

THE NEXT THREE QUESTIONS REFER TO THE FOLLOWING SCENARIO

The accompanying graph describes the motion of a marble on a table top for 10 seconds.



11. For which time interval(s) did the marble have a negative velocity?
   A) from t = 8.0 s to t = 10.0 s only
   B) from t = 6.9 s to t = 10.0 s only
   C) from t = 4.8 s to t = 10.0 s only
   D) from t = 4.8 s to t = 6.2 s and from t = 6.9 s to t = 10.0 s only
   E) from t = 3.2 s to t = 3.6 s, from t = 4.8 s to t = 5 s, and from t = 6.8 s to t = 7.2 s only

12. For which time interval(s) did the marble have a positive acceleration?
   A) from t = 0.0 s to t = 8.0 s only
   B) from t = 0.0 s to t = 3.6 only
   C) from t = 3.8 s to t = 4.8 s and t = 6.2 s to t = 6.8 s only
   D) from t = 2.0 s to t = 2.5 s, from t = 5.8 s to t = 6.2 s, and from t = 8.4 s to t = 8.8 s only
   E) from t = 3.3 s to t = 3.7 s, from t = 4.8 s to t = 5.0 s, and from t = 6.8 s to t = 7.2 s only

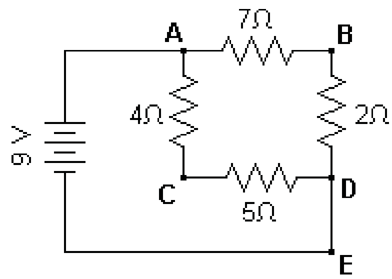
13. What is the marbles average acceleration between t = 3.3 s and t = 3.8 s
   A) -2.0 m/s^2
   B) 0.0 m/s^2
   C) 0.8 m/s^2
   D) 2.0 m/s^2
   E) 3.0 m/s^2

14. A fan blows the air and gives it kinetic energy. An hour after the fan has been turned off, what has happened to the kinetic energy of the air?
   A) it disappears
   B) it turns into potential energy
   C) it turns into thermal energy
   D) it turns into sound energy
   E) it turns into electrical energy

15. A jeweler can distinguish between a diamond and a piece of glass by observing the critical angle of the light in each material. Glass with an index of refraction of 1.52 has a critical angle of 41.1^o while a diamond with an index of refraction of 2.42 would have a critical angle of:
   A) 65.4^o B) 38.9^o C) 25.8^o D) 24.4^o E) 16.2^o

THE NEXT TWO QUESTIONS REFER TO THE FOLLOWING SCENARIO

A 9-volt battery is connected to four resistors to form a simple circuit as shown to the right.



16. How would the current through the 2 ohm resistor compare to the current through the 4 ohm resistor?

A) one-forth as large
B) one-half as large
C) four times as large
D) twice as large
E) equally as large

17. What would be the potential at point B with respect to point C in the above circuit?

A) +7 V B) +3 V C) 0 V D) -3 V E) -7 V

18. Two identical electrical point charges *Q*, separated by a distance *d* produce an electrical force of *F* on one another. If the distance is decreased to a distance of 0.40*d*, what is the strength of the resulting force?

A) 16*F* B) 6.3*F* C) 2.5*F* D) 0.40*F* E) 0.16*F*

19. A heavy (2.0 kg) point-like object rests 2.0m from the center of a rough turntable as the turntable rotates. The period of the turntable's rotation is 5.0 seconds. The coefficient of kinetic friction between the object and turntable is 0.50, while the coefficient of static friction is 0.80. What is the magnitude of the force of friction acting on the object?

A) 19.6 N B) 16.0 N C) 9.8 N D) 6.3 N E) 0 N

20. A car accelerates uniformly from rest for a time of 2.00s through a distance of 4.00 m. What was the acceleration of the car?

A) 0.50 m/s^2 B) 0.71 m/s^2 C) 1.00 m/s^2 D) 1.41 m/s^2 E) 2.00 m/s^2

21. According to the kinetic theory of gases, when the absolute temperature of an ideal gas doubles, the average kinetic energy of the molecules of the gas

A) quadruples
B) doubles
C) stays the same
D) is cut in half
E) is quartered

22. An object placed in front of a converging mirror creates a real image. The distance between the object and the mirror is then doubled, resulting in an image ⅓ as large as before. Where was the object originally?

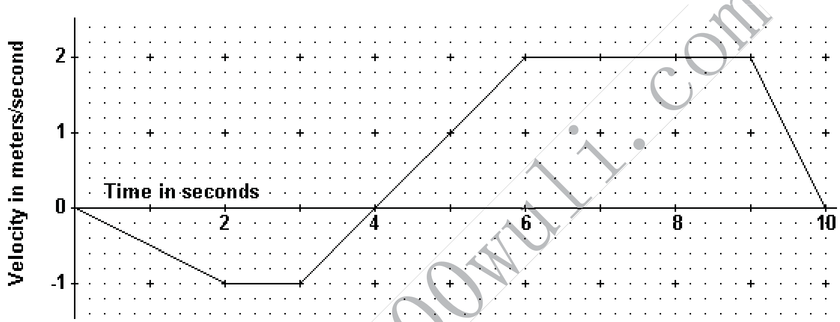
A) at the focal point of the mirror
B) halfway between the focal point and radius of curvature of the mirror
C) at the radius of curvature of the mirror
D) at three times the focal length of the mirror
E) at three times the radius of curvature of the mirror.

23. A cylindrical resistor has length L and radius r. This piece of material is then drawn so that it is a cylinder with new length $2L$. What happens to the resistance of this material because of this process?

A) the resistance is quartered.
B) the resistance is halved.
C) the resistance is unchanged.
D) the resistance is doubled.
E) the resistance is quadrupled.

THE NEXT THREE QUESTIONS REFER TO THE FOLLOWING SCENARIO

The accompanying graph describes the motion of a toy car across the floor for 10 seconds.



24. What is the acceleration of the toy car at $t = 4$ s?

A) $-1\ m/s^2$ B) $0\ m/s^2$ C) $1\ m/s^2$ D) $2\ m/s^2$ E) $4\ m/s^2$

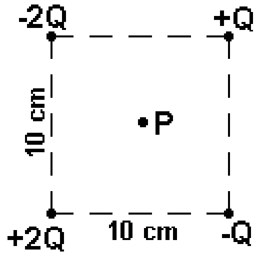
25. What was the total displacement of the toy car for the entire 10 second interval shown?

A) 0 meters B) 6.5 meters C) 9 meters D) 10 meters E) 11.5 meters

26. At what times or time intervals must the net force on the toy car be zero?

A) at $t = 4$ s only
B) at $t = 0$ s, at $t = 4$ s and at $t = 10$ s only
C) from $t = 2$ s to $t = 3$ s and from $t = 6$ s to $t = 9$ s only
D) from $t = 0$ s to $t = 2$ s, from $t = 3$ s to $t = 6$ s and from $t = 9$ s to $t = 10$ s only
E) the entire time from $t = 0$ s to $t = 10$ s

27. Four electrical charges are arranged on the corners of a 10 cm square as shown. What would be the direction of the resulting electric field at the center point P?



A) → D) ↑
B) ← E) ↓
C) ↗

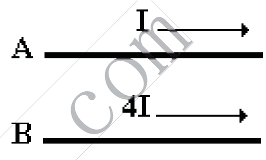
28. When gas escapes from a pressurized cylinder, the stream of gas feels cool. This is because

A) work is being done at the expense of thermal energy
B) of the convection inside the cylinder
C) pressurized cylinders are good thermal insulators
D) the gas inside the cylinder is actually frozen
E) the moisture in the air condenses and cools

29. An object is thrown upwards with a velocity of 30 m/s near the surface of the earth. After two seconds what would be the direction of the displacement, velocity and acceleration?

	displacement	velocity	acceleration
A)	up	up	up
B)	up	up	down
C)	up	down	down
D)	up	down	up
E)	down	down	down

30. Two parallel wires are carrying different electric currents in the same direction as shown in the diagram. How does the magnitude of the force on A from B compare to the force on B from A?



A) $F_{\text{on A from B}} = 4\ F_{\text{on B from A}}$
B) $F_{\text{on A from B}} = \frac{1}{4}\ F_{\text{on B from A}}$
C) $F_{\text{on A from B}} = 2\ F_{\text{on B from A}}$
D) $F_{\text{on A from B}} = \frac{1}{2}\ F_{\text{on B from A}}$
E) $F_{\text{on A from B}} = F_{\text{on B from A}}$

31. If a white object is viewed through a particular thin metallic foil, the object will appear green. However, if the same metallic foil is placed on a sheet of white paper and illuminated with white light, the metal will have a reddish color. This phenomena is best explained if we assume that the metal foil

A) reflects green and red light
B) transmits green and red light
C) transmits green light and absorbs the other colors
D) absorbs red light and transmits the other colors
E) reflects red light and transmits the other colors

THE NEXT TWO QUESTIONS REFER TO THE FOLLOWING SCENARIO

A figure skater has a moment of inertia of 5.0 $kg{\cdot}m^2$ with her arms outstretched. If she begins a spin at 2.0 rad/s with her arms outstretched and then brings her arms in tight to her body, her rate of spin increases to 8.0 rad/s in 3 seconds. Friction and wind resistance can be considered negligible.

32. What is the change in the skater's angular momentum as she brings her arms in tight to her body?

A) 10 $kg{\cdot}m^2/s$
B) 30 $kg{\cdot}m^2/s$
C) 40 $kg{\cdot}m^2/s$
D) 120 $kg{\cdot}m^2/s$
E) her angular momentum does not change

33. What is the skater's angular acceleration as her arms are moved in during the three second interval?

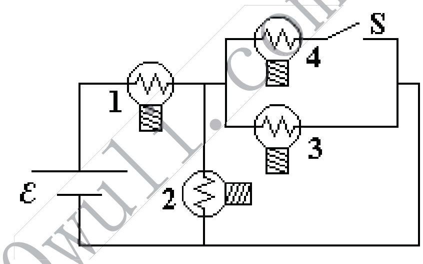
A) 0.67 rad/sec^2
B) 1.7 rad/sec^2
C) 2.0 rad/sec^2
D) 2.7 rad/sec^2
E) 3.3 rad/sec^2

34. A positively charged particle of mass M is at rest on a table. A non- zero electric field E is directed into the plane of the table. A non-zero magnetic field B is directed out of the plane of the table. What is true about the magnitude of the electric force on the particle F_E compared to the magnetic force on the particle F_B?

A) $F_E > F_B$
B) $F_E < F_B$
C) $F_E = F_B$
D) It cannot be determined without knowing the exact value of the charge of the particle
E) The relative sizes of the electric and magnetic fields are needed to answer this question

35. A circuit is connected as shown. All light bulbs are identical. When the switch in the circuit is closed illuminating bulb #4, which other bulb(s) also become brighter?

A) Bulb #1 only
B) Bulb #2 only
C) Bulbs #2 and #3 only
D) Bulbs #1, #2, and #3
E) None of the bulbs.



36. An ideal fluid flows through a long horizontal circular pipe. In one region of the pipe, it has radius *R*. The pipe then widens to radius 2*R*. What is the ratio of the fluid's speed in the region of radius R to the speed of the fluid in region with radius 2*R*?

A) ¼ B) ½ C) 1 D) 2 E) 4

THE NEXT TWO QUESTIONS REFER TO THE FOLLOWING SCENARIO

An object on a spring undergoes Simple Harmonic Motion. Its motion can be described by the following equation $y = (0.3\text{ m}) \sin(10\pi t + 4)$ where m is in meters and t is in seconds.

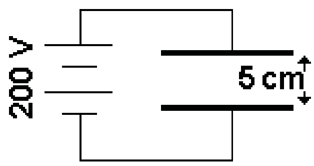
37. What is the amplitude of the vibrating mass on the spring?

A) 0.2 m B) 0.3 m C) 4 m D) 3π m E) 10π m

38. What is the period of vibration of the mass on the spring?

A) 0.2 s B) 0.3 s C) 4 s D) 3π s E) 10π s

39. A proton is released between the two parallel plates of the fully charged capacitor shown to the right. What would be the resulting acceleration of the proton?



A) 1.0×10^{-7} m/s^2
B) 9.6×10^{8} m/s^2
C) 3.8×10^{11} m/s^2
D) 7.3×10^{13} m/s^2
E) 6.3×10^{19} m/s^2

40. Monochromatic light with a wavelength of 6×10^{-7} meters falls upon a single slit. After passing through the slit, it forms a diffraction pattern on a screen 1m away. The distance between the center maximum and the first maximum away from the center is 3mm. What is the thickness of the slit?

A) 0.1 mm B) 0.2 mm C) 0.3 mm D) 0.4 mm E) 0.5 mm

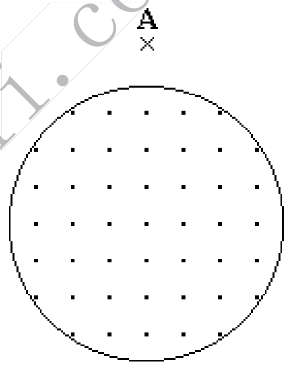
ATTENTION: All Division I students, STOP HERE. Your last answer should be number 40. Numbers 41-50 should remain blank for Division I students. All Division II students, continue to question 50.

41. Two uniform spheres of mass M have radii R and $2R$. Each sphere is rotating about a fixed axis through a diameter. The rotational kinetic energies of the spheres are identical. What is the ratio of the magnitude of the angular momenta of these spheres? That is, $\frac{L_{2R}}{L_R} =$

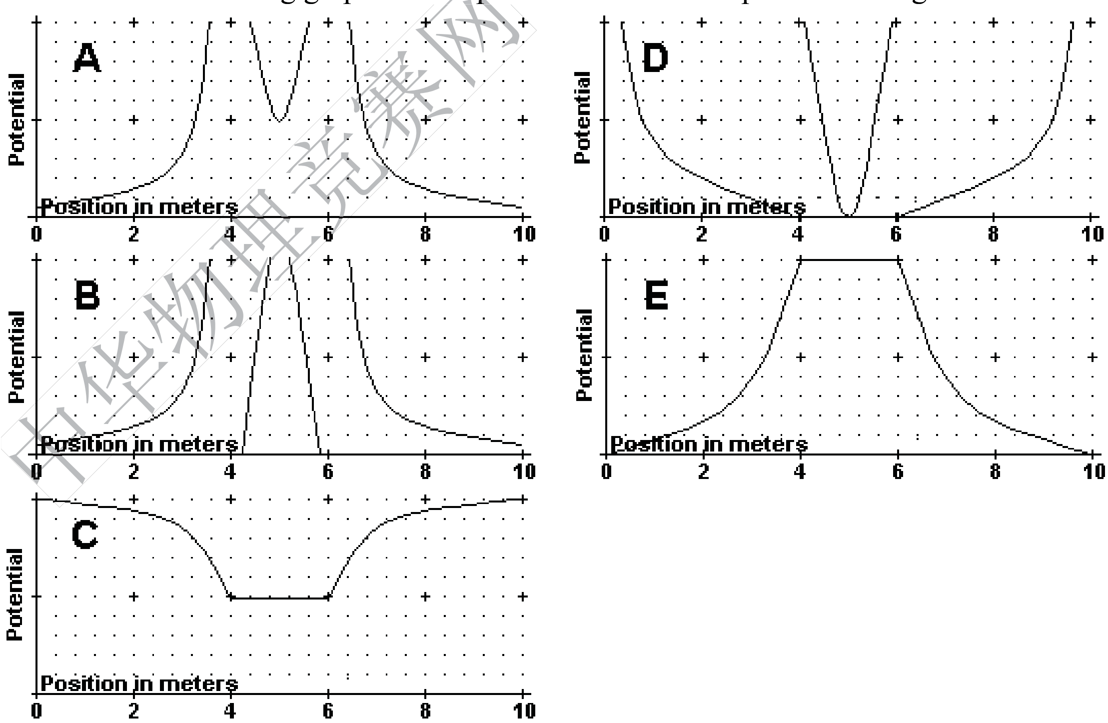
A) 4 B) $2\sqrt{2}$ C) 2 D) $\sqrt{2}$ E) 1

42. A uniform electric field is directed out of the plane of the page, contained within the circular region shown in the diagram. The magnitude of this field increases at a constant rate. What is the direction of the induced magnetic field at the point labeled A in the diagram?

A) ←
B) →
C) ↑
D) ↓
E) There is no induced magnetic field



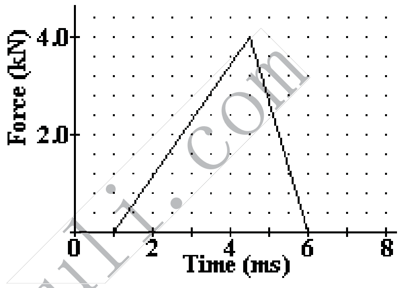
43. The diagram shows two identical positive charges located at points 4 and 6 on the positive x axis. Which of the following graphs best represent the electrical potential along the axis?



44. A circular parallel-plate capacitor is connected to a battery in a circuit. The capacitor is fully charged before the battery is disconnected from the circuit. A uniform material of dielectric constant κ is inserted between the plates of the capacitor, effectively filling the space between the plates. Let U_{old} be the energy stored by the capacitor before the dielectric was inserted, while U_{new} is the energy stored after the dielectric was inserted. The ratio of U_{new}/U_{old} is

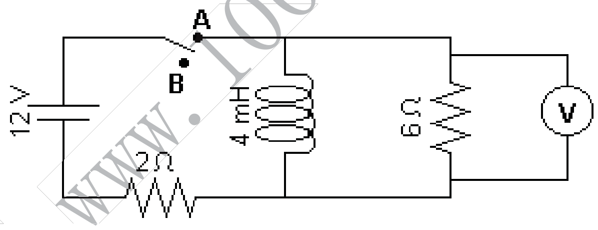
A) $\frac{1}{\kappa^2}$ B) $\frac{1}{\kappa}$ C) 1 D) κ E) κ^2

45. A point-like object of mass 2.0 kg moves along the x-axis with a velocity of +4.0 m/s. A net horizontal force acting along the x-axis is applied to the object with the force-time profile shown. What is the total work that was done by the force?



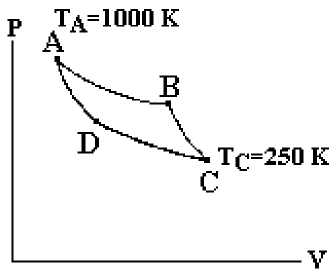
A) 10 J
B) 20 J
C) 25 J
D) 65 J
E) 81 J

46. In the circuit shown, the switch is moved to position A. After a very long time, the switch is flipped from position A to position B, thereby opening the circuit. At the instant immediately following the flip of the switch, the DC voltmeter shown registers a voltage of magnitude:



A) 0 v B) 4 v C) 12 v D) 36 v E) 48 v

47. A monatomic ideal gas is used as the working substance for the Carnot cycle shown in the figure. Processes A → B and C → D are isothermal, while processes B → C and D → A are adiabatic. During process A → B, there are 400 J of work done by the gas on the surroundings. How much heat is expelled by the gas during process C → D?



A) 1600 J
B) 800 J
C) 400 J
D) 200 J
E) 100 J

48. Two completely identical samples of the same ideal gas are in equal volume containers with the same pressure and temperature in containers labeled A and B.

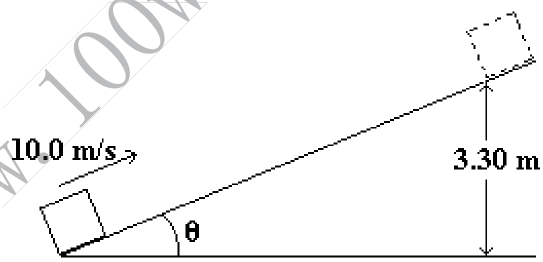
The gas in container A performs non-zero work W on the surroundings during an isobaric (constant pressure) process before the pressure is reduced isochorically (constant volume) to ½ its initial amount.

The gas in container B has its pressure reduced isochorically (constant volume) to ½ its initial value and then the gas performs non-zero work W on the surroundings during an isobaric (constant pressure) process.

After the processes are performed on the gases in containers A and B, which is at the higher temperature?

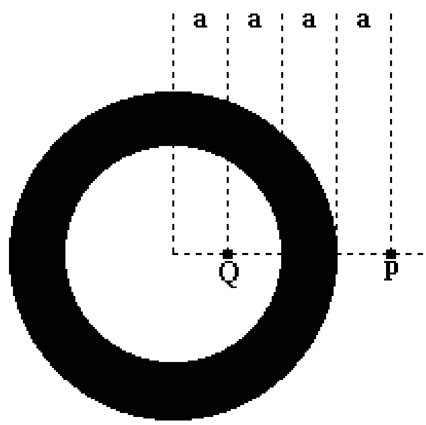
A) The gas in container A
B) The gas in container B
C) The gases have equal temperature
D) The value of the work W is necessary to answer this question.
E) The value of the work W is necessary, along with both the initial pressure and volume, in order to answer the question.

49. A sled slides up a uniform incline of unknown angle θ. The sled, which started at the bottom of the incline moving at 10.0 m/s, rises to a height of 3.30 m above its starting position and momentarily comes to rest. The sled then slides back down the hill. What is the sled's speed when it returns to its original position at the bottom of the hill?



A) 10.0 m/s
B) 8.1 m/s
C) 5.7 m/s
D) 4.0 m/s
E) It cannot be determined, as θ is required

50. A solid uncharged conducting sphere has radius $3a$ contains a hollowed spherical region of radius $2a$. A point charge $+Q$ is placed at a position a distance a from the common center of the spheres. What is the magnitude of the electric field at the position $r = 4a$ from the center of the spheres as marked in the figure by P?



A) 0
B) $\frac{3kQ}{16a^2}$
C) $\frac{kQ}{9a^2}$
D) $\frac{kQ}{16a^2}$
E) None of the previous

<u>ATTENTION</u>: All Division II students STOP. All Division II answers should appear in Numbers 11-50 on your answer sheet. Numbers 1-10 on you answer sheet should remain blank.

Question	Answer	Question	Answer
1	C	26	C
2	D	27	D
3	D	28	A
4	E	29	B
5	B	30	E
6	A	31	E
7	B	32	E
8	C	33	C
9	B	34	A
10	C	35	A
11	D	36	E
12	D	37	B
13	A	38	A
14	C	39	C
15	D	40	C
16	E	41	C
17	D	42	A
18	B	43	A
19	D	44	B
20	E	45	D
21	B	46	D
22	C	47	E
23	E	48	B
24	C	49	C
25	B	50	D