PHYSICS BOWL - APRIL 24, 1996

40 QUESTIONS–45 MINUTES

This contest is sponsored by the **American Association of Physics Teachers** (AAPT) and **Metrologic Instruments** 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 a second-year physics course. A school's score in a division is the sum of the four highest student scores in that division. To compete in a division, a school must have at least four students participating. A school may compete in either or both divisions, provided that the school has at least four eligible students participating in a division.

Winning schools will receive a diode laser from Metrologic Instruments. T-shirts will be given to members of the winning and second-place teams in each region. All participating students will be recognized with a certificate from AAPT and Metrologic Instruments.

INSTRUCTIONS

Identification number: Turn to the last page of these instructions and form your ten-digit identification number.

Answer sheet: Enter your information and answers on the answer sheet provided. Be sure to use a #2 pencil, fill the area completely, and make no stray marks on the sheet. In the indicated spaces, write in and encode your name (last name first). In the block labeled "IDENTIFICATION NUMBER," write in and encode your ten-digit identification number from the last page of these instructions. In the block labeled "SPECIAL CODES," write in and encode the six-digit number provided by your teacher. You will use only the first 40 answer blocks on the answer sheet.

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). At the regional level, it is possible that schools will have tie scores for first place. In that event, the four top-scoring student entries will be rescored for these schools, **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 in a region, and you should consider them carefully.

Good Luck!

YOU MAY TURN TO THE NEXT PAGE

acceleration due to gravity	g	$= 10\ m/s^2$
gravitational constant	G	$= 6.7 \times 10^{-11}\ N{\cdot}m^2/kg^2$
specific heat of water	c_w	$= 1.0\ kcal/kg{\cdot}K = 4.2 \times 10^3\ J/kg{\cdot}K$
atomic mass unit	$1\ u$	$= 1.7 \times 10^{-27}\ kg = 931.5\ MeV/c^2$
electron volt	$1\ eV$	$= 1.6 \times 10^{-19}\ J$
mass of electron	m_e	$= 9.1 \times 10^{-31}\ kg$
mass of proton	m_p	$= 1.7 \times 10^{-27}\ kg$
electronic charge	e	$= 1.6 \times 10^{-19}\ C$
Coulomb's constant	k	$= 9.0 \times 10^9\ N{\cdot}m^2/C^2$
permittivity constant	ε_0	$= 8.9 \times 10^{-12}\ C^2/N{\cdot}m^2$
permeability constant	μ_0	$= 4\pi \times 10^{-7}\ T{\cdot}m/A$
speed of sound in air (20 ^oC)	v_s	$= 340\ m/s$
speed of light in vacuum	c	$= 3.0 \times 10^8\ m/s$
Planck's Constant	h	$= 6.6 \times 10^{-34}\ J{\cdot}s = 4.14 \times 10^{-15}\ eV{\cdot}s$

$\Delta x = v_0 t + \frac{1}{2} a t^2$

$v = v_0 + at$

$\bar{v} = \frac{\Delta x}{\Delta t}$

$v^2 = v_0^2 + 2a\Delta x$

$v_{0x} = v_0 \cos\theta$

$v_{0y} = v_0 \sin\theta$

$a_c = \frac{v^2}{r}$

$\sum \mathbf{F} = m\mathbf{a}$

$W = mg$

$F = G\frac{m_1 m_2}{r^2}$

$\mathbf{p} = m\mathbf{v}$

$W = Fs\cos\theta = F_{\parallel}s$

$KE = K = \frac{1}{2}mv^2$

$PE = U = mgh$

$PE = U = \frac{1}{2}kx^2$

$P = \frac{W}{\Delta t} = Fv\cos\theta = F_{\parallel}v$

$\tau = RF\sin\theta = RF_{\perp} = R_{\perp}F$

$\sum \boldsymbol{\tau} = I\boldsymbol{\alpha}$

$n = \frac{c}{v}$

$v = f\lambda$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n\lambda = d\frac{x}{L} = d\sin\theta_n$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$m = -\frac{d_i}{d_o}$

$Q = mc\Delta T$

$Q = mL$

$\Delta U = Q - W$

$pV = nRT$

$W = p\Delta V$

$F = k\frac{q_1 q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$V = \frac{W}{q}$

$V = k\frac{q}{r}$

$V = Ed$

$Q = CV$

$V = RI$

$P = VI$

$F = qvB\sin\theta = qvB_{\perp}$

$F = ILB\sin\theta = ILB_{\perp}$

$B = \frac{\mu_0 I}{2\pi r}$

$B = \mu_0 nI$

$emf = BLv$

$E = mc^2$

$E = hf$

$p = \frac{h}{\lambda}$

IDENTIFICATION NUMBER

Use the instructions below to form your ten-digit identification number

___ ___   ___   ___ ___ ___ ___ ___   _0_ _0_

Region   Div.   ZIP code

Region: If you attend a specialized science and math school or if your school chooses to compete for the extra prizes, enter “20” in the region boxes and proceed to the division instructions. If not, find your state, province, or other geographic region in the following list and enter its two digit code in the region boxes.

02 Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

03 New York, Maritime Provinces, Ontario, Quebec

04 New Jersey, Pennsylvania

05 Delaware, District of Columbia, Maryland, North Carolina, Virginia

06 Alabama, Florida, Georgia, South Carolina, Puerto Rico, Virgin Islands

07 Kentucky, Ohio, West Virginia

08 Indiana, Michigan

09 Illinois, Iowa

10 Minnesota, North Dakota, South Dakota, Wisconsin

11 Arkansas, Louisiana, Mississippi, Tennessee

12 Colorado, Kansas, Missouri, Nebraska, Oklahoma, Wyoming

13 Arizona, New Mexico, Texas, Utah

14 California, Hawaii, Nevada, American Samoa, Guam

15 Alaska, Idaho, Montana, Oregon, Washington, Alberta, British Columbia, Manitoba, Saskatchewan, and others

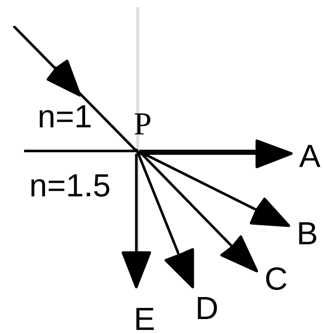
20 Specialized Science and Math Schools

Division: Enter a “1” for division I (first-year physics students) or a “2” for division II (second-year physics students) in the Div. box.

ZIP code: Enter your school’s five-digit ZIP code in the ZIP code boxes.

1. A light year is a unit of:
A. acceleration B. distance C. speed D. time E. velocity

2. A beam of light is directed toward a point P on a boundary as shown to the right. Which segment best represents the refracted ray?



A. PA
B. PB
C. PC
D. PD
E. PE

3. If the frequency of sound is doubled, the wavelength:
A. halves and the speed remains unchanged.
B. doubles and the speed remains unchanged.
C. is unchanged and the speed doubles.
D. is unchanged and the speed halves.
E. the wavelength halves and the speed halves.

4. When the velocity of a moving object is doubled, its _____ is also doubled.
A. acceleration B. kinetic energy C. mass D. momentum E. potential energy

5. When metal rod 1 is placed in contact with metal rod 2, thermal energy flows from 1 to 2. A possible explanation is that 1 has a higher ____ than 2.
A. heat B. heat capacity C. mass D. specific heat E. temperature

6. Impulse, $\vec{F}_{net}\Delta t$, is best related to:
A. momentum.
B. change in momentum.
C. kinetic energy.
D. change in kinetic energy.
E. none of these.

7. An amber rod is given a net negative charge and held at rest. Which of the following statements is true?

A. The amber rod is surrounded only by a magnetic field that circles the rod.

B. The amber rod is surrounded only by an electric field that is directed out from the rod.

C. The amber rod is surrounded only by an electric field that is directed into the rod.

D. The amber rod is surrounded by both a magnetic field that circles the rod and an electric field that is directed out from the rod.

E. The amber rod is surrounded by both a magnetic field that circles the rod and an electric field that is directed into the rod.

8. A ball is rolled off the edge of a horizontal table. The ball has an initial speed v_o and lands on the floor some distance from the base of the table. Which of the following statements concerning the fall of the ball is FALSE?

A. The time of flight depends on the height of the table.

B. One of the components of the final speed will be v_o.

C. The ball will accelerate.

D. The ball will have a longer flight time if v_o is increased.

E. The ball will fall because of the force due to gravity.

9. When a falling object reaches terminal velocity, it:

A. is no longer subject to the friction of air.

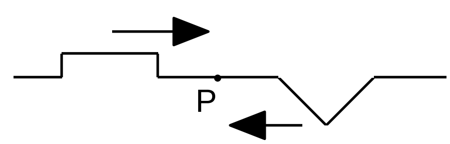
B. moves downward with constant velocity.

C. has an acceleration of approximately 10 m/s^2.

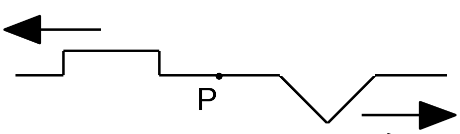
D. has no downward velocity.

E. has an upward acceleration.

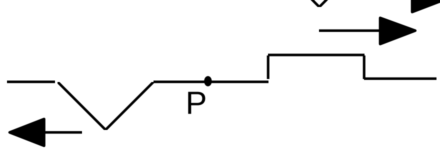
10 . Two wave pulses approach each other as seen in the figure to the right. The wave pulses overlap at point P. Which diagram best represents the appearance of the wave pulses as they leave point P?



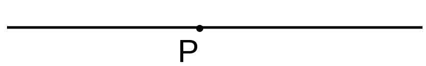
A.



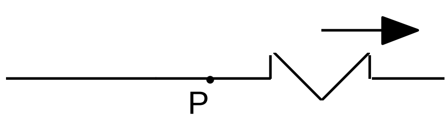
B.



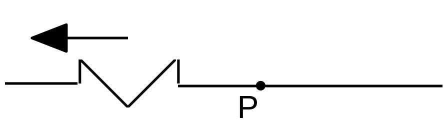
C.



D.



E.



11. A simple pendulum of mass m and length L has a period of oscillation T at angular amplitude $\theta = 5^o$ measured from its equilibrium position. If the amplitude is changed to 10^o and everything else remains constant, the new period of the pendulum would be approximately:

A. $2T$ B. $(\sqrt{2})T$ C. T D. $T/\sqrt{2}$ E. $T/2$

12. Two football players with mass 75 kg and 100 kg run directly toward each other with speeds 6.0 m/s and 8.0 m/s respectively. If they grab each other as they collide, the combined speed of the two players just after the collision would be:

A. 2.0 m/s B. 3.4 m/s C. 4.6 m/s D. 7.1 m/s E. 8.0 m/s

13. A potassium $^{40}_{19}K$ nucleus emits a β^- and becomes:

A. $^{36}_{17}Cl$ B. $^{44}_{21}Sc$ C. $^{40}_{18}Ar$ D. $^{40}_{19}K$ E. $^{40}_{20}Ca$

14. A 30-kg child who is running at 4.0 m/s jumps onto a stationary 10 kg skateboard. The speed of the child and the skateboard is approximately:

A. 3.0 m/s B. 4.0 m/s C. 5.0 m/s D. 6.0 m/s E. 7.0 m/s

15. A car whose mass is 1500 kg is accelerated uniformly from rest to a speed of 20 m/s in 10 s. The magnitude of the net force accelerating the car is:

A. 1000 N B. 2000 N C. 3000 N D. 20000 N E. 30000 N

16. When two resistors, having resistance R_1 and R_2, are connected in parallel, the equivalent resistance of the combination is 5 Ω. Which of the following statements about the resistances is correct?

A. Both R_1 and R_2 are greater than 5 Ω.

B. Both R_1 and R_2 are equal to 5 Ω.

C. Both R_1 and R_2 are less than 5 Ω.

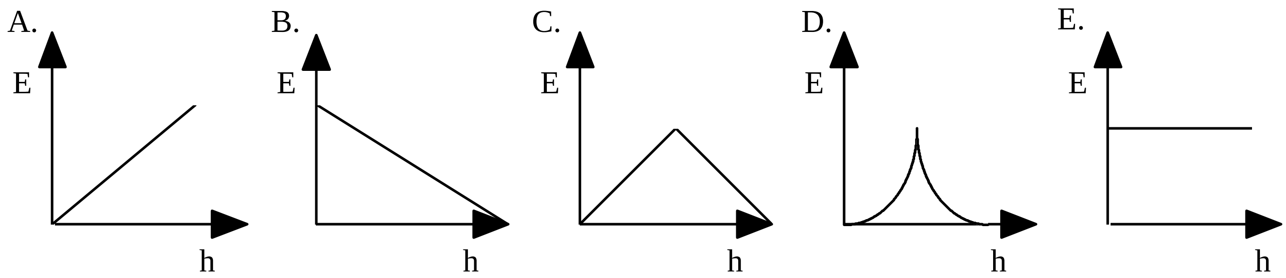
D. The sum of R_1 and R_2 is 5 Ω.

E. One of the resistances is greater than 5 Ω, one of the resistances is less than 5 Ω.

17. A ball which is dropped from the top of a building strikes the ground with a speed of 30 m/s. Assume air resistance can be ignored. The height of the building is approximately:

A. 15 m B. 30 m C. 45 m D. 75 m E. 90 m

18. A rubber ball is held motionless a height h_o above a hard floor and released. Assuming that the collision with the floor is elastic, which one of the following graphs best shows the relationship between the total energy E of the ball and its height h above the surface?



19. Light that has wavelength of 500 nm in air has wavelength 400 nm in a transparent material. What is the index of refraction of the material?

A. 0.64 B. 0.80 C. 1.00 D. 1.25 E. 1.56

20. A force of 10 N stretches a spring that has a spring constant of 20 N/m. The potential energy stored in the spring is:

A. 2.5 J B. 5.0 J C. 10 J D. 40 J E. 200 J

21. Two isolated conducting spheres (S_1 of radius 0.030 m and initial charge + 6.0 nC and S_2 of radius 0.040 m and initial charge + 2.0 nC) are connected by a conducting wire. Charge will flow in the wire until:

A. both spheres are equally charged.

B. the net charge is zero.

C. the force of repulsion between the two spheres becomes equal.

D. both spheres have the same surface charge density.

E. both spheres are at the same potential.

22. When an ideal gas is isothermally compressed:

A. thermal energy flows from the gas to the surroundings.

B. the temperature of the gas decreases.

C. no thermal energy enters or leaves the gas.

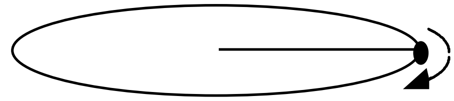
D. the temperature of the gas increases.

E. thermal energy flows from the surroundings to the gas.

23. A hypothetical planet has seven times the mass of Earth and twice the radius of Earth. The magnitude of the gravitational acceleration at the surface of this planet is most nearly:

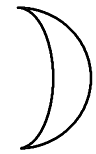
A. 2.9 m/s^2 B. 5.7 m/s^2 C. 17.5 m/s^2 D. 35 m/s^2 E. 122 m/s^2

24. A 2.0-kg ball is attached to a 0.80 m string and whirled in a horizontal circle at a constant speed of 6.0 m/s. See figure to the right. The work done on the ball during each revolution is:



A. 450 J B. 90 J C. 72 J D. 16 J E. zero

25. Which of the following is NOT possible for the images formed by the lens in the accompanying figure?

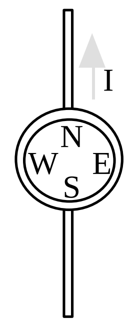


A. real and inverted
B. real and smaller in size
C. real and larger in size
D. virtual and erect
E. virtual and smaller in size

26. If the speed of sound in air is 340 m/s, the length of the organ pipe, open at both ends, that can resonate at the fundamental frequency of 136 Hz, would be:

A. 0.625 m B. 0.750 m C. 1.25 m D. 2.50 m E. 3.75 m

27. A long straight wire conductor is placed below a compass. When the conventional current in the conductor is from south to north and large, the N pole of the compass:



A. remains undeflected.
B. points to the south.
C. points to the west.
D. points to the east.
E. has its polarity reversed.

28. A photon with frequency *f* behaves as if it had a mass equal to:

A. hfc^2 B. $\frac{hf}{c^2}$ C. $\frac{c^2}{hf}$ D. $\frac{fc^2}{h}$ E. $\frac{h}{fc^2}$

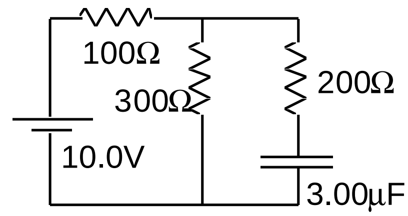
29. Two large parallel plates a distance *d* apart are charged by connecting them to a battery of potential difference *V*. The battery is disconnected, and the plates are slowly moved apart. As the distance between plates increases:

A. the charge on the plates decreases.
B. the electric field intensity between the plates increases.
C. the electric field intensity between the plates decreases.
D. the potential difference between the plates decreases.
E. the potential difference between the plates increases.

30. An 800-kg elevator accelerates downward at 2.0 m/s^2. The force exerted by the cable on the elevator is:

A. 1.6 kN down B. 1.6 kN up C. 6.4 kN up D. 8.0 kN down E. 9.6 kN down

31. See the accompanying figure. What is the current through the 300 Ω resistor when the capacitor is fully charged?



A. zero

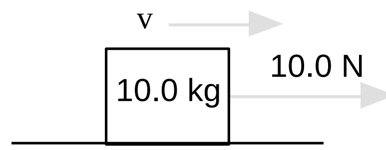
B. 0.020 A

C. 0.025 A

D. 0.033 A

E. 0.100 A

32. The 10.0 kg box shown in the figure to the right is sliding to the right along the floor. A horizontal force of 10.0 N is being applied to the right. The coefficient of kinetic friction between the box and the floor is 0.20. The box is moving with:



A. acceleration to the left.

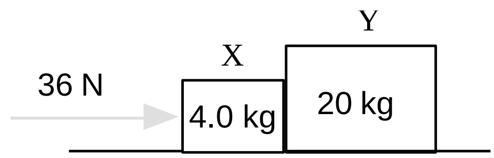
B. centripetal acceleration.

C. acceleration to the right.

D. constant speed and constant velocity.

E. constant speed but not constant velocity.

33. Two blocks X and Y are in contact on a horizontal frictionless surface. A 36 N constant force is applied to X as shown to the right. The force exerted by X on Y is:

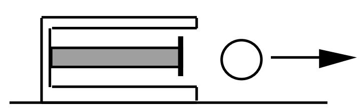


A. 1.5 N B. 6.0 N C. 29 N D. 30 N E. 36 N

34. A point charge $+q$ is placed midway between two point charges $+3q$ and $-q$ separated by a distance $2d$. If Coulomb's constant is k, the magnitude of the force on the charge $+q$ is:

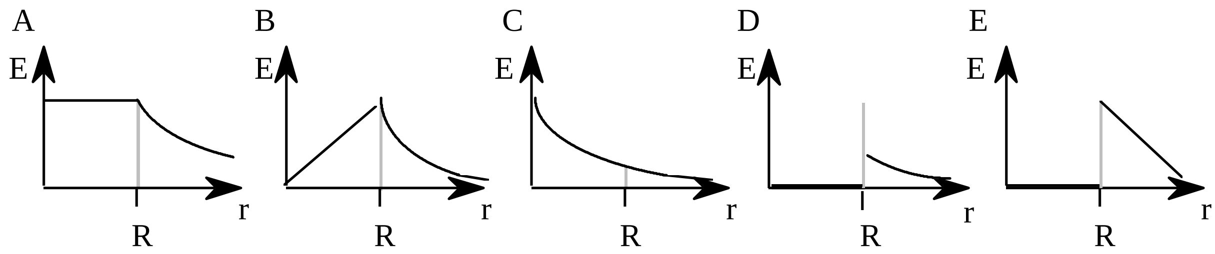
A. $2\frac{kq^2}{d^2}$ B. $4\frac{kq^2}{d^2}$ C. $6\frac{kq^2}{d^2}$ D. $8\frac{kq^2}{d^2}$ E. $10\frac{kq^2}{d^2}$

35. A projectile of mass m is fired horizontally from a spring gun that rests on a horizontal frictionless surface. See the accompanying figure. The mass of the gun is M. If the kinetic energy of the projectile after firing is E_k, the gun will recoil with a kinetic energy equal to:

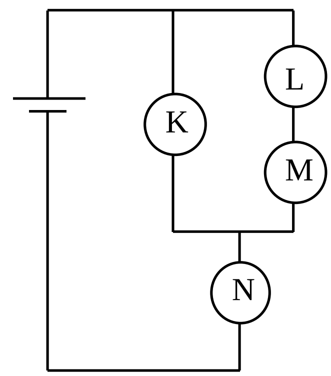


A. E_k B. $\frac{E_k m}{M}$ C. $\frac{E_k m}{M+m}$ D. $\frac{E_k(M+m)}{m}$ E. $E_k\sqrt{\frac{m}{M}}$

36. An isolated conducting sphere of radius R has positive charge + Q. Which graph best depicts the electric field as a function of r, the distance from the center of the sphere?



37. Four identical light bulbs K, L, M, and N are connected in the electrical circuit shown in the accompanying figure. Bulb M burns out. Which of the following statements is true?



A. All the light bulbs go out.

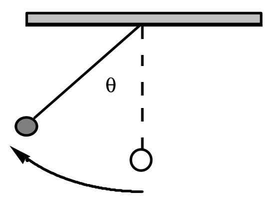
B. Only bulb M goes out.

C. Bulb N goes out but at least one other bulb remains lit.

D. The brightness of bulb N remains the same.

E. Bulb N becomes dimmer but does not go out.

38. A pendulum bob mass *m* on a cord length *L* is pulled sideways until the cord makes an angle θ with the vertical as shown in the figure to the right. The change in potential energy of the bob during the displacement is:



A. mgL (1 – cos θ)

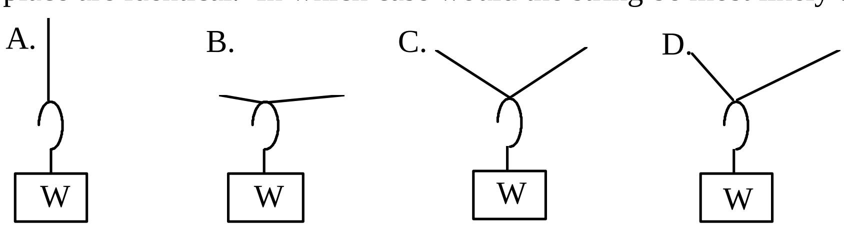
B. mgL (1 – sin θ)

C. mgL sin θ

D. mgL cos θ

E. 2mgL (1 – sin θ)

39. Assume the objects in the following diagrams have equal mass and the strings holding them in place are identical. In which case would the string be most likely to break?



E. All would be equally likely to break.

40. A proton of mass M and kinetic energy E_k passes undeflected through a region with electric and magnetic fields perpendicular to each other. The electric field has magnitude E. The magnitude of the magnetic field B is:

A. $\sqrt{\dfrac{ME^2}{E_k}}$ B. $\sqrt{\dfrac{ME}{2E_k}}$ C. $\sqrt{\dfrac{2ME^2}{E_k}}$ D. $\sqrt{\dfrac{ME^2}{2E_k}}$ E. $\sqrt{\dfrac{ME^2}{E_k^{\,2}}}$

1.	B	21.	E
2.	D	22.	A
3.	A	23.	C
4.	D	24.	E
5.	E	25.	E
6.	B	26.	C
7.	C	27.	D
8.	D	28.	B
9.	B	29.	E
10.	B	30.	C
11.	C	31.	C
12.	A	32.	A
13.	E	33.	D
14.	A	34.	B
15.	C	35.	B
16.	A	36.	D
17.	C	37.	E
18.	E	38.	A
19.	D	39.	B
20.	A	40.	D