PHYSICS BOWL - APRIL 27, 1995

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·m^2/kg^2
specific heat of water	c_w	$= 1.0$ kcal/kg·K $= 4.2 \times 10^3$ J/kg·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·m^2/C^2
permittivity constant	ε_0	$= 8.9 \times 10^{-12}$ C^2/N·m^2
permeability constant	μ_0	$= 4\pi \times 10^{-7}$ T·m/A
speed of sound in air (20 °C)	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·s $= 4.14 \times 10^{-15}$ eV·s

$\Delta x = v_0 t + \frac{1}{2} a t^2$	$v = v_0 + at$	$\bar{v} = \frac{\Delta x}{\Delta t}$
$v^2 = v_0^2 + 2a\Delta x$	$v_{0x} = v_0 \cos\theta$	$v_{0y} = v_0 \sin\theta$
$a_c = \frac{v^2}{r}$	$\sum \mathbf{F} = m\mathbf{a}$	$W = mg$
$F = G\frac{m_1 m_2}{r^2}$	$\mathbf{p} = m\mathbf{v}$	$W = Fs\cos\theta = F_{\parallel}s$
$KE = K = \frac{1}{2} m v^2$	$PE = U = mgh$	$PE = U = \frac{1}{2} k x^2$
$P = \frac{W}{\Delta t} = Fv\cos\theta = F_{\parallel}v$	$\tau = RF\sin\theta = RF_{\perp} = R_{\perp}F$	$\sum \boldsymbol{\tau} = I\boldsymbol{\alpha}$
$n = \frac{c}{v}$	$v = f\lambda$	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$n\lambda = d\frac{x}{L} = d\sin\theta_n$	$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$	$m = -\frac{d_i}{d_o}$
$Q = mc\Delta T$	$Q = mL$	$\Delta U = Q - W$
$pV = nRT$	$W = p\Delta V$	$F = k\frac{q_1 q_2}{r^2}$
$\mathbf{E} = \frac{\mathbf{F}}{q}$	$V = \frac{W}{q}$	$V = k\frac{q}{r}$
$V = Ed$	$Q = CV$	$V = RI$
$P = VI$	$F = qvB\sin\theta = qvB_{\perp}$	$F = ILB\sin\theta = ILB_{\perp}$
$B = \frac{\mu_0 I}{2\pi r}$	$B = \mu_0 nI$	$emf = BLv$
$E = mc^2$	$E = hf$	$p = \frac{h}{\lambda}$

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

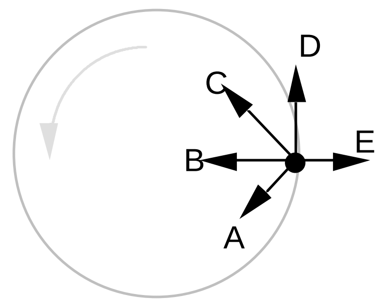
Division: Enter a "1" for division I (first-year physics students) or a "2" for division II (second-year physics students) in the Div. box.

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

1. Which is not associated with a sound wave?

A. amplitude B. period C. polarization D. velocity E. wavelength

2. An object shown in the accompanying figure moves in uniform circular motion. Which arrow best depicts the net force acting on the object at the instant shown?



A. A
B. B
C. C
D. D
E. E

3. A toy car moves 0.80 m in 1.0 s at the constant velocity. If it continues, how far will it travel in 3.0 s?

A. 2.4 m B. 3.6 m C. 4.8 m D. 7.2 m E. 14.4 m

4. A wave has a frequency of 50 Hz. The period of the wave is:

A. 0.010 s B. 0.20 s C. 7.0 s D. 20 s E. 0.020 s

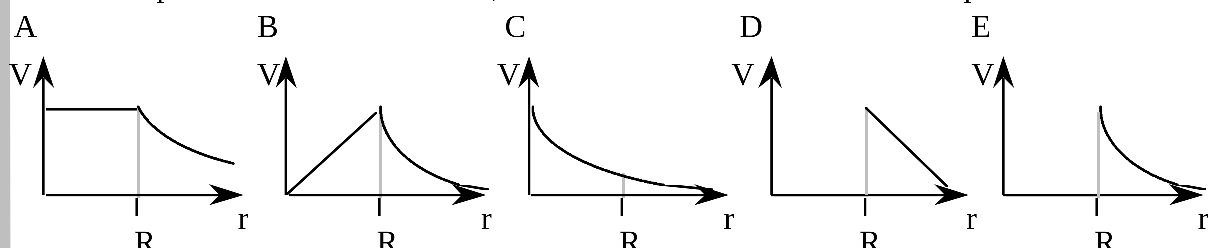
5. What temperature change on the Kelvin scale is equivalent to a 10 degree change on the Celsius scale?

A. 283 K B. 273 K C. 18 K D. 10 K E. 0

6. The “reaction” force does not cancel the “action” force because:

A. The action force is greater than the reaction force.
B. The action force is less than the reaction force.
C. They act on different bodies.
D. They are in the same direction.
E. The reaction exists only after the action force is removed.

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



8. How long must a 100 N net force act to produce a change in momentum of 200 kg·m/s?

A. 0.25 s B. 0.50 s C. 1.0 s D. 2.0 s E. 4.0 s

9. Two spherical bodies attract each other with a gravitational force of 4.0 N. What will be the force if the distance between them is doubled?

A. 1.0 N B. 2.0 N C. 4.0 N D. 8.0 N E. 16.0 N

10. A plane mirror produces an image that is:

A. real, inverted, and larger than the object.

B. real, upright, and the same size as the object.

C. real, upright, and smaller than the object.

D. virtual, inverted, and smaller than the object.

E. virtual, upright, and the same size as the object.

11. Which of the following types of electromagnetic radiation has the least energy per photon?

A. gamma B. infrared C. radio D. visible E. x-rays

12 The principle underlying fiber optics is:

A. diffraction B. dispersion C. interference D. polarization E. total internal reflection

13. A freely falling body is found to be moving downwards at 27 m/s at one instant. If it continues to fall, one second later the object would be moving with a downward velocity closest to:

A. 270 m/s/s B. 37 m/s C. 27 m/s D. 17 m/s E. 10 m/s

14. Which would be the most comfortable temperature for your bath water?

A. $0^{o}C$ B. 40 K C. $110^{o}C$ D. 310 K E. 560 K

15. If the unit for force is F, the unit for velocity V, and the unit for time T, then the unit for energy is:

A. FVT B. F/T C. FV/T D. F/T^2 E. FV^2/T^2

16. A charged particle with constant speed enters a uniform magnetic field whose direction is perpendicular to the particle's velocity. The particle will:

A. Speed up.

B. Slow down.

C. Experience no change in velocity.

D. Follow a parabolic arc.

E. Follow a circular arc.

17. Which is a vector quantity?

A. energy B. mass C. momentum D. power E. work

18. The period of a spring-mass system undergoing simple harmonic motion is *T*. If the amplitude of the spring-mass system's motion is doubled, the period will be:

A. (1/4) T B. (1/2) T C. T D. 2 T E. 4 T

19. A baseball is thrown horizontally from a cliff. At the same instant, a bowling ball is dropped from the same height. Assuming air resistance can be ignored, which of the following statements is correct?

A. The bowling ball hits the ground first.

B. Both the baseball and the bowling ball hit the ground at the same time.

C. The baseball has the greater acceleration just before it hits the ground.

D. The bowling ball has the greater velocity just before it hits the ground.

E. The bowling ball has the greater acceleration just before it hits the ground.

20. One kilogram of water at 85ºC is added to a one kilogram thermally isolated copper container initially at 15ºC. Which of the following statements is true once the system has reached thermal equilibrium?

A. The thermal energy gained by the copper is greater than the thermal energy lost by the water.

B. The thermal energy gained by the copper is less than the thermal energy lost by the water.

C. The temperature change of the copper is greater than the temperature change of the water.

D. The temperature change of the copper is the same as the temperature change of the water.

E. The temperature change of the copper is less than the temperature change of the water.

21 A diverging lens produces an image of a real object that is:

A. real, inverted, and larger than the object.

B. real, upright, and the same size as the object.

C. virtual, inverted, and smaller than the object.

D. virtual, upright, and larger than the object.

E. virtual, upright, and smaller than the object.

22. A radioactive element has a half-life of 4.0 hours. Approximately how much of the radioactive element will remain after 12.0 hours?

A. 1/16 B. 1/8 C. 1/6 D. 1/4 E. 1/3

23. A Brief History of Time is the title of a book written by:

A. Albert Einstein

B. Stephen Hawking

C. Hendrick Lorentz

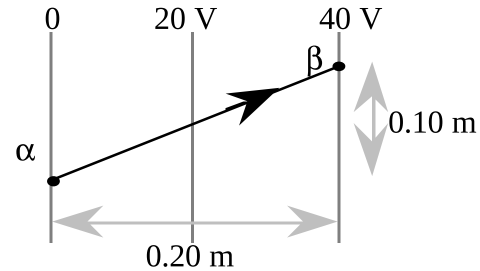
D. Isaac Newton

E. Andrew Timex

24. The theoretical (Carnot) efficiency of a heat engine operating between 600ºC and 100ºC is:

A. 16.7% B. 20.0% C. 42.7% D. 57.3% E. 83.3%

25. In the figure to the right, equipotential lines are drawn at 0, 20.0 V, and 40.0 V. The total work done in moving a point charge of + 3.00 μC from position α to position β is:



A. 4.00 μJ

B. 8.00 μJ

C. 12.0 μJ

D. 24.0 μJ

E. 120 μJ

26. Two positive point charges repel each other with force 0.36 N when their separation is 1.5 m. What force do they exert on each other when their separation is 1.0 m?

A. 0.81 N B. 0.54 N C. 0.36 N D. 0.24 N E. 0.16 N

27. A rocket near the surface of the earth is accelerating vertically upward at 10 m/s^2. The rocket releases an instrument package. Immediately after release the acceleration of the instrument package is:

A. 20 m/s^2 up B. 10 m/s^2 up C. 0 D. 10 m/s^2 down E. 20 m/s^2 down

28. A radon $^{220}_{86}\mathrm{Rn}$ nucleus emits an alpha particle and becomes a

A. $^{216}_{84}\mathrm{Po}$ B. $^{220}_{85}\mathrm{At}$ C. $^{220}_{86}\mathrm{Rn}$ D. $^{220}_{87}\mathrm{Fr}$ E. $^{224}_{88}\mathrm{Ra}$

29. Two objects – *P* and *Q* – have the same momentum. *Q* can have more kinetic energy than *P* if it:

A. has more mass than P.

B. has the same mass as P.

C. is moving faster than P.

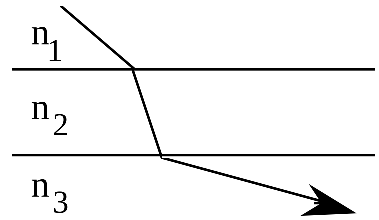
D. is moving at the same speed as P.

E. None of the above. Q can't have more kinetic energy than P.

30. A 0.20 m long copper rod has constant velocity 0.30 m/s traveling through a uniform magnetic field of 0.060 T. The rod, velocity, and magnetic field are all mutually perpendicular. What is the potential difference induced across the rod's length?

A. 0.0036 V B. 0.040 V C. 0.090 V D. 1.0 V E. 25 V

31. A beam of light passes from medium 1 to medium 2 to medium 3 as shown in the accompanying figure. What is true about the respective indices of refraction (n_1, n_2, and n_3)?



A. $n_1 > n_2 > n_3$

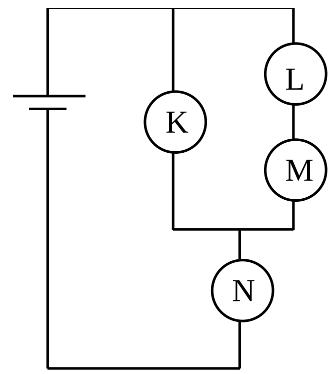
B. $n_1 > n_3 > n_2$

C. $n_2 > n_3 > n_1$

D. $n_2 > n_1 > n_3$

E. $n_3 > n_1 > n_2$

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



A. All the light bulbs go out.

B. Only bulb N goes out.

C. Bulb N becomes brighter.

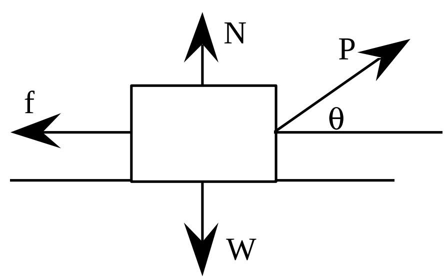
D. The brightness of bulb N remains the same.

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

33. An atomic particle of mass m moving at speed v is found to have wavelength λ. What is the wavelength of a second particle with speed $3v$ and the same mass?

A. $(1/9)\ \lambda$ B. $(1/3)\ \lambda$ C. λ D. $3\ \lambda$ E. $9\ \lambda$

34. A student pulls a wooden box along a rough horizontal floor at constant speed by means of a force P as shown to the right. Which of the following must be true?



A. P > f and N < W.

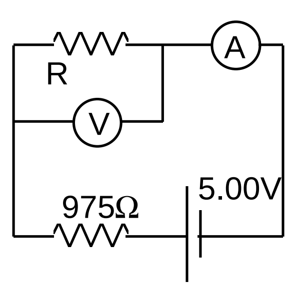
B. P > f and N = W.

C. P = f and N > W.

D. P = f and N = W.

E. P < f and N = W.

35. The voltmeter in the accompanying circuit diagram has internal resistance 10.0 kΩ and the ammeter has internal resistance 25.0 Ω. The ammeter reading is 1.00 mA. The voltmeter reading is most nearly:



A. 1.0 V

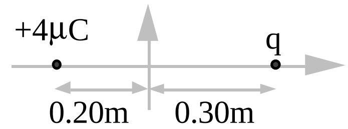
B. 2.0 V

C. 3.0 V

D. 4.0 V

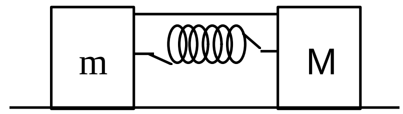
E. 5.0 V

36. Assume the electric potential is zero at infinity. A point charge of +4.0 μC is placed on the negative x-axis 0.20 m to the left of the origin, as shown in the accompanying figure. A second point charge q is placed on the positive x-axis 0.30 m to the right of the origin. The net electric potential at the origin is also zero. What is q's charge?



A. –9.0 μC B. –6.0 μC C. 0 D. +6.0 μC E. +9.0 μC

37. A spring is compressed between two objects with unequal masses, m and M, held together by a string as shown in the figure to the right. The objects are initially at rest on a horizontal frictionless surface. The string is then cut. Which statement is true?



A. Kinetic energy is the same as before the string was cut.

B. The total final kinetic energy is zero.

C. The two objects have equal kinetic energy.

D. The speed of one object is equal to the speed of the other.

E. The total final momentum of the two objects is zero.

38. A block with initial velocity 4.0 m/s slides 8.0 m across a rough horizontal floor before coming to rest. The coefficient of friction is:

A. 0.80 B. 0.40 C. 0.20 D. 0.10 E. 0.05

39. A car starts from rest and accelerates at 0.80 m/s^2 for 10 s. It then continues at constant velocity. Twenty seconds (20 s) after it began to move, the car has:

A. velocity 8.0 m/s and has traveled 40 m.

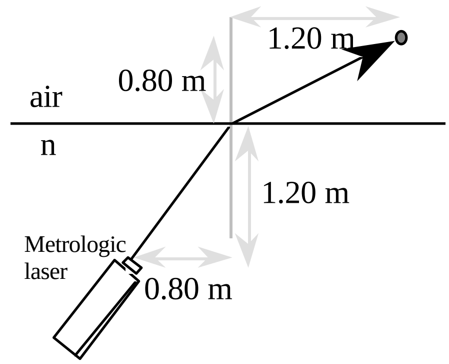
B. velocity 8.0 m/s and has traveled 80 m.

C. velocity 8.0 m/s and has traveled 120 m.

D. velocity 16 m/s and has traveled 160 m.

E. velocity 16 m/s and has traveled 320 m.

40. A Metrologic® laser is embedded in a material of index of refraction *n*. The laser beam emerges from the material and hits a target. See the accompanying figure for the position parameters of the laser and target. The value of *n* is:



A. 1.4

B. 1.5

C. 2.1

D. 3.5

E. 5.0

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