PHYSICS BOWL - APRIL 21, 1994

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 ^{o}C)	v_s	$= 340\ m/s$
speed of light in vacuum	c	$= 3.0 \times 10^8\ m/s$
Planck's Constant	h	$= 6.6 \times 10^{-34}\ J\cdot s = 4.14 \times 10^{-15}\ eV\cdot s$

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

$v = v_0 + at$

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

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

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

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

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

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

$W = mg$

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

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

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

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

$PE = U = mgh$

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

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

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

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

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

$v = f\lambda$

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

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

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

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

$Q = mc\Delta T$

$Q = mL$

$\Delta U = Q - W$

$pV = nRT$

$W = p\Delta V$

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

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

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

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

$V = Ed$

$Q = CV$

$V = RI$

$P = VI$

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

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

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

$B = \mu_0 nI$

$emf = BLv$

$E = mc^2$

$E = hf$

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

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.

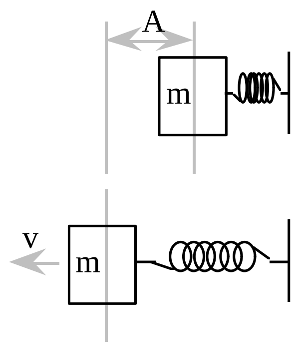
1. Starting from rest, object 1 falls freely for 4.0 seconds, and object 2 falls freely for 8.0 seconds. Compared to object 1, object 2 falls:
A. half as far.
B. twice as far.
C. three times as far.
D. four times as far.
E. sixteen times as far.

2. A car starts from rest and uniformly accelerates to a final speed of 20.0 m/s in a time of 15.0 s. How far does the car travel during this time?
A. 150 m B. 300 m C. 450 m D. 600 m E. 800 m

3. A ball is thrown off a high cliff with no horizontal velocity. It lands 6.0 s later with a velocity of 40 m/s. What was the initial velocity of the ball?
A. 100 m/s up B. 20 m/s up C. 0 D. 20 m/s down E. 100 m/s down

4. Newton's First Law is based in part on the work of:
A. Dalton B. Davy C. Galileo D. Joule E. Young

5. A mass *m;* attached to a horizontal massless spring with spring constant *k;* is set into simple harmonic motion. Its maximum displacement from its equilibrium position is *A*. What is the mass's speed as it passes through its equilibrium position?



A. 0
B. $A\sqrt{\frac{k}{m}}$
C. $A\sqrt{\frac{m}{k}}$
D. $\frac{1}{A}\sqrt{\frac{k}{m}}$
E. $\frac{1}{A}\sqrt{\frac{m}{k}}$

6. Which of the following statements about the speed of waves on a string are true?

I. The speed depends on the tension in the string.

II. The speed depends on the frequency.

III. The speed depends on the mass per unit length of the string.

A. II only B. I & II only C. I & III only D. II & III only E. I, II, & III

7. A positively charged conductor attracts a second object. Which of the following statements *could* be true?

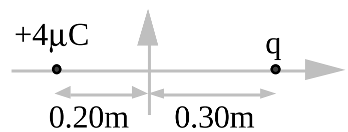
I. The second object is a conductor with negative net charge.

II. The second object is a conductor with zero net charge.

III. The second object is an insulator with zero net charge..

A. I only B. II only C. III only D. I & II only E. I, II & III

8. 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 field at the origin is zero. What is *q*?



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

9. An atomic mass unit is approximately equal to the mass of a(n):

A alpha particle B. electron C. photon D. positron E. proton

10. Which device can be used to detect nuclear radiation?

A. cyclotron B. photographic film C. betatron D. synchrotron E. Van de Graaff

11. The critical angle of a material is the angle of incidence for which the angle of refraction is:

A. 0º B. 30º C. 45º D. 90º E. 180º

12. Which of the following could *NOT* be used to indicate a temperature change? A change in:

A. color of a metal rod.

B. length of a liquid column.

C. pressure of a gas at constant volume.

D. electrical resistance.

E. mass of one mole of gas at constant pressure.

13. The purpose of the December 1993 space shuttle Endeavor mission was to repair the Hubble Space Telescope. The shuttle astronauts corrected the major problem of the telescope when they:

A. replaced an improperly ground lens.

B. installed corrective optics to compensate for the mis-shaped mirror.

C. freed a stuck camera shutter and installed a new roll of film.

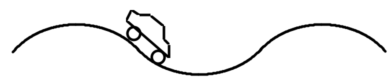
D. installed a new primary mirror.

E. repositioned the transmitting antenna to point towards Earth.

14. An arrow is aimed horizontally, directly at the center of a target 20 m away. The arrow hits 0.050 m below the center of the target. Neglecting air resistance, what was the initial speed of the arrow?

A. 20 m/s B. 40 m/s C. 100 m/s D. 200 m/s E. 400 m/s

15. A car is traveling on a road in hilly terrain, see figure to the right. Assume the car has speed v and the tops and bottoms of the hills have radius of curvature R. The driver of the car is most likely to feel weightless:



A. at the top of a hill when $v > \sqrt{gR}$.

B. at the bottom of a hill when $v > \sqrt{gR}$.

C. going down a hill when $v = \sqrt{gR}$

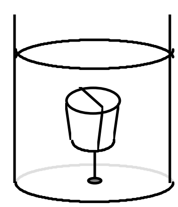
D. at the top of a hill when $v < \sqrt{gR}$.

E. at the bottom of a hill when $v < \sqrt{gR}$.

16. A car of mass m, traveling at speed v, stops in time t when maximum braking force is applied. Assuming the braking force is independent of mass, what time would be required to stop a car of mass $2m$ traveling at speed v?

A. $\frac{1}{2} t$ B. t C. $\sqrt{2}\ t$ D. $2\,t$ E. $4\,t$

17. A cork has weight mg and density 25% of water density. A string is tied around the cork and attached to the bottom of a water-filled container. As shown in the accompanying figure, the cork is totally immersed in the water. Expressed in terms of the cork weight mg, the tension in the string is:



A. 0 B. mg C. $2\ mg$ D. $3\ mg$ E. $4\ mg$

18. An object is located 0.20 meters from a converging lens which has a focal length of 0.15 meters. Relative to the object, the image formed by the lens will be:

A. real, erect, and smaller.

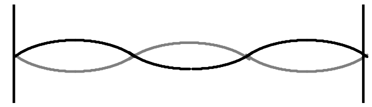
B. real, inverted, and smaller.

C. real, inverted, and larger.

D. virtual, erect, and larger.

E. virtual, inverted, and smaller.

19. A string is firmly attached at both ends. When a frequency of 60 Hz is applied, the string vibrates in the standing wave pattern shown to the right. Assume the tension in the string and its mass per unit length do not change. Which of the following frequencies could *NOT* also produce a standing wave pattern in the string?



A. 30 Hz B. 40 Hz C. 80 Hz D. 100 Hz E. 180 Hz

20. A magnet is dropped through a vertical copper pipe slightly larger than the magnet. Relative to the speed it would fall in air, the magnet in the pipe falls:

A. more slowly because it is attracted by the innate magnetic field of the pipe.

B. more slowly because the currents induced in the pipe produce an opposing magnetic field.

C. at the same rate.

D. more quickly because it is attracted by the innate magnetic field of the pipe.

E. more quickly because the currents induced in the pipe produce a opposing magnetic field.

21. Which of the following statements about solid conductors in electrostatics are true?

I. The electric field inside the conductor is always zero.

II. The electric potential inside the conductor is always zero.

III. Any net charge is on the surface.

A. I only B. II only C. III only D. I & III only E. II & III only

22. A radioactive oxygen ${}^{15}_{8}O$ nucleus emits a positron and becomes:

A. ${}^{14}_{7}N$ B. ${}^{15}_{7}N$ C. ${}^{15}_{8}O$ D. ${}^{14}_{9}F$ E. ${}^{15}_{9}F$

23. Albert Einstein won the Nobel Prize in Physics for his work on:

A. general relativity.

B. high temperature super conductors.

C. the photoelectric effect.

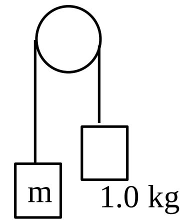
D. special relativity.

E. transistors.

24. A sample of radioactive material has an initial activity of 10,000 counts/minute. 30 minutes later, its activity is 2,500 counts/minute. The half-life of the material is:

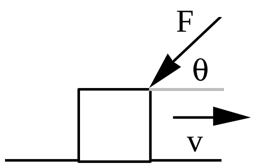
A. 7.5 minutes B. 10 minutes C. 15 minutes D. 20 minutes E. 22 minutes

25. One end of a massless rope is attached to a mass *m*; the other end is attached to a mass of 1.00 kg. The rope is hung over a massless frictionless pulley as shown in the accompanying figure. Mass *m* accelerates downward at 5.0 m/s^2. What is *m*?



A. 3.0 kg B. 2.0 kg C. 1.5 kg D. 1.0 kg E. 0.5 kg

26. As shown in the accompanying figure, a force *F* is exerted at an angle of θ. The block of weight *mg* is initially moving the right with speed *v*. The coefficient of friction between the rough floor and the block is μ. The frictional force acting on the block is:



A. μ*mg* to the left.

B. μ*mg* to the right.

C. μ*mg* – *F* sin θ to the left.

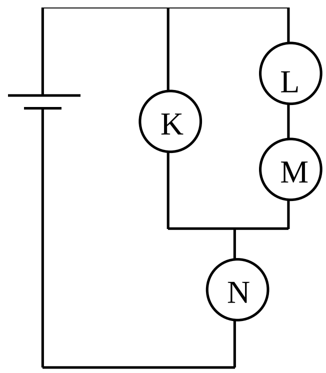
D. μ(*mg* – *F* cos θ) to the right.

E. μ(*mg* + *F* sin θ) to the left.

27. A mass *m* of helium gas is in a container of constant volume *V*. It is initially at pressure *p* and absolute (Kelvin) temperature *T*. Additional helium is added, bringing the total mass of helium gas to *3m*. After this addition, the temperature is found to be *2T*. What is the gas pressure?

A. $^2/_3\, p$ B. $^3/_2\, p$ C. 2 *p* D. 3 *p* E. 6 *p*

28. Four identical light bulbs K, L, M, and N are connected in the electrical circuit shown in the accompanying figure. In order of decreasing brightness (starting with the brightest), the bulbs are:



A. K = L > M > N

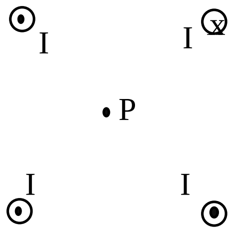
B. K = L = M > N

C. K > L = M > N

D. N > K > L = M

E. N > K = L = M

29. Four infinitely long wires are arranged as shown in the accompanying figure's end-on view. All four wires are perpendicular to the plane of the page and have the same magnitude of current *I*. The conventional current in the wire in the upper right-hand corner is directed into the plane of the page. The other conventional currents are out of the plane of the page. Point *P* is a distance *a* from all four wires. What is the total magnetic field at point *P*?



A. $\frac{\mu_0 I}{2\pi a}$ toward the upper left hand corner.

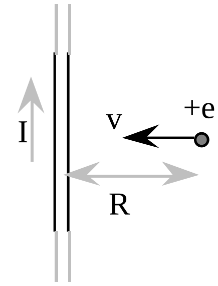
B. $\frac{\mu_0 I}{2\pi a}$ toward the lower left hand corner.

C. $2\frac{\mu_0 I}{2\pi a}$ toward the upper left hand corner.

D. $2\frac{\mu_0 I}{2\pi a}$ toward the lower left hand corner.

E. 0

30. The conventional current I in a long straight wire flows in the upward direction as shown in the figure to the right. (Electron flow is downward.) At the instant a proton of charge $+e$ is a distance R from the wire and heading directly toward it, the force on the proton is:



A. $\frac{\mu_o}{2\pi} I^2$ toward the wire.

B. $\frac{\mu_o}{2\pi} \frac{I^2 L}{R}$ upward (in the same direction as I).

C. $\frac{\mu_o}{2\pi} \frac{I^2 L}{R}$ downward (in the opposite direction to I).

D. $ev\frac{\mu_o}{2\pi} \frac{I}{R}$ upward (in the same direction as I).

E. $ev\frac{\mu_o}{2\pi} \frac{I}{R}$ downward (in the opposite direction to I).

31. Light of a single frequency falls on a photoelectric material but no electrons are emitted. Electrons may be emitted if the:

A. frequency of the light is decreased.
B. frequency of the light is increased.
C. intensity of the light is decreased.
D. intensity of the light is increased.
E. velocity of the light is increased.

32. In Young's double slit experiment, second and higher order bright bands can overlap. Which third order band would occur at the same location as a second order band of wavelength 660 nm?

A. 1320 nm B. 990 nm C. 495 nm D. 440 nm E. 330 nm

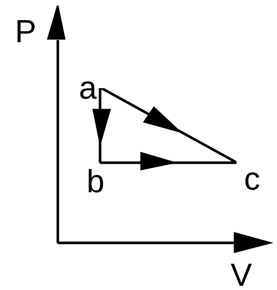
33. An air track car with mass m and velocity v to the right collides elastically with a second air track car with mass $2m$ and initial velocity zero. What is the velocity of the $2m$ car after the collision?

A. $\frac{2}{3}v$ to the right B. $\frac{1}{\sqrt{2}}v$ to the right C. $\frac{1}{2}v$ to the right D. v to the left E. $\frac{1}{3}v$ to the left

34. A hypothetical planet orbits a star with mass one-half the mass of our sun. The planet's orbital radius is the same as the Earth's. Approximately how many Earth years does it take for the planet to complete one orbit?

A. $\frac{1}{2}$ B. $\frac{1}{\sqrt{2}}$ C. 1 D. $\sqrt{2}$ E. 2

35. A gas can be taken from state *a* to *c* by two different reversible processes, *a*→*c* or *a*→*b*→*c*. During the direct process *a*→*c*, 20.0 J of work are done by the system and 30.0 J of heat are added to the system. During the process *a*→*b*→*c*, 25.0 J of heat are added to the system. How much work is done by the system during *a*→*b*→*c*?



A. 5.0 J

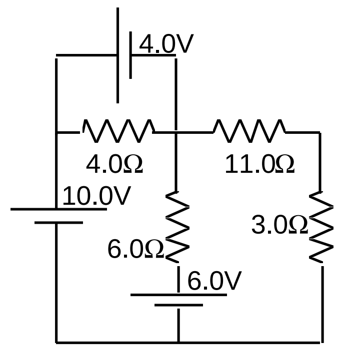
B. 10.0 J

C. 15.0 J

D. 20.0 J

E. 25.0 J

36. What is the current through the 6.0 Ω resistor shown in the accompanying circuit diagram? Assume all batteries have negligible resistance.



A. 0

B. 0.40 A

C. 0.50 A

D. 1.3 A

E. 1.5 A

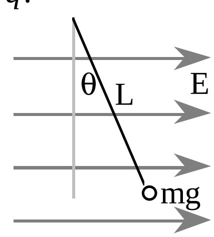
37. You are given three 1.0 Ω resistors. Which of the following equivalent resistances *CANNOT* be produced using all three resistors?

A. $^1/_3$ Ω B. $^2/_3$ Ω C. 1.0 Ω D. 1.5 Ω E. 3.0 Ω

38. A force F at an angle θ above the horizontal is used to pull a heavy suitcase of weight mg a distance d along a level floor at constant velocity. The coefficient of friction between the floor and the suitcase is μ. The work done by the frictional force is:

A. $-Fd\cos\theta$ B. $mgh - Fd\cos\theta$ C. $-\mu Fd\cos\theta$ D. $-\mu mgd$ E. $-\mu mgd\cos\theta$

39. A small object with charge q and weight mg is attached to one end of a string of length L. The other end is attached to a stationary support. The system is placed in a uniform horizontal electric field E, as shown in the accompanying figure. In the presence of the field, the string makes a constant angle θ with the vertical. What is the sign and magnitude of q?



A. positive with magnitude $\dfrac{mg}{E}$

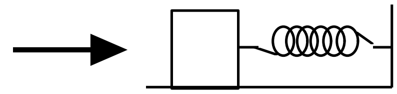
B. positive with magnitude $\dfrac{mg}{E}\tan\theta$

C. negative with magnitude $\dfrac{mg}{E}$

D. negative with magnitude $\dfrac{mg}{E}\tan\theta$

E. negative with magnitude $\dfrac{E}{mg}\tan\theta$

0. A block of mass M is initially at rest on a frictionless floor, as shown in the accompanying gure. The block, attached to a massless spring with spring constant k, is initially at its quilibrium position. An arrow with mass m and velocity v is shot into the block The arrow icks in the block. What is the maximum compression of the spring?



A. $x = v\sqrt{\dfrac{m}{k}}$

B. $x = v\sqrt{\dfrac{k}{m}}$

C. $x = v\sqrt{\dfrac{m+M}{k}}$

D. $x = \dfrac{(m+M)v}{\sqrt{mk}}$

E. $x = \dfrac{mv}{\sqrt{(m+M)k}}$

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