PHYSICS BOWL - APRIL 23, 1997

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 it has at least four eligible students participating in each 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. Five laser pointers will be given to each first place school in Regions 20 and 21. All participating students will be recognized with a certificate from AAPT and Metrologic Instruments.

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: Enter your information and answers on the answer sheet provided. Write your name in the indicated space. In the block labeled "WRITE I.D. NUMBER HERE," write in and encode the ten-digit identification number your teacher gives you. Be sure to use a #2 pencil, fill the area completely, and make no stray marks on the answer sheet. You will use only the first 40 answer blocks on the 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). If there are schools in a region that have tie scores for first place, the four top-scoring student entries will be retotaled 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!

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

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	ε_0	= 8.9 x 10^{-12} C^2/N·m^2
permeability constant	μ_0	= 4B x 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 x 10^8 m/s
Planck's Constant	h	= 6.6 x 10^{-34} J·s = 4.14 x 10^{-15} eV·s

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

$v_f = v_0 + at$

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

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

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

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

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

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

$F_g = mg$

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

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

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

$E_k = \frac{1}{2} mv^2$

$E_p = mgh$

$E_p = \frac{1}{2} kx^2$

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

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

$\sum \tau = I\alpha$

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

$v = f\lambda$

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

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

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

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

$Q = mc\Delta T$

$Q = mL$

$\Delta U = Q - W$

$pV = nRT$

$W = p\Delta V$

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

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

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

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

$V = Ed$

$Q = CV$

$V = RI$

$P = VI$

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

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

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

$B = \mu_0 nI$

$emf = BLv$

$E = mc^2$

$E = hf$

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

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

Quantities in bold type are vectors. Quantities in regular type are scalars or the magnitude of vectors.

IDENTIFICATION NUMBER

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

__ __ __ __ __ __ __ __ 0 0

Region Div. Mail code

Region: If you attend a specialized science and math school or if your school finished in first place last year, you must compete in one of the specialized regions, 20 or 21. If not, you may compete in these regions or your regular region. Five laser pointers will be given to each first place school in Regions 20 and 21. Use the following list to find your two digit region code.

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, North Carolina, Virginia
06	Florida, Georgia, South Carolina, Puerto Rico, Virgin Islands
07	Kentucky, Maryland, Ohio, West Virginia
08	Illinois, Indiana
09	Iowa, Michigan, Minnesota, Missouri, Wisconsin
10	Alabama, Arkansas, Louisiana, Mississippi, Tennessee
11	Idaho, Montana, Nebraska, North Dakota, South Dakota, Wyoming
12	Arizona, Colorado, Kansas, Nevada, New Mexico, Oklahoma, Texas, Utah
13	California
14	Alaska, American Samoa, Guam, Hawaii, Oregon, Washington, Alberta, British Columbia, Manitoba, Saskatchewan, and others
20	Specialized Science and Math Schools and last years first place schools with ZIP codes 49999 or less or located in provinces Ontario and eastward
21	Specialized Science and Math Schools and last years first place schools with ZIP codes 50000 or greater or located in provinces Manitoba and westward

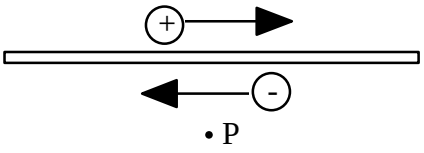
Division: Enter a "1" for division I (first-year physics students) or a "2" for division II (second-year physics students) in the Div. box.

Mail code: If your school's address has a five-digit ZIP code, enter it in the mail code boxes. If your school's address has a six character postal code, enter "00" followed by the *numbers* in your school's postal code. If your school's address has neither, enter "00000".

1. A force *F* directed at an angle of θ above the horizontal is used to pull a crate a distance *D* across a level floor. The work done by the force *F* is

A. *FD* B. *FD* cos θ C. *FD* sin θ D. *mg* sin θ E. *mgD* cos θ

2. An electric current flows through a horizontal wire from left to right as shown in the accompanying diagram. Which option best represents the direction of the magnetic field at point P?



A. into the page
B. out of the page
C. to the right of the page
D. toward the top of the page
E. toward the bottom of the page

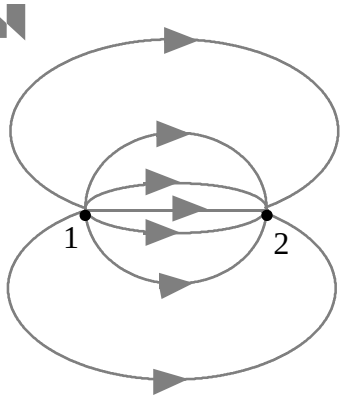
3. A student working on an energy conservation problem has obtained the answer $50\ J{\cdot}s^2/m^2$. The student has solved for

A. energy B. force C. mass D. velocity E. work

4. Which station broadcasts with 3.27 m radio waves?

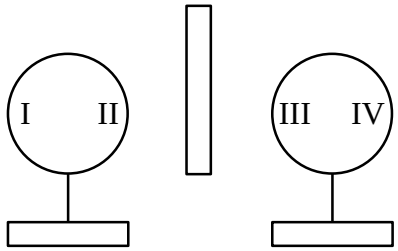
A. 91.7 MHz B. 92.5 MHz C. 98.5 MHz D. 102.5 MHz E. 106.3 MHz

5. Point charges 1 and 2 have equal magnitude. The diagram to the right shows the electric field lines surrounding them. Which of the following statements is true?



A. Charge 1 is positive, charge 2 is negative.
B. Charge 1 is negative, charge 2 is positive.
C. Both charges 1 and 2 are positive.
D. Both charges 1 and 2 are negative.
E. Both charges 1 and 2 have the same sign, but it is impossible to tell which.

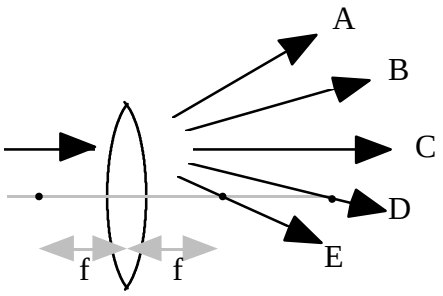
6. A charged rod is placed between two insulated conducting spheres as shown. The spheres have no net charge. Region II has the same polarity as Region



A. I only B. III only C. IV only

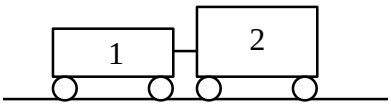
D. I & III only E. I & IV only

7. A narrow beam of monochromatic light enters a lens parallel to the optic axis, as shown in the accompanying diagram. Which arrow best represents the direction of the light after leaving the lens?



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

8. Cart 1 and cart 2 are held together as shown in the diagram to the right. Cart 2 is more massive than cart 1. As they are forced apart by the release of a compressed spring, which of the following quantities will have the same magnitude for both carts?



A. acceleration B. change of velocity C. force D. speed E. velocity

9. At a certain time, an object in free fall has velocity 4.0 m/s in the upward direction. What is the approximate velocity of the object one second later?

A. 14 m/s up B. 10 m/s up C. 4.0 m/s up D. 6.0 m/s down E. 10 m/s down

10. A compressed spring has 16 J of potential energy. What is the maximum speed it can impart to a 2.0-kg object ?

A. 2.8 m/s B. 4.0 m/s C. 5.6 m/s D. 8.0 m/s E. 16 m/s

11. What does the "?" represent in the nuclear reaction ${}_1^2\mathrm{H}+{}_1^2\mathrm{H}\rightarrow{}_2^3\mathrm{He}+?$.

A. an α B. a β C. a γ D. a neutron E. a proton

12. Two artificial satellites, 1 and 2, are put into circular orbit at the same altitude above Earth's surface. The mass of satellite 2 is twice the mass of satellite 1. If the period of satellite 1 is *T*, what is the period of satellite 2?

A. $T/4$ B. $T/2$ C. T D. $2T$ E. $4T$

13. A small sphere is moving in a vertical circle at constant speed. The magnitude of the net force on the sphere

A. at the bottom of the loop is greater than the net force at the top.
B. at the top of the loop is greater than the net force at the bottom.
C. increases as the sphere moves from the bottom to the top.
D. decreases as the sphere moves from the bottom to the top.
E. is the same at the top of the loop as it is at the bottom of the loop.

14. A 5000-kg freight car moving at 4.0 km/h collides and couples with an 8000-kg freight car which is initially at rest. The approximate common final speed of these two cars is

A. 1.0 km/h B. 1.3 km/h C. 1.5 km/h D. 2.5 km/h E. 4.0 km/h

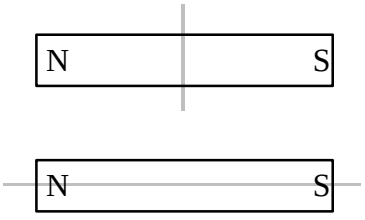
15. Which of the following is always true for an isothermal process of an ideal gas?

A. The internal energy does not change.
B. No heat flows into or out of the system.
C. The pressure does not change.
D. The volume does not change.
E. No work is done by or on the system.

16. How much work is required to move - 24 μC of charge 4.0 m parallel to a uniform 6.0 N/C electric field?

A. 1.0 μJ B. 16 μJ C. 36 μJ D. 62 μJ E. 576 μJ

17. Two bar magnets are to be cut in half along the dotted lines shown to the right. None of the pieces are rotated. After the cut:

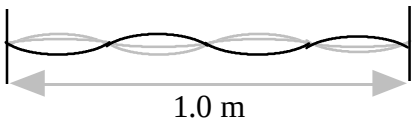


A. None of the halves will attract any other.
B. The two halves of each magnet will attract each other.
C. The two halves of each magnet will repel each other.
D. The two halves of the top magnet will repel, the two halves of the bottom magnet will attract.
E. The two halves of the top magnet will attract, the two halves of the bottom magnet will repel.

18. A motorist travels 400 km at 80 km/h and 400 km at 100 km/h. What is the average speed of the motorist on this trip?

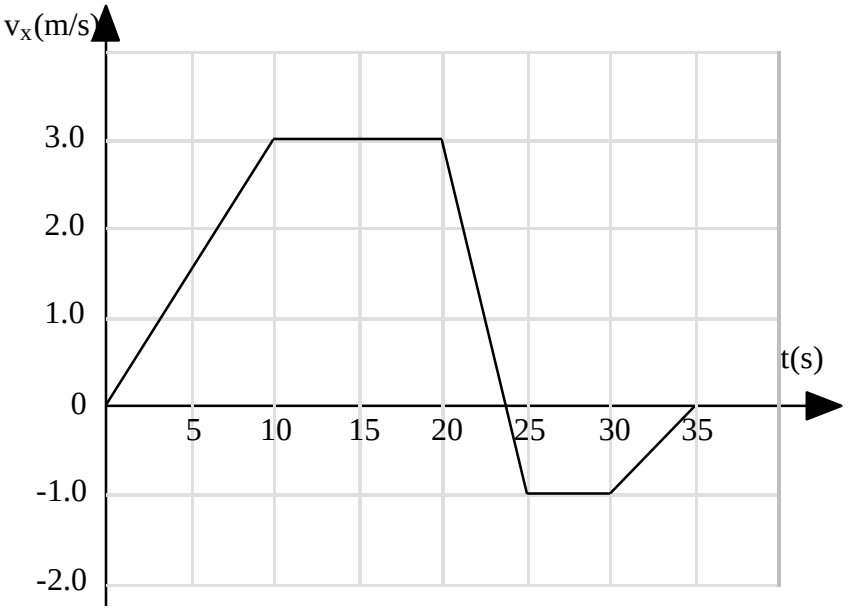
A. 84 km/h B. 89 km/h C. 90 km/h D. 91 km/h E. 95 km/h

19. The standing wave pattern diagrammed to the right is produced in a string fixed at both ends. The speed of waves in the string is 2.0 m/s. What is the frequency of the standing wave pattern?



A. 0.25 Hz B. 1.0 Hz C. 2.0 Hz D. 4.0 Hz E. 8.0 Hz

Questions 20, 21, and 22 refer to the motion of a toy car traveling along the x-axis. The graph shown below is a plot of the car's velocity in the x direction, v_x, versus time, t.



20. During what time interval was the car moving towards its initial position at constant velocity?

A. 0-10 s B. 10-20 s C. 20-25 s D. 25-30 s E. 30-35 s

21. What was the acceleration at 33 s?

A. + 0.40 m/s^2 B. + 0.20 m/s^2 C. 0 D. - 0.20 m/s^2 E. - 0.40 m/s^2

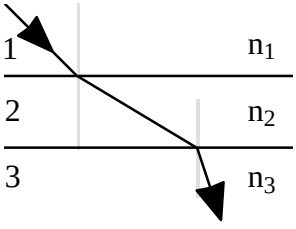
22. How far did the car travel during the first 15 seconds?

A. 0 B. 3.0 m C. 15 m D. 30 m E. 45 m

23. String L and string H have the same tension and length. String L has mass *m* and string H has mass *4m*. If the speed waves in string L is *v*, the speed of waves in string H is

A. *v*/2 B. *v* C. 1.4 *v* D. 2 *v* E. 4 *v*

24. The accompanying diagram shows the path that a light ray takes passing through three transparent materials. The indices of refraction in materials 1, 2, and 3 are n_1, n_2, and n_3, respectively. Which of the following best describes the relation between the indices of refraction?



A. $n_1 > n_2 > n_3$ B. $n_1 > n_3 > n_2$ C. $n_2 > n_1 > n_3$
D. $n_2 > n_3 > n_1$ E. $n_3 > n_1 > n_2$

25. Originally there are N atoms of an unstable isotope. After 20 minutes, only 1/16 of them have not decayed. What is the half life of the isotope?

A. 10 minutes B. 5 minutes C. 4 minutes D. 2 minutes E. 1 minute

26. The average speed of the atoms of a gas at 100 K is 200 m/s. What would most nearly be the average speed of the atoms at 300 K?

A. 67 m/s B. 140 m/s C. 200 m/s D. 350 m/s E. 600 m/s

27. Three resistors – R_1, R_2, and R_3 – are connected in series to a battery. Suppose R_1 carries a current of 2.0 A, R_2 has a resistance of 3.0 Ω, and R_3 dissipates 6.0 W of power. What is the voltage across R_3?

A. 1.0 V B. 2.0 V C. 3.0 V D. 6.0 V E. 12 V

28. An ion with charge *q*, mass *m*, and speed *v* enters a magnetic field *B* and is deflected into a path with a radius of curvature *R*. If a second ion has speed *2v*, while *m*, *q*, and *B* are unchanged, what will be the radius of the second ion's path?

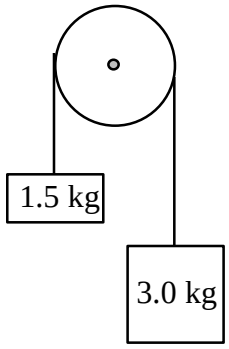
A. 4*R* B. 2*R* C. *R* D. *R*/2 E. *R*/4

29. A student performs an experiment similar to Young's Double Slit Experiment. Coherent light passes through two narrow slits and produces a pattern of alternating bright and dark lines on a screen. Which of the following would cause the bright lines on the screen to be further apart?

I. Increasing the distance between the slits.
II. Decreasing the distance between the slits.
III. Decreasing the wavelength of the light.

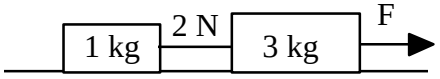
A. I only B. II only C. III only D. I & III only E. II & III only

30. A string with masses of 1.5 kg and 3.0 kg on its ends is hung over a frictionless, massless pulley as shown to the right. What is the approximate magnitude of the acceleration of the masses?



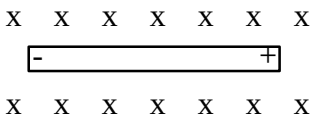
A. 1.5 m/s^2
B. 3.0 m/s^2
C. 3.3 m/s^2
D. 6.7 m/s^2
E. 10 m/s^2

31. Two blocks of mass 1.0 kg and 3.0 kg are connected by a string which has a tension of 2.0 N. A force *F* acts in the direction shown to the right. Assuming friction is negligible, what is the value of *F*?



A. 1.0 N B. 2.0 N C. 4.0 N D. 6.0 N E. 8.0 N

32. A wire moves through a magnetic field directed into the page. The wire experiences an induced charge separation as shown. Which way is the wire moving?



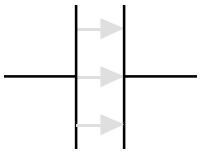
A. to the right
B. to the left
C. out of the page
D. toward the top of the page
E. toward the bottom of the page

33. A softball player catches a ball of mass *m*, which is moving toward her with horizontal speed *v*. While bringing the ball to rest, her hand moves back a distance *d*. Assuming constant deceleration, the horizontal force exerted on the ball by her hand is

A. $mv^2/(2d)$ B. mv^2/d C. mvd D. $2mv/d$ E. mv/d

34. Two large oppositely charged insulated plates have a uniform electric field between them. The distance between the plates is increased. Which of the following statements is true?

I. The field strength decreases.
II. The field strength increases.
III. The potential difference between the plates increases.

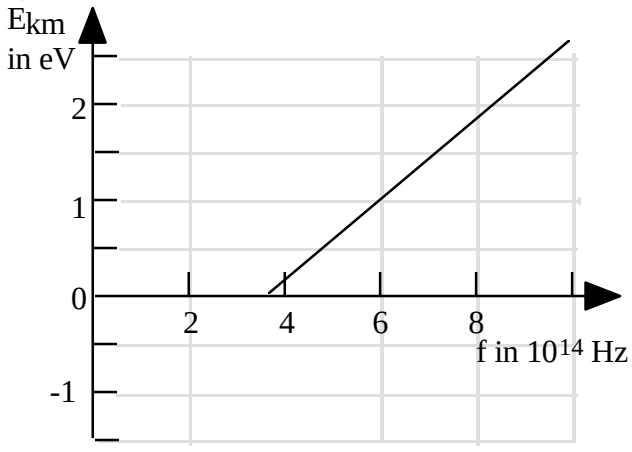


A. I only B. II only C. III only D. I and III only E. II and III only

35. When a single resistor is connected to a battery, a total power *P* is dissipated in the circuit. How much total power is dissipated in a circuit if *n* identical resistors are connected in series using the same battery? Assume the internal resistance of the battery is zero.

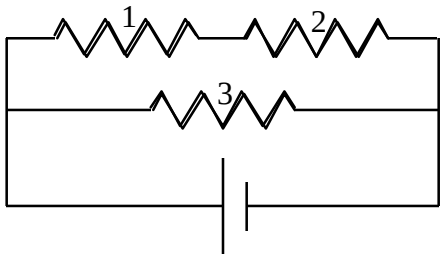
A. n^2P B. nP C. P D. P/n E. P/n^2

36. A student performs the Photoelectric Effect Experiment and obtains the data depicted in the accompanying graph of E_{Km}, the maximum kinetic energy of the photoelectrons in eV, versus *f*, the frequency of the photons in 10^{+14} Hz. What is the approximate work function for this material?



A. 1.5 eV
B. 2.0 eV
C. 2.7 eV
D. 4.0 eV
E. 6.0 eV

7. Consider the compound circuit shown to the right. The three bulbs 1, 2, and 3 – represented as resistors in the diagram – are identical. Which of the following statements are true?



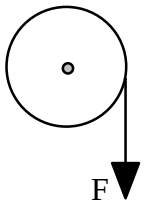
I. Bulb 3 is brighter than bulb 1 or 2.
II. Bulb 3 has more current passing through it than bulb 1 or 2.
III. Bulb 3 has a greater voltage drop across it than bulb 1 or 2.

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

8. A vehicle traveling at a constant 0.60 c passes a clock at a street intersection. For a one-second interval on that clock, what interval will the driver of the vehicle measure?

A. 0.60 s B. 0.80 s C. 1 s D. 1.25 s E. 1.67 s

9. A cylinder free to turn around a fixed axis has a string wrapped around it as shown to the right. The string is pulled with a force F equal to the cylinders weight. What is the acceleration of the string?



A. $2g$ B. g C. $g/2$ D. $g/4$ E. F/g

10. A boat is traveling at 6.0 km/h 30º W of N with respect to a river. The river is flowing at 3.0 km/h from W to E. As observed from shore, the boat is traveling

A. 45º E of N B. 30º E of N C. due N D. 30º W of N E. 45º W of N

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