

28th ANNUAL ALABAMA HIGH SCHOOL PHYSICS CONTEST

The University of Alabama

February 6, 2004

This is an examination covering the basic principles of Physics. It is designed to test both your knowledge and your ability to apply that knowledge. We hope you will find it challenging and interesting. There are easy problems and harder problems. It would probably be best to do the easier problems first. The exam is multiple choice, and there is *NO* penalty for wrong answers. Each answer is to be understood as having an uncertainty of one unit in the last digit. There are 32 questions and you have 1 hour and 15 minutes, so take your time.

Mark your answers on the computer-grading sheet given you, using a pencil. There is only one correct answer for each question. Fill in your name and school code on the answer sheet. There is a blank page at the end of the test for your work. Be sure to read all answers to a question before making your choice. There are no tricks, but some of the *WRONG* answers result from making a simple error. If you have questions, raise your hand.

On the last page of the test is one additional question to be graded only in case of a tie. This question will be graded in detail, so indicate all your reasoning. Please furnish all the information requested on the last page before you turn in your computer form, even if you do not attempt the tie breaker question. You may turn in your test and leave the room when you are done, but please do it quietly so as to not disturb others who are still working.

USEFUL INFORMATION

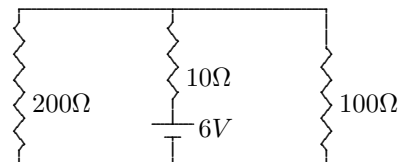
$$\begin{array}{ll} g = 9.8 \text{ m/s}^2 & c = 3 \times 10^8 \text{ m/s} \\ h = 6.63 \times 10^{-34} \text{ J sec} & e = 1.6 \times 10^{-19} \text{ C} \\ 1 \text{ cal} = 4.186 \text{ J} & k_c = 1/(4\pi\epsilon_0) = 9 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2 \\ \text{Newton's Constant } G_N = 6.67 \cdot 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2 & \end{array}$$

- A man holds a glass of mass 0.1 kg stationary for 0.5 second. The work he does against the force of gravity is
a) 0.05 joule b) 0.2 joule c) 0.05 Newton d) 0.2 Newton e) 0
- In a magnetic field, B, the force on a particle of charge Q and velocity v perpendicular to B is $F=QvB$. The units of the B field are
a) meters/Coulomb b) kg/(Coulomb sec) c) meter sec/kg d) kg/amp e) kg meter/sec
- Starting from rest a car undergoes a uniform acceleration of 5 m/s^2 for 10 seconds. What is its average speed?
a) 50 m/s b) 25 m/s c) 1 m/s d) 100 m/s e) 200 m/s
- A boat of mass M_1 pulls on a barge of mass M_2 with a force F_1 . According to Newton's third law the barge pulls back on the boat with a force $-F_1$. The boat's propeller exerts a force F_2 on the water. The water exerts the opposite force $-F_2$ on the boat's propeller. If no other forces are acting, the acceleration of the barge is
a) F_1/M_2 b) $(F_1 - F_2)/M_2$ c) $(F_1 + F_2)/(M_1 + M_2)$ d) $F_1/M_1 - F_2/M_2$ e) zero
- A ball is thrown vertically upward with an initial velocity of 9.8 m/s from shoulder level of a boy whose shoulders are 1 m from the ground. How long does it take before the ball strikes the ground? (Give answer to two significant figures.)
a) 3.7 s b) 4.2 s c) 7.4 s d) 2.1 s e) 1.9 s
- A 2 kg block slides from rest down a frictionless plane inclined at an angle of 30 degrees from the horizontal. Its initial position is 1 m above the ground. What is its kinetic energy when it reaches ground level?
a) 19.6 J b) 9.8 J c) 192 J d) 86 J e) 0
- The stable isotope of Oxygen has eight protons and eight neutrons. How many electrons are there in a water molecule?
a) 8 b) 16 c) 18 d) 9 e) 10
- A rock is thrown horizontally from a cliff of height h. It strikes the ground a distance x from the base of the cliff. The initial speed v was:
a) $\sqrt{xg/(2h)}$ b) $x\sqrt{g/(2h)}$ c) $\sqrt{g/h}$ d) $\sqrt{g/x}$ e) $\sqrt{hg/(2x)}$
- An object of mass M and initial speed v is brought to rest in a distance d under the action of a force F acting in the direction of the initial velocity and a frictional force F_s . F_s has magnitude
a) $-F + mv^2/(2d)$ b) $F + mv^2/(2d)$ c) $F - mv^2/(2d)$ d) $mv^2/(2d)$ e) F
- A roller coaster of mass M rolls from rest down a frictionless track whose height y as a function of horizontal distance x from the starting point is $y = he^{-ax}$. Its speed as function of x is
a) $-ah e^{-ax}$ b) $mghe^{-ax}$ c) $\sqrt{ghe^{-ax}}$ d) $\sqrt{2gh(1 - e^{-ax})}$ e) $\sqrt{2gh(1 + e^{-ax})}$
- A sphere of radius 1 cm and mass 3 grams is placed on top of a cube of mass 100 grams and side-length 5 cm. What is the density of the system?
a) 0.80 g/cm³ b) 0.82 g/cm³ c) 1.75 g/cm³ d) 0.54 g/cm³ e) 1.2 g/cm³

12. Two stars each of mass $2 \cdot 10^{30}$ kg a distance 10^{12} m apart rotate about the midpoint of the line joining them. The acceleration of each star is
 a) $53.2 \cdot 10^{-5}$ m/s² b) $13.3 \cdot 10^7$ m/s² c) $53.2 \cdot 10^7$ m/s² d) $13.3 \cdot 10^{-5}$ m/s² e) none of these
13. A railroad car of mass 10^4 kg travelling on a frictionless track with speed 10 m/s strikes a second car of mass 10^5 kg initially travelling in the same direction with a speed of 5 m/s. If the two cars stick together, what is their speed after the collision?
 a) 10 m/s b) 5.45 m/s c) 5 m/s d) 3.63 m/s e) 0
14. A ball of mass 2 kg is thrown downward from a window 30 m above the ground with an initial speed of 4 m/s. What is its downward acceleration when it is 15 m above the ground?
 a) 9.8 m/s² b) 4.9 m/s² c) .53 m/s² d) 4.0 m/s² e) none of these
15. A girl of mass 50 kg slowly scales a smooth vertical cliff supported by a rope attached to the top. If the rope makes an angle of 30° with the cliff, the normal force exerted by the cliff on the girl has magnitude
 a) 24.5 Newton b) 28.3 Newton c) 42.4 Newton d) 98 Newton e) 0
16. A steel ship of mass M and total volume V floats in water of density ρ . What mass of water can leak into the ship before it sinks?
 a) $\rho V - M$ b) $(\rho V - M)/2$ c) $\rho V + M$ d) $M - \rho V$ e) $\rho V/M$
17. A weight of mass 3 kg attached to a cord is spun in a horizontal circle of radius 4 m. If the tension in the cord is 75 Newton, what is the speed of the weight?
 a) 100 m/s b) 10 m/s c) 7.5 m/s d) 75 m/s e) 98 m/s
18. A correct relation between the frequency f of a wave, its speed v , and its wavelength λ is
 a) $v = f/\lambda$ b) $v = \lambda/f$ c) $v = \lambda^2 f$ d) $v = \lambda f$ e) $v = \lambda f^2$
19. If one drops a 5 kg rock from a 100 m high bridge into a river below, how long must one wait to hear the sound of the splash? (The speed of sound is 343 m/s.)
 a) 4.52 s b) 3.486 s c) 2.4 s d) 3.43 s e) 4.81 s
20. In one hour a hundred watt light bulb radiates $2 \cdot 10^5$ joules of visible light. How much energy does it emit in other forms?
 a) 60 joules b) 100 joules c) $1.6 \cdot 10^5$ joules d) $2 \cdot 10^7$ joules e) 1800 joules
21. What constant force is required to stop a 1000 kg car in 5 s if it is travelling at 90 km/h?
 a) 18000 N b) 5000 N c) $4.5 \cdot 10^5$ N d) $3 \cdot 10^5$ N e) 18 N
22. A 17 kg child descends a slide 4.6 m high and reaches the bottom with a speed of 2.2 m/s. How much heat was generated in this process?
 a) 766 J b) 41 J c) 725 J d) 807 J e) none

23. If a star of mass 10^{32} kg were to slowly collide with a star of equal mass made of anti-matter, how much energy would be released in the annihilation?
 a) $2 \cdot 10^{32}$ joules b) $2 \cdot 10^{64}$ joules c) $1.8 \cdot 10^{49}$ joules d) 10^{32} joules e) $4.8 \cdot 10^{54}$ joules
24. At this time (Feb 6, 2004) Mars is about $5.6 \cdot 10^7$ km from earth. How long does it take to send a radio message to the Mars Rover and receive a response on earth?
 a) 1.1 day b) 2.9 hr c) 6.2 min d) 185 s e) 24 s
25. An explosion in space breaks an object originally at rest into two fragments. The fragment of mass m_1 has twice the kinetic energy of the fragment of mass m_2 . The masses are related by
 a) $m_1 = 2m_2$ b) $m_1 = m_2/2$ c) $m_1 = m_2$ d) $m_1 = 4m_2$ e) $m_1 = m_2/4$
26. On the surface of a planet of mass M and radius R the acceleration of gravity is (in magnitude)
 a) GM/R^2 b) GM/R c) $4\pi R^3/3$ d) GM^2/R^2 e) GM/R^3
27. How much work is done in pushing a 10 kg block up a frictionless plane inclined at 30° from the horizontal? The length of the plane is 20 m.
 a) 1697 J b) 980 J c) 200 j d) 173 J e) 100 J

28. In the circuit shown, what current flows through the 6 volt battery?



- a) .019 amp b) .028 amp c) .054 amp d) .078 amp e) 1.67 amp
29. A 10 g ice cube at $0^\circ C$ is put into a perfectly insulated thermos containing 100 g of water initially at $30^\circ C$. What will be the final temperature in the thermos? (It takes 80 calories to melt one gram of ice and 1 calorie to raise 1 g of water $1^\circ C$.)
 a) $0^\circ C$ b) $8^\circ C$ c) $16^\circ C$ d) $20^\circ C$ e) $30^\circ C$
30. An ideal gas occupies a volume of 10^4 m³ at a pressure of 0.5 Atm and a temperature of $25^\circ C$. What volume will it occupy if the pressure is doubled and the temperature is reduced by $10^\circ C$?
 a) 30000 m³ b) 8333 m³ c) 4830 m³ d) 4167 m³ e) 2500 m³
31. A mass of 0.5 kg is attached to the end of a spring with force constant 10 N/m. If the spring is displaced 0.02 m from its equilibrium position and released, how long does it take for the mass to return to its equilibrium position for the first time?
 a) 0.07 s b) 0.35 s c) 0.70 s d) 1.05 s e) 1.33 s
32. A ball is thrown from a window 15 m above the ground with a downward initial speed of 2 m/s. How long does it take the ball to reach the ground?
 a) 1.97 s b) 1.74 s c) 1.76 s d) 1.56 s e) 3.52 s

Name _____

School _____

HOME ADDRESS _____

HOME PHONE _____

CITY _____

ZIP _____

e-mail: _____

year in school Sr. _____ Jr. _____ So. _____ Fr. _____

Teacher's name: _____

If you do NOT wish to be considered for a scholarship at Alabama, please sign here.

TIE BREAKER: Show all of your work since what you do is as important as whether you get the *right* answer.

An unknown baseball player of negligible height and unknown weight is practicing in an indoor practice facility which is exactly cubical but of unknown size. From the center of one wall, he throws a ball of unknown mass with an unknown speed at an unknown angle from the horizontal, so that it just grazes the ceiling and lands on the floor exactly at the center of the opposite wall. Ignoring friction, determine one of the unknown quantities.