41st ANNUAL ALABAMA HIGH SCHOOL PHYSICS CONTEST

Version A

The University of Alabama, Friday Jan. 27, 2017

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. Calculators can not be used. Each answer is to be understood as having an uncertainty of one unit in the last digit. There are 33 questions (plus one question to identify your test version) and you have 1 hour and 15 minutes; thus to finish you will need to average at most 2.3 minutes per question.

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

$g = 10\ \text{m/s}^2$ $\qquad$ $c = 3 \cdot 10^8\ \text{m/s}$

$h = 6.63 \cdot 10^{-34}\ \text{J} \cdot \text{s}$ $\qquad$ $e = 1.6 \cdot 10^{-19}\ \text{C}$

$1\ \text{cal} = 4.186\ \text{J}$

$k_e = 1/(4\pi\epsilon_0) = 9 \cdot 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$

neutron mass $= 1.6749 \cdot 10^{-27}$ kg

proton mass $= 1.6726 \cdot 10^{-27}$ kg

electron mass $= 9.11 \cdot 10^{-31}$ kg

Earth's mass $= 5.97 \cdot 10^{24}$ kg

Moon's mass $= 7.35 \cdot 10^{22}$ kg

Earth's radius $= 6.38 \cdot 10^6$ m

Gravitational Constant $G_N = 6.67 \cdot 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2$

atomic mass unit $1\ \text{u} = 1.66 \cdot 10^{-27}$ kg

$\sin 30^\circ = 1/2 = 0.5$

$\sin 45^\circ = \sqrt{2}/2 = 0.71$

$\cos 30^\circ = \sqrt{3}/2 = 0.87$

$\cos 45^\circ = \sqrt{2}/2 = 0.71$

$\cos 60^\circ = 1/2 = 0.5$

1. Important: You are **group A**, so please **mark A** on your answer sheet for **question 1!**

2. A person in a car drives for 10 minutes on city streets at a constant speed of 24 mph, then for 20 minutes on a highway at a constant speed of 60 mph. What is the driver's average speed during this drive?

a) 42 mph b) 48 mph c) 60 mph d) 24 mph e) 35 mph

3. A juggler throws a bowling pin straight up in the air. After the pin leaves his hand and while it is in the air, which statement is true?

a) The velocity of the pin is always in the same direction as the acceleration.
b) The velocity of the pin is never in the same direction as the acceleration.
c) The acceleration of the pin is zero.
d) The velocity of the pin is opposite its acceleration on the way up.
e) The velocity of the pin is in the same direction as its acceleration on the way up.

4. The speed of a nerve impulse in the human body is about 100 m/s. If you stub your toe in the dark, *approximately* how long does it take for the nerve impulse to travel to your brain? (Note: 1 m = 3.3 feet.)

a) 0.01 s b) 0.1 s c) 1 s d) 10 s e) 100 s

5. A 50 kg ice skater is moving at 3 m/s when she grabs the loose end of a rope, the opposite end of which is tired to a pole. She then moves in a circle with a radius of 1 m around the pole. What is the force exerted by the rope on her arms, assuming she holds the rope horizontally?

a) 17 N b) 150 N c) 300 N d) 450 N e) 600 N

6. Einsteins famous equation, $E = mc^2$, says that

a) the speed of light c never changes
b) electromagnetism E is the same as mass m
c) kinetic energy E is determined by mass m
d) light going at speed c has energy E
e) mass m is a form of energy E

7. A 4 kg box is pushed horizontally across a frictionless floor with a constant force of 20 N. What is the acceleration of the box while it is being pushed?

a) 10 m/s^2 b) 5 m/s^2 c) 80 m/s^2 d) 16 m/s^2 e) 40 m/s^2

8. A block of mass 4 kg is suspended vertically from one end of a spring with spring constant 400 N/m; the other end of the spring is attached to the ceiling. Treat the spring as an ideal, massless spring. How far is the spring stretched compared to its equilibrium (unstreteched) length?

a) 0.01 m
b) 0.1 m
c) 1 m
d) 10 m
e) 100 m

9. A ball is dropped from a height of 5 m above the ground. Neglecting air resistance, what is the speed of the ball when it hits the ground?

a) 10 m/s
b) 20 m/s
c) 2 m/s
d) 5 m/s
e) cannot say without knowing the mass of the ball

10. A 4 kg book is pressed up against a vertical wall by a horizontal force, and held stationary by static friction. The coefficient of static friction between the book and the wall is 0.5. What horizontal force must be applied to the book to keep it from sliding down the wall?

a) 5 N b) 10 N c) 20 N d) 40 N e) 80 N

11. What would happen to the Earth's orbit if the Sun were instantly replaced by a black hole of the same mass as the Sun at the same location as the Sun?

a) The Earth would fly off into space
b) The Earth would fall into the black hole
c) The Earth would continue on its orbit unchanged
d) The Earth would continue to orbit the Sun but at a closer distance
e) The Earth would continue to orbit the Sun but at a larger distance

12. Car A is traveling in a straight line, at a constant speed of 10 m/s. Car B is also traveling in the same direction, at a constant speed of 30 m/s, but starts off a distance 100 m behind car A. How long will it take Car B to catch up to car A?

a) 1 s b) 5 s c) 2 s d) 3 s e) 10 s

13. A ball is dropped from rest a certain height above the surface of the Earth. If it takes the ball 2 s to hit the ground, what was its initial height when it was dropped? (You may ignore air resistance in this problem.)

a) 100 m b) 50 m c) 10 m d) 20 m e) 200 m

14. Suppose a new planet is discovered which is half the mass and twice the radius of Earth. What would you expect the acceleration due to gravity on the surface of this new planet to approximately be?

a) 2.5 m/s^2 b) 5 m/s^2 c) 20 m/s^2 d) 10 m/s^2 e) 1.25 m/s^2

15. An ideal gas is sealed in a container whose volume can vary. The pressure of this gas is then doubled, and at the same time, the temperature is halved. What is the resulting change in the volume of this gas?

a) The volume remains the same
b) The volume is doubled
c) The volume is halved
d) The volume increases by a factor of four
e) The volume decreases by a factor of four

16. Two children of mass 10 kg and 15 kg are sitting on the same side of a seesaw, at a distance from the pivot of 1.5 m and 1.0 m respectively. A third child, mass 30 kg, is sitting on the opposite side of the seesaw. To balance the seesaw, how far from the pivot must the third child sit?

a) 0.67 m b) 0.5 m c) 2.0 m d) 1.0 m e) 1.5 m

17. Two stationary charged particles exert a Coulomb force on each other. If the distance between the two particles is doubled, how does the magnitude of the force change?

a) The force does not change
b) The force increases by a factor of four
c) The force decreases by a factor of four
d) The force is doubled
e) The force is halved

18. Which one of the following statements is CERTAINLY TRUE? Assume the waves are propagating in vacuum.

a) Radio waves, microwaves, visible light and X-rays all have the same wavelength
b) Radio waves, microwaves, visible light and X-rays all travel at the same speed
c) Radio waves, microwaves, visible light and X-rays all have the same frequency
d) Radio waves, microwaves, visible light and X-rays must all have the same amplitude
e) Radio waves, microwaves, visible light and X-rays must all have the same intensity

19. An object of mass 7 kg skids across a rough horizontal surface. The coefficient of kinetic friction between the object and the surface is 0.30. If the inital speed of the object is 15 m/s, how long does it take for the object to come to a stop?

a) 5 s b) 1 s c) 2 s d) 3 s e) 7 s

20. Which one of the following statements relating to the Second Law of Thermodynamics is TRUE?

a) It is possible to construct an engine that is 100% efficient
b) Systems tend naturally to move to states of greater order
c) Any natural process tends to increase the entropy of a system
d) Heat can flow spontaneously from a colder object to a hotter object
e) It is possible to construct a device whose sole effect is to transform a given amount of heat into an equal amount of mechanical work

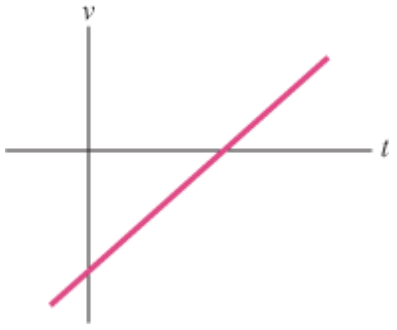
21. A railroad carriage of mass 10,000 kg is moving with a speed of 9 m/s. It collides with another carriage of mass 20,000 kg, which is initially at rest. After the collision, the two carriages join together and move away with a common speed. What is that speed?

a) 12 m/s b) 9 m/s c) 6 m/s d) 1 m/s e) 3 m/s

22. Consider the following four configurations of electric charges: **A**, a charge Q and a second charge, also Q, separated by a distance R; **B**, a charge Q and a second charge $2Q$, separated by a distance R; **C**, a charge Q and a second charge $2Q$, separated by a distance $R/2$; **D**, a charge Q and a second charge, also Q, separated by a distance $2R$. Which of the following gives the correct order for the magnitude of the force experienced between the charges in each configuration?

a) $B > A > C > D$
b) $A > B > C > D$
c) $B > D > C > A$
d) $C > B > A > D$
e) $D > C > A > B$

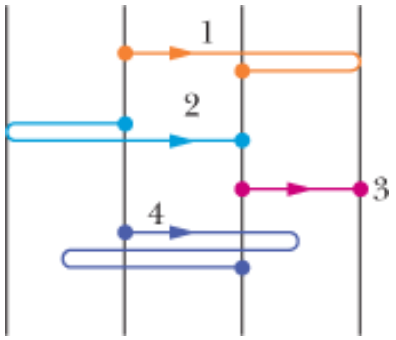
23. The graph below shows the velocity of an object as a function of time.



Which best describes the motion of the object during the period shown on the graph?

a) The object travels in a straight line at constant speed
b) The object travels in one direction, slows down, stops, and turns around
c) The object slows down continuously
d) The object speeds up continuously
e) The object speeds up, then slows down

24. The figure below shows four paths along which objects move from a starting point to a final point, all in the same time interval. The paths pass over a grid of equally spaced straight lines.



Rank the objects by their average speed.

a) $1 > 2 > 3 > 4$
b) $2 > 3 > 4 = 1$
c) $4 > 3 > 2 > 1$
d) $3 > 4 > 2 = 1$
e) $4 > 1 = 2 > 3$

25. A 1.2 kg ball drops vertically onto a floor, hitting with a speed of 25 m/s. It rebounds with an initial speed of 10 m/s. What impulse acts on the ball during the contact?

a) 18 N·s b) 42 N·s c) 15 N·s d) 30 N·s e) 50 N·s

26. A wave has an angular frequency ω of 628 rad/s and a wavelength of 2 m. What is the speed of the wave?

a) 200 m/s b) 1260 m/s c) 628 m/s d) 100 m/s e) 2 m/s

27. If the index of refraction for a given material is 1.25, what is the speed of light in that material relative to the speed of light in vacuum c?

a) No material can have a refractive index larger than 1.
b) $1.25c$
c) $0.8c$
d) c
e) $0.5c$

28. The Chernobyl disaster was a catastrophic nuclear accident that occurred in Ukraine, then USSR, in 1986. It led to release of massive amounts of radioactive material, and it is estimated that about 24 kg of radioactive isotope ^{137}Cs was released in the air by 1987. ^{137}Cs has a half-life of 30 years. How many kilograms of Chernobyl-born ^{137}Cs there still remains in the world today, in 2017?

a) 24 kg b) 12 kg c) 0 kg d) 8.8 kg e) 16 kg

29. Trick riding refers to the act of performing stunts while riding a horse, such as the rider standing upright on a galloping horse. Consider a trick-rider standing on a horse that travels along the straight line with a constant speed of 20 mph. The rider then jumps straight up. Ignoring air resistance, where will the rider land? (Do not try this yourself)

a) Behind the running horse
b) Right back on the saddle
c) In front of the horse
d) To the side of the horse
e) On the Moon

30. Students on a Spring break first traveled ∼200 miles South from Tuscaloosa, AL, to Mobile, AL. They then went ∼240 miles East to Tallahassee, FL. Which of the following is the closest to the distance, in miles, they drove back from Tallahassee directly to Tuscaloosa?

a) 40 miles b) 220 miles c) 300 miles d) 440 miles e) Can't be determined without Google Maps

31. A ping-pong ball and a ball made of magic putty, both with the same mass, are thrown straight at the wall with the same velocity, $v_{initial}$. The ping-pong ball bounces right back (v_{final}=$-v_{initial}$), while the putty ball sticks to the wall (v_{final}=0). Which of the statements about the change in the magnitudes of the balls' momenta (Δp_{pong} and Δp_{putty}) is true?

a) $\Delta p_{putty} = \Delta p_{pong}$
b) $\Delta p_{putty} = 2\Delta p_{pong}$
c) $\Delta p_{putty} = 0.5\Delta p_{pong}$
d) $\Delta p_{putty} = 0.25\Delta p_{pong}$
e) None of the above

32. A swimmer wants to cross a 100 m wide river that flows due south at a speed of 1 m/s. How many meters downstream the swimmer will reach the east bank if she swims directly east at a speed of 2 m/s?

a) 100 m b) 2 m c) 40 m d) 50 m e) 200 m

33. A 100 kg bike driving 30 m/s (∼67 mph) hits a concrete pole and stops instantaneously. Calculate the kinetic energy of this collision and estimate the number of 9 mm bullets (muzzle energy ∼450 J) that produces an equivalent impact.

a) 1 b) 10 c) 100 d) 1000 e) Depends on the brand of the bike

34. Our Solar System is revolving around the center of our Milky Way galaxy at an average speed of ∼240 km/s. It completes one revolution (the Galactic year) in about 225 million Earth years (∼$7{\cdot}10^{15}$ s). Assuming a perfectly circular motion, approximately how far, in km, the Sun is from the galactic center? (Reminder: $\pi \approx 3$)

a) $3{\cdot}10^{17}$ km b) $5.6{\cdot}10^{17}$ km c) $3{\cdot}10^{5}$ km d) $2.8{\cdot}10^{15}$ km e) $1.4{\cdot}10^{15}$ km

Name: _____ School _____
Home Address: _____ Phone:_____
City: _____ Zip:_____

Email:_____

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

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.

A block of mass $m = 4.0$ kg is pushed a distance D up an incline plane by a horizontal force $F = (160/\sqrt{3})$ N. The block starts from rest and after it travels the distance D its speed is measured to be 10 m/s. The coefficient of friction is $\mu_k = (1/\sqrt{3})$ and $\theta = 30°$. Find D