42nd ANNUAL ALABAMA HIGH SCHOOL PHYSICS CONTEST

Version A

The University of Alabama, Friday Feb. 16, 2018

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 32 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

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

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

speed of sound= 343m/s $\qquad$ 1 cal = 4.186 J

$k_e = 1/(4\pi\epsilon_0) = 9 \cdot 10^9$ N $\cdot$ m^2/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 $G_N = 6.67 \cdot 10^{-11}$ N $\cdot$ m^2/kg^2

atomic mass unit 1 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. How much work does a 75 kg fireman do when climbing up a flight of stairs which is 10 m high?

a) 750 J b) 75000 J c) 7500 J d) 750000 J e) 75 J

3. A light bulb is connected to the two contacts of a battery by two identical wires. Next, the cross section of one wire is doubled and the cross section of the other wire is halved. Subsequently,

a) the light bulb will periodically turn on and off
b) the brightness of the light bulb is unaffected
c) the light bulb will shine brighter
d) the light bulb will become darker
e) the given information is not sufficient to decide

4. A 50-kg boy on a sled starts from rest and slides down a hill. He then continues sliding horizontally for 10 seconds before coming to a stop. If the boy traveled 20 m horizontally, what was the magnitude of the (assumed constant) friction force between the sled and the road?

a) 420 N
b) 16 N
c) 4 N
d) 20 N
e) 0.8 N

5. A 1-kg object is moving in a circular path with a constant speed of 10 m/s. Find the magnitude of the change of the object's momentum when it completes one quarter of a complete circle?

a) 10 kg·m/s b) $\sqrt{2}$·10 kg·m/s c) $\sqrt{2}$·5 kg·m/s d) 5 kg·m/s e) 0 kg·m/s

6. Two people, one of mass 60 kg and one of mass 50 kg, are sitting on a frictionless surface at rest. They then push each other apart. How far apart are they when the more massive person has moved 10 m?

a) 22 m b) 10 m c) 18 m d) 12 m e) 2 m

7. A charged particle with a certain velocity enters a region of space in which it is subject to a constant electric field and a constant magnetic field (the gravitational force is neglected). The velocity direction and the directions of the two fields are mutually perpendicular to each other. The electric and magnetic fields have the magnitudes E=5 V/m and B=1 T. It is observed that the particle is undeflected despite the presence of the two fields. What is its velocity?

a) 3.33 m/s b) 10 m/s c) 1 m/s d) 5 m/s e) 2.5 m/s

8. Earth's radius is $6.37 \cdot 10^6$ m. If the acceleration of gravity on the Earth's surface is 9.80 m/s^2, how many meters above the Earth's surface does the acceleration of gravity equal 2.45 m/s^2?

a) $2.18 \cdot 10^6$ m
b) $1.27 \cdot 10^7$ m
c) $6.37 \cdot 10^6$ m
d) $3.84 \cdot 10^8$ m
e) Acceleration of gravity is always constant

9. The tire pressure in each of the four tires of a car is 240 kPa. If each tire has a contact area with the road of 250 cm^2, what is the mass of the car?

a) 9600 kg b) 4800 kg c) 600 kg d) 24000 kg e) 2400 kg

10. Consider the g-string of a guitar with 64 cm length, which oscillates at a frequency of 392 Hz (first harmonic). By pressing a finger onto the guitar, the length of the string is reduced. Where do you have to place your finger in order to obtain an oscillation at 784 Hz (G4)?

a) 56 cm b) 16 cm c) 8 cm d) 32 cm e) 48 cm

11. Car A and car B start out from the same point and drive in opposite directions, car A with velocity v_A=4 m/s and car B with velocity v_B=1 m/s. After 5 seconds, both cars turn around and switch their velocities. Some time later they collide. What is the distance between the starting point and the point of collision?

a) 5 m b) 5.5 m c) 10 m d) 15 m e) 12 m

12. A mosquito flaps its wings at 600 Hz. A bumblebee's wings complete one flap (downstroke plus upstroke) in 6 ms. Which of the two flaps its wings more times during a 1 min flight, and by how much?

a) mosquito, by 36000 flaps
b) mosquito, by 26000 flaps
c) bumblebee, by 26000 flaps
d) both the same
e) bumblebee, by 10000 flaps

13. Two twins have the same mass. One of the twins travels to the North Pole, while the other one travels to the equator. If both twins step on the scales, which will have smaller apparent weight?

a) Both the same
b) The one who eats lots of veggies
c) The one on the Pole
d) The one on the Equator
e) Can't be determined

14. A fisherman sees wave crests passing the front of his anchored boat every 2 s. The distance between wave crests is 5 m. What is the speed of the waves?

a) 10 m/s b) 5 m/s c) 7 m/s d) 2.5 m/s e) 2 m/s

15. A hiker shouts across a lake. 2 s later, she hears the echo of her shout from a cliff at the end of the lake. How long is the lake?

a) 85 m b) 686 m c) 171 m d) 343 m e) 250 m

16. A ball is thrown straight up. Neglecting air resistance, which statement is not true regarding the energy of the ball?

a) The kinetic energy increases while the ball is coming down.
b) The sum of kinetic and potential energy is constant.
c) The potential energy of the ball decreases while the ball is going up.
d) The kinetic energy decreases while the ball is going up.
e) The potential energy decreases while the ball is coming down.

17. SpaceX launched the Falcon 9 rocket into the Low Earth Orbit (LEO). It uses rocket fuel called RP-1 (essentially, kerosene) to provide the needed energy. What is the approximate mass of RP-1 needed to bring Falcon 9 up to the LEO altitude of 350 km? Assume 500 ton for the Falcon's mass, 45 MJ/kg energy content of RP-1, and just enough energy to bring the rocket up (v_f=0). Ignore atmosphere resistance, decrease of total mass as the fuel tank empties, and small change in acceleration of gravity with elevation. Note: 1 ton = 1000 kg.

a) 4 tons b) 400 tons c) 40 tons d) 400 kg e) 4 kg

18. What speed should a 50 g snowball have for its momentum to be the same as an 8 g bullet flying at 400 m/s?

a) 40 m/s b) 1600 m/s c) 800 m/s d) 32 m/s e) 64 m/s

19. Separation of uranium isotopes requires a centrifuge that can sustain centripetal acceleration of roughly $9{\cdot}10^6$ m/s^2. Assuming a centrifuge's radius of 1 m, what is the corresponding speed in m/s?

a) 9000 b) 18 c) 3000 d) $3{\cdot}10^6$ e) $9{\cdot}10^6$

20. An ideal gas expands isothermally (at constant temperature) and performs 1000 J of work in the process. Which of the following is true?

a) The internal energy of the gas goes to zero; no heat is absorbed by the gas.
b) The internal energy of the gas doubles; 1000 J of heat is absorbed by the gas.
c) The internal energy of the gas remains constant; no heat is absorbed by the gas.
d) The internal energy of the gas remains constant; 1000 J of heat is lost by the gas.
e) The internal energy of the gas remains constant; 1000 J of heat is absorbed by the gas.

21. Two stationary charges exert the Coulomb force F_1 on each other. If one of the charges is doubled and the other one is halved, they exert the Coulomb force F_2 on each other. How are F_1 and F_2 related?

a) $F_2 = 2F_1$ b) $F_2 = F_1/4$ c) $F_2 = 4F_1$ d) $F_2 = F_1$ e) $F_2 = F_1/2$

22. A swimmer wants to cross a 100 m wide river that flows due south at a speed of 1 m/s. She starts on the west bank. How many meters downstream the swimmer will reach the east bank if she swims directly east at a speed of 2 m/s until she reaches the middle of the river and then continues with a speed of 1 m/s?

a) 75 m b) 100 m c) 200 m d) 50 m e) 10 m

23. A ball is thrown straight up into the air with initial speed v=10 m/s. What is its speed once it comes back to its initial height? Ignore air resistance.

a) 5 m/s b) 10 m/s c) 1 m/s d) 2 m/s e) 9 m/s

24. A projectile is shot from the ground at an angle of 45 degrees with initial velocity 10 m/s. Neglecting friction in the air, after which time does the projectile hit the ground again?

a) 1.53 s b) 1.42 s c) 2.24 s d) 1 s e) 1.84 s

25. Two point electric charges of 1 C each are separated by 1 m. If one of the charges is increased to 4 C, to what distance must the separation between the charges increase in order for the Coulomb force between them to remain constant?

a) 4 m
b) 2 m
c) 8 m
d) 32 m
e) 16 m

26. A mass m at the end of a spring oscillates with a frequency of 2 Hz. When 1 kg is added to the original mass m, the frequency of oscillations is now 1 Hz. What is the original mass m?

a) 1 kg b) 0.1 kg c) 0.7 kg d) 0.3 kg e) 0.5 kg

27. The Moon does not crash into the Earth because:

a) the Earth's velocity is too high
b) it is beyond the main pull of the Earth's gravity
c) the net force on it is zero
d) it is freely falling but has a high tangential velocity
e) it is being pulled by the Sun as well as the Earth

28. 1000 calories are required to raise the temperature of 1 kg of water by 1° C. Suppose a water heater generates 32000 kJ per hour. About how much water can it heat from 10° C to 50° C in one hour?

a) 200 kg b) 50 kg c) 400 kg d) 800 kg e) 100 kg

29. A railroad carriage of mass 10,000 kg is moving with a speed of 8 m/s. It collides with another railroad carriage of mass 5,000 kg moving in the opposite direction at a speed of 16 m/s. After the collision the two carriages join together. How much kinetic energy is lost?

a) 480,000 J b) 540,000 J c) 960,000 J d) 320,000 J e) 100,000 J

30. A sled, starting from rest, slides down an icy frictionless incline with a slope of 30° and a vertical height of 5 m. How fast is the sled going when it reaches the bottom?

a) 5 m/s b) 10 m/s c) 20 m/s d) 2 m/s e) 1 m/s

31. A figure skater performs a pirouette. She starts by spinning slowly with her arms stretched out sideways. We are interested in what happens next when she pulls her arms radially inwards, thereby increasing her rotational frequency. Which statement is correct?

a) The rotational energy is conserved during this process
b) The angular momentum is conserved during this process
c) (a) and (c) are correct
d) (a) and (b) are correct
e) The linear momentum is conserved during this process

32. Two trains are running along neighboring tracks and are passing by each other. The first train moves at a speed of 15 m/s relative to the ground and is 200 m long. The second train moves in the opposite direction (towards the first one) at a speed of 25 m/s relative to the ground and is 600 m long. Determine how long it takes for the two trains to pass by each other (i.e. the amount of time during which the trains' coordinates overlap)

a) 30 s b) 40 s c) 20 s d) 50 s e) 10 s

33. Two wheels have the exact same mass and radius, and rotate at the same angular velocity. One wheel is a solid disk with the mass evenly distributed throughout the disk. The other wheel is made with spokes so nearly all the mass is distributed around the rim. How do the rotational kinetic energies of the two wheels compare?

a) They are nearly the same.
b) The wheel with spokes has twice the kinetic energy.
c) The wheel with spokes has four times the kinetic energy.
d) It is impossible to say without knowing the mass and radius of the wheels.
e) The solid wheel has twice the kinetic energy.

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 40 kg satellite circles a planet of mass $M = 12 \cdot 10^{22}$ kg in an orbit with a period $T_1 = 3 \cdot 10^2$ s. What minimum energy E is required to change the orbit to one with a period of $T_2 = \frac{8}{\sqrt{3}} \cdot 10^2$ s? Both the initial and final orbits are circular.

Assume the Gravitational constant to be $G_N = 9 \cdot 10^{-11}$ N $\cdot$ m^2/kg^2 and $\pi = 3$ in order to simply the calculations.