2021 Academic Challenge

PHYSICS TEST - REGIONAL

This Test Consists of 35 Questions

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GENERAL DIRECTIONS

Please read the following instructions carefully. This is a timed test; any instructions from the test supervisor should be followed promptly.

The test supervisor will give instructions for filling in any necessary information on the answer sheet. Most Academic Challenge sites will ask you to indicate your answer to each question by marking an oval that corresponds to the correct answer for that question. Only one oval should be marked to answer each question. Multiple ovals will automatically be graded as an incorrect answer.

Be sure ovals are marked as  , not  ,  ,  , etc.

If you wish to change an answer, erase your first mark completely before marking your new choice.

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not waste your time on questions that seem too difficult for you. Go on to the other questions, and then come back to the difficult ones later if time remains.

***** TIME: 40 MINUTES *****

DO NOT OPEN TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO!

Fundamental Constants

Quantity	Symbol	Value
Avogadro's number	N_A	6.022×10^{23}/mol
Boltzmann's constant	k	1.381×10^{-23} J/K
Electron charge magnitude	e	1.602×10^{-19} C
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ T·m/A
Permittivity of free space	ϵ_0	8.854×10^{-12} C^2/(N·m^2)
Electrostatic Constant	$k = (4\pi\epsilon_0)^{-1}$	8.988×10^{9} N·m^2/C^2
Planck's constant	h	6.626×10^{-34} J·s
Electron mass	m_e	9.1094×10^{-31} kg
Neutron mass	m_n	1.6749×10^{-27} kg
Proton mass	m_p	1.6726×10^{-27} kg
Speed of light in vacuum	c	2.9979×10^{8} m/s
Universal gravitational constant	G	6.673×10^{-11} N·m^2/kg^2
Universal gas constant	R	8.3145 J/(mol·K)

Other information:

Acceleration due to gravity at Earth's surface: g = 9.81 m/s^2

0.00 ^{o}C = 273.15 K

Academic Challenge
Physics Test (Regional) – 2021

1. The speed of our solar system relative to the center of the Milky Way Galaxy is 2.30x10^5 m/s. What is that speed in miles per hour? (1 inch = 2.54 cm)

a. $8.28 \times 10^3 \frac{mi}{hr}$ b. $5.14 \times 10^4 \frac{mi}{hr}$ c. $5.14 \times 10^5 \frac{mi}{hr}$
d. $8.28 \times 10^5 \frac{mi}{hr}$ e. $5.14 \times 10^6 \frac{mi}{hr}$

2. In orienteering one might find a set of directions such as:
   1. 1.33 km due north
   2. 2.25 km due west
   3. 1.82 km 40.0˚ north of west
   4. 1.11 km due south

   If the terrain were not a problem so the person could go directly to the end point what direction and distance would get them there?

a. 3.90 km at 20.9˚ north of west
b. 4.15 km at 35.2˚ north of west
c. 4.55 km at 26.6˚ north of west
d. 5.13 km at 45.0˚ north of west
e. 6.51 km at 40.0˚ north of west

3. The density of Aluminum is 2.70x10^3 kg/m^3. What is the mass of a sphere of aluminum with a radius of 9.25 cm?

a. 1.23 kg
b. 2.14 kg
c. 2.69 kg
d. 8.95 kg
e. 72.6 kg

4. A 6.84 kg crate is pulled up a 10.0° incline by a rope attached. The rope makes a 25.0° angle above the incline. The coefficient of kinetic friction between the crate and the incline is 0.137. The crate accelerates with an acceleration of 0.351 m/s^2. How much work did the rope do on the crate in moving it 2.79 m?

a. 1.57 J b. 6.70 J c. 9.19 J d. 60.6 J e. 390 J

5. A roller coaster car on a frictionless track starts from rest a height h above the lowest point. The track makes a vertical circular loop when it gets to that lowest point. What is the maximum radius of the vertical loop such that the car remains in contact with the track?

a. $\frac{1}{4}h$ b. $\frac{7}{16}h$ c. $\frac{2}{5}h$ d. $\frac{1}{2}h$ e. $\frac{2}{3}h$

6. A wooden crate of mass 17.1 kg is projected up a 25.5° incline with an initial speed of 4.12 m/s. The coefficient of kinetic friction between the crate and the incline is 0.587. What is the distance that the crate will slide up the incline before coming to rest?

   a. 0.545 m b. 0.749 m c. 0.901 m d. 1.11 m e. 2.01 m

7. A luxury railroad car is accelerating on level tracks. The acceleration is constant at 1.25 m/s^2. A 12.1 kg chandelier is hanging from the center of the car and can swing freely on a 1.10 m light flexible cord. What angle does the cord make with the vertical?

   a. 0.00° b. 5.90° c. 7.26° d. 51.3° e. 82.7°

8. A skier starts from rest down a snow covered hill that makes an angle of 65.0° with the horizontal. The skier has a constant acceleration down the hill of 6.12 m/s^2. What is the coefficient of friction between the skis and the snow on the mountain?

   a. 0.0613 b. 0.222 c. 0.376 d. 0.624 e. 0.668

9. As a continuation of the previous problem, what is the speed of the skier when they have traveled 80 m down the slope?

   a. 17.8 m/s b. 23.5 m/s c. 31.3 m/s d. 39.6 m/s e. 55.1 m/s

10. In order to save gunpowder, a cannoneer uses the minimum necessary to fire his projectile a distance of 3810 m. Assuming no air resistance and optimal launch angle, what is the speed that the projectile leaves the cannon with to achieve his goal?

    a. 61.7 m/s b. 137 m/s c. 193 m/s d. 273 m/s e. 388 m/s

11. The Earth has a mass of 5.98×10^{24} kg. It can be considered a uniform sphere of radius 6.38×10^{6} m. It rotates on its axis once per 24 hours. What is the angular momentum of the Earth due to this rotation?

    a. $1.13 \times 10^{33} \frac{kg\ m^2}{s}$ b. $7.08 \times 10^{33} \frac{kg\ m^2}{s}$ c. $8.85 \times 10^{33} \frac{kg\ m^2}{s}$
    d. $1.77 \times 10^{34} \frac{kg\ m^2}{s}$ e. $2.55 \times 10^{37} \frac{kg\ m^2}{s}$

12. There are many “fail” videos showing people swinging on a long rope and unable to hold on. This is because, in addition to the force of gravity, their grip must provide the centripetal acceleration. Consider a 61.7 kg swinger starting 3.44 m above the bottom of the arc who swings from the end of a 5.55 m long rope until they reach the bottom of the arc. What is the force with which the hands must grip the rope at that point?

    a. 146 N b. 606 N c. 645 N d. 750 N e. 1360 N

13. An elevator is lifted at a constant velocity to a height of 38.3 m in 21 s. If the elevator and the people inside have a total mass of 665 kg what power is needed in the lifting mechanics to accomplish this?

a. $6.50 \times 10^3 W$ b. $1.19 \times 10^4 W$ c. $2.16 \times 10^4 W$
d. $1.37 \times 10^5 W$ e. $2.50 \times 10^5 W$

14. A squirrel drops an acorn from 22.9 m high in a tree. The acorn drops and strikes a 2.65 kg rock that is at rest at ground level. The acorn bounces a total of 2.15 m high and 1.55 J of mechanical energy was lost by the acorn in the bounce. What impulse does the acorn impart to the rock?

a. $0.112 \frac{kg\ m}{s}$ b. $0.211 \frac{kg\ m}{s}$ c. $2.87 \frac{kg\ m}{s}$ d. $39.0 \frac{kg\ m}{s}$ e. $73.4 \frac{kg\ m}{s}$

15. What speed would a rocket ship have to go in order to have its length shortened by 1% according to an observer at rest relative to the rocket?

a. $1.50 \times 10^6 \frac{m}{s}$ b. $3.00 \times 10^6 \frac{m}{s}$ c. $3.00 \times 10^7 \frac{m}{s}$
d. $4.23 \times 10^7 \frac{m}{s}$ e. $1.41 \times 10^8 \frac{m}{s}$

16. Consider a rock that has been thrown to skip across a smooth pond. When it first hits the water it leaves the surface with a velocity of 6.58 m/s at 8.75° above the surface. How far before the next time it strikes the water?

a. 0.0511 m b. 0.202 m c. 0.671 m d. 1.33 m e. 4.31 m

17. Consider 1.06×10^{24} atoms of an ideal gas in a container at 115° C. This system is allowed to expand isothermally to 4 times its original volume. What is the heat flow into the system during this process?

a. 0.00 J b. 2330 J c. 5670 J d. 6730 J e. 7870 J

18. Ignoring air resistance, the path of a batted baseball is most nearly

a. Is a parabola.
b. Is a hyperbola.
c. Is sinusoidal.
d. Is a straight line.
e. Is circular.

19. What is the torque if the radius vector is $(4\hat{x} + 2\hat{y})m$ and the force vector is $(-5\hat{x} + 7\hat{y})N$.

a. -8 Nm
b. $-6\hat{z}$ Nm

c. $12\hat{z}$ Nm
d. -27 Nm
e. $38\hat{z}$ Nm

20. A solid aluminum cube (density = 2.70×10^3 kg/m^3) that is 5.01 cm on a side is held up by a thin light string. It is partially submerged in water (density = 1.00×10^3 kg/m^3). While partially submerged, the tension in the string is 2.96 N. What fraction of the cube is under water?

a. 0.111 b. 0.301 c. 0.370 d. 0.701 e. 0.883

21. A wire of length 17.0 m and mass 332 g is stretched under a tension of 478 N. How long does it take a transverse pulse generated at one end of the wire to return to that same end?

a. 0.109 s b. 0.217 s c. 0.232 s d. 3.44 s e. 6.87 s

22. Which law or equation relates the net flux of an electric field through a closed surface to the net charge enclosed by that surface?

a. Ampere's Law b. Biot-Savart Law c. Bernoulli's Equation
d. Gauss' Law e. Lenz's Law

23. Use dimensional analysis to find the answer to the following problem:

A rocket is moving at a non-relativistic speed in a gravity free region of space and experiences no atmospheric drag. At some instant, the mass of the rocket is *M* (in kg), it expels fuel mass at the rate *R* (in kg/s) and the expelled fuel has an exhaust velocity relative to the rocket of *u* (in m/s). Relative to an inertial frame, what is the magnitude of the acceleration of the rocket at this instant?

a. $\frac{R}{M\,u}$ b. $R\,M\,u$ c. $\frac{R\,M}{u}$ d. $\frac{R\,u}{M}$ e. $\frac{u^2}{M\,R}$

24. Consider a meteorite of mass 3.85×10^4 kg and moving directly toward the Earth with a speed of 2.75×10^4 m/s. What is its gravitational potential energy when it is a distance of 2.11×10^7 m from the center of the Earth? The mass of the Earth is 5.97×10^{24} kg and the radius of the Earth is 6.37×10^6 m.

a. -7.27×10^{11} J b. -2.41×10^{12} J c. -5.56×10^{12} J
d. -7.97×10^{12} J e. -1.46×10^{13} J

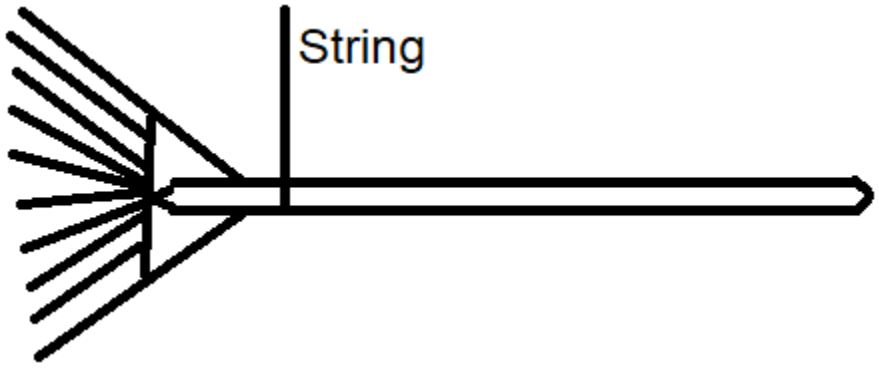
25. As a continuation of the previous problem, consider this meteorite striking the surface of the Earth and giving up its kinetic energy at that point. What would be the energy released in units of the first atomic bomb, which had an energy of 9.20×10^{13} J?

a. 0.0183 b. 0.150 c. 0.158 d. 0.177 e. 5.67

26. A 55.1 kg base runner in a baseball game is running toward 3rd base with a speed of 6.81 m/s. The coefficient of friction between the player and the ground is 0.295 as the player slides. What is the magnitude of the stopping force that the sliding player will feel?

a. 16.3 N b. 23.4 N c. 111 N d. 159 N e. 1830 N

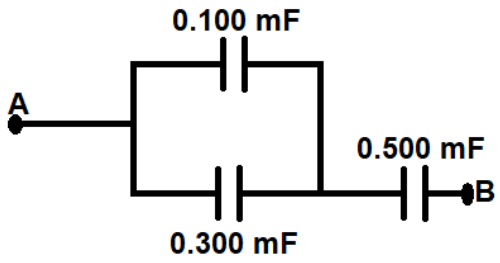
27. Consider a standard broom that is balanced at its center of mass on a string as shown in the picture:



If this broom were cut along the line of the string, how would the masses of the two parts compare?

a. The broom end would have more mass than the handle end.
b. The handle end would have more mass than the broom end.
c. The two pieces would have equal mass.
d. We cannot make a prediction without knowing the mass of the whole broom.
e. The center of mass is not the point where the broom would balance, it is distributed over an area in this case.

28. For the given network of capacitors, what is the capacitance between terminals A and B?



a. 0.0652 mF b. 0.222 mF c. 0.288 mF
d. 0.575 mF e. 0.900 mF

29. Consider two equal-mass billiard balls colliding on a pool table. One is stationary on the table before the collision. By conservation of momentum, what can we say about the motion of the balls after the collision?

a. The angle between their two velocity vectors is always 45° in the center of mass reference frame.

b. The angle between their two velocity vectors is always 45° in the table's reference frame.
c. Because they are equal mass, only one ball can move at a time.
d. The angle between their two velocity vectors is always 180° in the table's reference frame.
e. The center of mass reference frame continues to move at a constant velocity before, during, and after the collision.

30. A bucket of water, total mass of 3.75 kg, is being raised out of a well with a rope. The bucket is moving with a constant acceleration of 1.04 m/s^2. What is the force that the rope exerts on the bucket?

a. 3.90 N b. 32.9 N c. 35.4 N d. 36.8 N e. 40.7 N

31. Consider the following fission reaction:

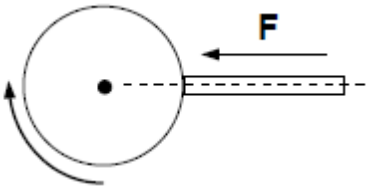
$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{88}_{38}Sr + {}^{136}_{54}Xe + Y\,{}^{1}_{0}n + 127\ MeV $$

What is the value of Y in this equation?

a. 0 b. 2 c. 11 d. 12 e. 127

32. The concept that matter has both wave and particle properties was originally put forth by
a. Heisenberg
b. Einstein
c. Rayleigh
d. Schrödinger
e. de Broglie

33. A 22.0 cm radius grinding wheel is attached to an electric motor. The motor acts with a clockwise torque of 5.20 N·m on the grinding wheel as the wheel rotates as shown in the diagram. A machinist pushes a piece of metal into the grinding wheel with a radial force **F** of magnitude 65.0 N. The angular velocity of the grinding wheel remains constant under these conditions. What is the coefficient of friction between the metal and the grinding wheel?



a. 0.00157 b. 0.0176 c. 0.0800 d. 0.176 e. 0.364

34. A reflection diffraction grating has 3600 grooves per cm. What is the angle between the first order maxima of the red (656 nm) and teal (486 nm) lines from a hydrogen spectrum?

a. 0.0625° b. 3.50° c. 3.58° d. 10.1° e. 13.7°

35. Consider some cesium metal to be used in a photoelectric effect measurement system. Cesium has an atomic mass of 133 AMU and atomic number of 55. Cesium has a density of 1.93 g/cm^3 and a work function of 1.95 eV. In this experiment the maximum kinetic energy of the ejected electrons is found to be 0.315 eV. What is the wavelength of the incident light?

a. 547 nm b. 552 nm c. 636 nm d. 759 nm e. 3940 nm