2017 Academic Challenge

PHYSICS TEST – SECTIONAL

– 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. 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} $C^2/(N \cdot m^2)$
Electrostatic Constant	$k = (4\pi\varepsilon_0)^{-1}$	8.988×10^9 $N \cdot m^2/C^2$
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} $N \cdot m^2/kg^2$
Universal gas constant	R	8.3145 J/(mol·K)

Other information:

Acceleration due to gravity at Earth's surface: $g = 9.80$ m/s^2

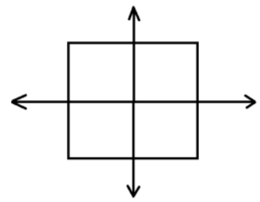
0.00 °C = 273.15 K

WYSE – Academic Challenge
Physics Test (Sectional) – 2017

1. The moment of inertia of a sphere rotating about an axis through its center is $\frac{2}{5}MR^2$, where M is the mass and R is the radius of the sphere. What is the moment of inertia of this sphere about an axis tangent to the surface of the sphere?

a. $\frac{2}{5}MR^2$ b. $\frac{1}{2}MR^2$ c. $\frac{3}{5}MR^2$ d. MR^2 e. $\frac{7}{5}MR^2$

2. A square piece of uniform plywood of mass 25.0 kg is 2.40 m on a side. Its center of mass is placed at the origin as shown. If the part of the plywood in the first quadrant is cut out of the plywood (1/4 of the total removed) what are the x and y coordinates of the center of mass of the remaining piece of plywood?



a. (0.0 m,0.0 m) b. (–0.20 m, –0.20 m) c. (–0.40 m, –0.40 m)
d. (–0.80 m, –0.80 m) e. (–1.20 m, –1.20 m)

3. Examples of leptons in particle physics are

a. pions and kaons. b. protons and neutrons. c. electrons and muons.
d. lambdas and omegas. e. quarks and gluons.

4. A solid sphere of mass 2.00 kg and radius 7.50 cm is rolled from rest down a 10.0˚ incline. The distance it rolls (without slipping) is 50.0 cm. It is timed over many trials and the average result is 0.900 s. This experiment is a way to measure the value of g. What value of g does the experiment in this case yield? (The moment of inertia of a uniform solid sphere of mass M and radius R is $(2/5)MR^2$ about an axis through its center.)

a. 2.49 m/s^2 b. 7.11 m/s^2 c. 9.80 m/s^2 d. 9.95 m/s^2 e. 11.5 m/s^2

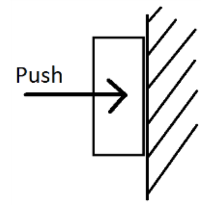
5. In an open, flat stretch of road an unfortunate motorist is stuck with a 1500. kg car whose engine has failed. The motorist is able to push the car forward with a constant force of 400. N. He pushes the car for a total of 50.0 m. Frictional forces impede this effort with a total of 18,000. J of work. If the car started from rest, what speed does it have at the end of the 50.0 m push?

a. 1.63 m/s b. 2.67 m/s c. 3.46 m/s d. 5.16 m/s e. 7.12 m/s

6. In the situation described in the previous problem, the car reaches a speed of 8.00 m/s. At that point, the 100. kg driver jumps in. The horizontal component of his jumping velocity is 12.0 m/s in the direction the car is moving. After he lands in the car and comes to rest relative to the car, what is the speed of the car?

a. 6.75 m/s b. 8.25 m/s c. 8.80 m/s d. 10.0 m/s e. 11.75 m/s

7. A person pushes an oak block into a vertical copper wall. The push is perpendicular to the wall. The coefficient of static friction between oak and copper is 0.521. The mass of the oak block is 1.17 kg. What is the minimum force of the push required to keep the block in place?



a. 2.25 N   b. 5.97 N   c. 11.5 N   d. 22.0 N   e. 30.0 N

8. A mass of 8.00 kg is on a frictionless incline. A force of 40.0 N is applied parallel to the incline to keep the mass in place. What is the angle of the incline?

a. 11.5˚   b. 30.7˚   c. 49.0˚   d. 59.3˚   e. 78.5˚

9. An object is dropped from a height of 6.81 m onto a solid horizontal surface. The coefficient of kinetic friction between the object and the surface is 0.541 and the coefficient of static friction is 0.721. The collision with the surface is totally inelastic. How high will this object bounce?

a. 6.81 m   b. 4.91 m   c. 3.68 m   d. 0.293 m   e. 0.00 m

10. A small flag is attached to a small flagstand on top of a truck. The truck is driving due north with a speed of 25.0 m/s. There is a cross wind of speed 17.4 m/s coming from 45˚ south of east. What direction does the flag point?

a. 0.00˚ from south
b. 0.00˚ from north
c. 45.9˚ south of west
d. 45.9˚ north of west
e. 55.2˚ north of west

11. A projectile is shot with an initial speed of 57.6 m/s from the top of a building 30.0 m high at an angle of 70.0˚ above the horizontal. Assuming no air resistance, find the highest point above the ground reached by this projectile.

a. 30.0 m   b. 49.8 m   c. 149 m   d. 179 m   e. 199 m

12. In the situation described in problem 11, what will be the horizontal distance traveled by the projectile before it reaches the ground?

a. 109 m   b. 149 m   c. 217 m   d. 228 m   e. 627 m

13. Consider a mass of 2.80 kg, resting on a frictionless table and attached to a spring of spring constant 4.35 N/m. The other end of the spring is fixed in place. The spring has an unstretched length of 45.0 cm. The mass is now pulled so that the length of the spring is 55.0 cm. The mass is released and the mass undergoes simple harmonic motion. What is the kinetic energy at the time when the spring is 50.0 cm long?

a. 0.0163J b. 0.114J c. 0.609J d. 163J e. 1142J

14. In a region where the magnetic field of the earth has a magnitude 30.0 μT and points vertically downward, an airplane with a wingspan 12.0 m flies due east at 60.0 m/s. In equilibrium, what is the electric potential difference between the two wing tips?

a. 2.16 mV b. 21.6 mV c. 43.2 mV d. 64.8 mV e. 432. mV

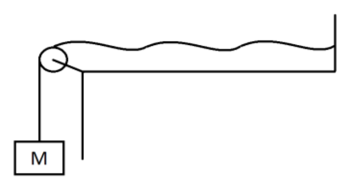
15. A 4.99 Ω resistor is connected in series with a capacitor that has a capacitive reactance 3.33 Ω for a 60.0 Hz sinusoidal signal. What is the magnitude of the equivalent series impedance of these two components?

a. 0.50 Ω b. 2.00 Ω c. 6.00 Ω d. 8.32 Ω e. 500. Ω

16. A cubic container that is 8.00 cm on each side is completely filled with a liquid that has a mass of 1.30 kilogram. The mass density of the liquid is

a. 0.0254 N/m^3. b. 16.3 kg/m^3. c. 203 kg/m^3.
d. 2.54×10^3 kg/m^3. e. 2.54×10^4 N/m^3.

17. A uniform string of mass per unit length 0.0150 kg/m is placed into a system as shown. The pulley shown is frictionless. The string is driven so that a sinusoidal transverse wave appears as shown that can be described by the following equation:



$$y(x,t) = (0.025\ \text{m})\cos(18.9\ \text{m}^{-1}x - 189\ \text{s}^{-1}t)$$

where $y(x,t)$ is the transverse displacement of the string. What is the mass of M shown in the diagram?

a. 0.153kg b. 0.961kg c. 1.50kg d. 9.61kg e. 15.3kg

18. Given a force per volume *f* and a length *L*, which expression has the dimensions of energy?

a. f/L b. fL c. fL^2 d. fL^3 e. fL^4

19. Vector **P** has a magnitude 5.00 and points in the direction 30.0° below the positive x axis. What is the component of vector **P** along the direction 45.0° above the positive x axis?

a. 1.29 b. 3.06 c. 3.54 d. 4.83 e. 18.7

20. An airplane with a mass 3.00×10^6 kg is to take off from a runway that is 1.20 km in length. If it starts from rest, what must its minimum average acceleration be to reach its minimum 80.0 m/s takeoff speed by the time it reaches the end of the runway?

a. 0.067 m/s^2 b. 2.00 m/s^2 c. 2.67 m/s^2 d. 13.3 m/s^2 e. 15.0 m/s^2

21. In the situation described in problem 20, for the plane to reach its takeoff speed in 12.0 s (before reaching the end of the runway) after starting from rest, what must be the average thrust provided by its jet engines during the acceleration?

a. 2.00×10^7 N b. 4.00×10^7 N c. 6.00×10^7 N
d. 8.00×10^7 N e. 9.80×10^7 N

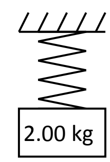
22. A child on a swing reaches the lowest point of her swing with a center of mass speed of 3.00 m/s. If the acceleration of her center of mass at this point is 4.00 m/s^2, what is the distance between the swing support and her center of mass?

a. 0.750 m b. 1.33 m c. 1.80 m d. 2.25 m e. 3.00 m

23. In the situation described in problem 22, what will be the maximum height above the lowest point in the swing reached by the girl's center of mass?

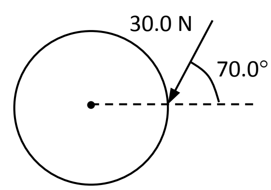
a. 0.153 m b. 0.306 m c. 0.375 m d. 0.459 m e. 0.750 m

24. In the diagram, the spring shown is compressed 3.00 cm from its relaxed length. If the 2.00 kg mass attached to the spring is released from rest at the position in the diagram, it drops 8.00 cm before momentarily coming to rest. What is the spring constant of the spring?



a. 4.90 N/cm b. 7.35 N/cm c. 9.80 N/cm
d. 19.6 N/cm e. 29.4 N/cm

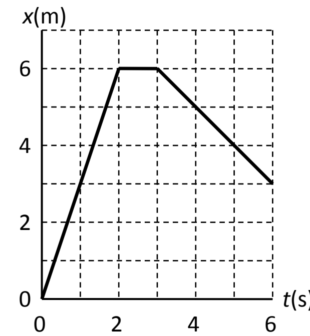
25. The 0.200 m diameter wheel shown in the diagram has a moment of inertia 2.00 kg·m^2 about the axis through the center of the wheel and is acted on by the 30.0 N force, as shown. If the wheel is initially spinning counterclockwise about the axis through the center of the wheel with an angular velocity 10.0 revolutions per second, what will be the angular velocity 40.0 s later?



a. 19.0 revolutions per second counterclockwise
b. 8.97 revolutions per second counterclockwise
c. 1.03 revolutions per second counterclockwise
d. 8.97 revolutions per second clockwise
e. 46.4 revolutions per second clockwise

26. The position of an object in rectilinear motion as a function of time is shown on the graph. What is the average speed during the interval from 0.0 s to 6.0 s?

a. 0.50 m/s
b. 0.67 m/s
c. 1.5 m/s
d. 2.2 m/s
e. 4.3 m/s



27. For the motion described in problem 26, what is the magnitude of the average acceleration of the object between 1.0 s and 5.0 s?

a. 0.0 m/s^2 b. 0.22 m/s^2 c. 0.50 m/s^2 d. 1.0 m/s^2 e. 3.5 m/s^2

28. Action hero A. S. holds a machine gun that fires 400. rounds of ammunition per minute. Each round fires a 60.0 g projectile horizontally at a muzzle speed of 1500. m/s. What average horizontal component of force must A. S. apply to the gun to hold it in place as the gun is fired?

a. 240. N b. 360. N c. 450. N d. 487 N e. 600. N

29. Hooke's law states

a. the compression or extension of a spring from its relaxed length is proportional to the force compressing or stretching the spring.
b. the square of the compression or extension of a spring from its relaxed length is proportional to the force compressing or stretching the spring.
c. the compression or extension of a spring from its relaxed length is proportional to the square of the force compressing or stretching the spring.
d. the cube of the compression or extension of a spring from its relaxed length is proportional to the force compressing or stretching the spring.
e. the cube of the compression or extension of a spring from its relaxed length is proportional to the square of the force compressing or stretching the spring.

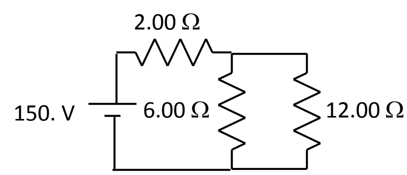
30. A constant mass of monatomic ideal gas expands from 2.00 m^3 to 5.00 m^3 at a constant pressure 2.00×10^5 Pa. If the change in internal energy of the gas during this process is 9.00×10^5 J, how much heat was added to the gas during the process?

a. -2.00×10^5 J b. 0.00 J c. 3.00×10^5 J
d. 4.00×10^5 J e. 15.0×10^5 J

31. A charged particle moves in the plane perpendicular to a uniform magnetic field. It moves along a circular path of radius *R*. It takes time *T* to travel once around the path. If an identical particle moves in the same magnetic field in a circlular path of radius 2.00*R*, how much time does it take to travel once around its circular path?

a. *T*/4.00 b. *T* c. $\sqrt{2.00}\,T$ d. 2.00*T* e. 4.00*T*

32. What is the magnitude of the voltage drop across the $2.00\ \Omega$ resistor in the circuit shown in the diagram?



a. 25.0 V
b. 50.0 V
c. 75.0 V
d. 100. V
e. 125 V

33. Applying the Rayleigh criterion at a wavelength 500. nm, what is the maximum distance from which a car's two headlights can be resolved as two separate light sources by a single human eye, if the headlights are 1.40 m apart and the pupil of the eye has a diameter 8.00 mm?

a. 0.200 km b. 3.59 km c. 5.66 km d. 18.4 km e. 22.4 km

34. A space ship has momentum p when it travels at a speed $0.500c$ (or 1.50×10^8 m/s). What will its momentum be when its speed increases to $0.900c$ (or 2.70×10^8 m/s)?

a. $1.80p$ b. $1.99p$ c. $2.38p$ d. $3.58p$ e. $4.95p$

35. A sample of radioactive isotope A with a mean lifetime 20.0 s contains 8.00×10^{16} isotope A atoms. A sample of radioactive isotope B with a mean lifetime 40.0 s contains 4.00×10^{16} isotope B atoms. How much time will pass before the number of isotope A atoms is the same as the number of isotope B atoms? Note: neither isotope is a decay product of the other.

a. 18.8 s b. 27.7 s c. 30.0 s d. 40.0 s e. 43.8 s