WYSE
Worldwide Youth in Science and Engineering

2015 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} $C^2/(N \cdot m^2)$
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

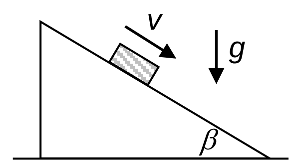
0.00 ^oC = 273.15 K

WYSE – Academic Challenge
Physics Test (Regional) – 2015

1. The dimensionality of torque is

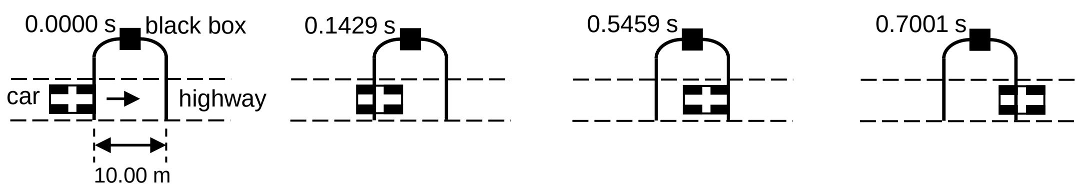
a. $[mass]\cdot[length]$.
b. $[mass]\cdot[length]^2/[time]$.
c. $[mass]\cdot[length]/[time]^2$.
d. $[mass]\cdot[length]^2/[time]^2$.
e. $[mass]\cdot[length]^2$.

2. A uniform block is observed to slide with constant velocity down a stationary inclined plane. Which of the following **must** be known in order to determine the coefficient of kinetic friction between the block and the plane? (m = the block's mass, v = the block's speed, β = the angle between the plane and the horizontal, g = the magnitude of the acceleration due to gravity)



a. β b. v c. m, g, β d. m, v e. m, g, β, v

3. To study the traffic along a certain section of highway, a state department of transportation has laid across one lane of the highway two parallel pneumatic tubes which are 10.00 m from each other, and which are perpendicular to the road way. The tubes are connected to a black box which records the time a tire presses against a tube. The situation is shown below for the four situations: the front tires contact the left tube, the back tires contact the left tube, the front tires contact the right tube, and the back tires contact the right tube. If the times recorded by the black box for these events are (in time order): 0.0000 s, 0.1429 s, 0.5459 s, 0.7001 s, what is the **average speed** of the vehicle according to the **REAR** wheel data?



a. 18.32 m/s b. 11.86 m/s c. 24.81 m/s d. 14.28 m/s e. 17.95 m/s

4. For the situation in problem 3, what is the ratio of the average speed of the car between the last two events compared to the average speed of the car between the first two events? That is, calculate:

v_{ave}(between 0.5459 s and 0.7001 s) / v_{ave}(between 0.0000 s and 0.1429 s).

a. 1.000 b. 0.9267 c. 0.2041 d. 0.2294 e. 1.079

5. An object with mass m_1 and a speed of 23.5 m/s makes a head-on collision with a second object of mass m_2 that is initially at rest. As a result of the collision, the object of mass m_2 acquires a speed of 15.0 m/s, and the object of mass m_1 rebounds in the direction opposite to its initial direction with a speed of 4.00 m/s. The value of m_1/m_2 is

a. 1.87. b. 0.789. c. 1.27. d. 0.529. e. 0.545.

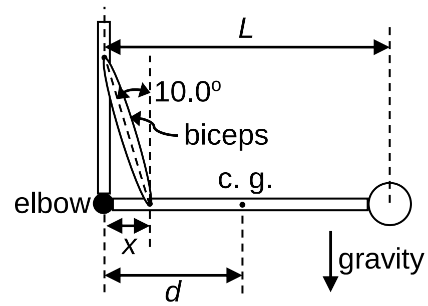
6. If a rocket ship in deep space moves in a straight line with a constant acceleration of magnitude 9.80 m/s^2, how long will it take the ship to acquire a speed of one-hundredth the speed of light, assuming it starts from rest?

a. 2.94×10^7 s b. 3.06×10^5 s c. 7.82×10^2 s d. 5.53×10^2 s e. 3.00×10^6 s

7. How far will the space ship in problem 6 have traveled during the time it takes to come up to the speed of one-hundredth the speed of light?

a. 4.59×10^{11} m
b. 9.17×10^{11} m
c. 1.83×10^{12} m
d. 1.50×10^6 m
e. 3.00×10^8 m

8. A man holds a 154.0 N ball in his hand, with his forearm horizontal and his upper arm vertical, as shown. The man's forearm weighs 22.0 N. The following distances along the forearm have been measured:



x = 0.0480 m (Elbow to biceps connection)

d = 0.150 m (Elbow to center of gravity (c. g.) of forearm)

L = 0.340 m (Elbow joint to ball's center of gravity)

Assuming that the biceps muscle makes an angle of 10.0° to the vertical, what is the magnitude of the force that the biceps exerts on the forearm?

a. 1180 N b. 176 N c. 6680 N d. 55.7 N e. 1160 N

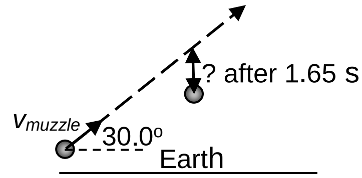
9. An object of mass 0.168 kg oscillates back and forth along the *x*-axis under the influence of a single force given by: $\{-(369\ \text{N/m})x + (93.7N)\}\hat{x}$, where *x* is the position of the object along the *x*-axis, and $\hat{x}$ is a unit vector in the positive *x*-direction. What is the acceleration of the object at *x* = 0.800 m?

a. $0.000\,\hat{x}$ m/s^2
b. $-1.20\ \hat{x}$ km/s^2
c. $-202\ \hat{x}$ m/s^2
d. $-33.9\ \hat{x}$ m/s^2
e. $202\ \hat{x}$ m/s^2

10. For the situation in problem 9, if the maximum *x* coordinate of the object is observed to be 0.800 m, where is the object when it reaches its maximum speed?

a. -0.800 m b. $-\infty$ m c. 0.000 m d. 0.254 m e. 0.800 m

11. A cannonball is fired in the direction indicated by the dashed arrow. Ignoring air friction, and assuming that the cannonball is still in the air, how far below the dashed arrow is the cannonball 1.65 s after being fired?

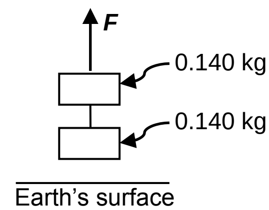


a. 8.08 m b. 13.3 m c. 26.7 m d. 16.2 m e. 131 m

12. If the firing angle in problem 11 is 30.0° above the horizontal, and the cannonball travels a horizontal distance of 248 m during the 1.65 s mentioned in problem 11, what is the cannonball's muzzle speed?

a. 150. m/s b. 130. m/s c. 174 m/s d. 354 m/s e. 473 m/s

13. The system shown to the right consists of two uniform blocks of mass 0.140 kg each which are connected by a light, inextensible string. A constant force ***F*** pulls upward on the system, causing the system to accelerate away from a surface on Earth at a constant rate of 2.20 m/s^2. What is the magnitude of ***F***?



a. 3.36 N b. 0.616 N c. 1.68 N d. 2.74 N e. 1.37 N

14. A boy is sitting on the edge of a merry-go-round, holding onto the railing as it carries him around in a circular orbit at constant speed. Which of the following statements is true?

a. The acceleration of the boy is zero.
b. The net force acting on the boy is radially inward.
c. The net force acting on the boy is in the direction of his velocity.
d. The net force acting on the boy is radially outward.
e. Since his speed is constant, the net force on the boy is zero.

15. The International Space Station (ISS), which has a mass of about 4.20×10^5 kg, orbits the Earth at an average height above the Earth of about 250. km. If the Earth's mass and average radius are, respectively, 5.98×10^{24} kg and 6.38×10^6 m, what is the average magnitude of the acceleration of the ISS? (Treat the orbit as circular, and the mass distribution of the Earth as spherically symmetric.)

a. 0.00 m/s^2 b. 9.80 m/s^2 c. 9.42 m/s^2 d. 9.08 m/s^2 e. 6.38×10^{-19} m/s^2

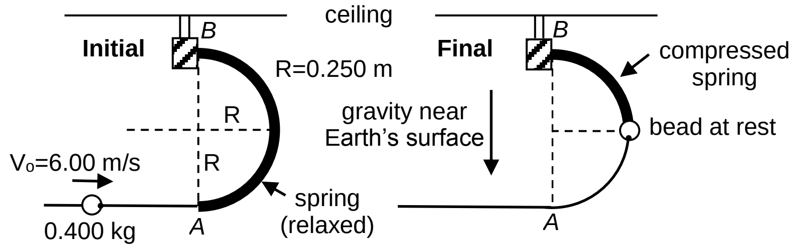
16. A crate slides west across the floor, sliding between two parallel rails that are oriented east to west. In order to alter its speed, you push on the crate with a constant force whose components are 3.50 N east and 6.00 N south. During the time that you push, the crate moves 4.00 m west. How much work have you done on the crate during the crate's displacement?

a. 27.8 J b. 38.0 J c. -14.0 J d. 10.0 J e. -27.8 J

17. A 125 kg object moves along a frictionless, horizontal surface in a straight line with an initial speed of 49.0 m/s. A constant force then acts upon the object in a direction opposite to the object's velocity, causing the object to decelerate at a rate of 2.25 m/s^2 until the object stops. In units of Joules, what total amount of work does the force do in bringing the object to rest?

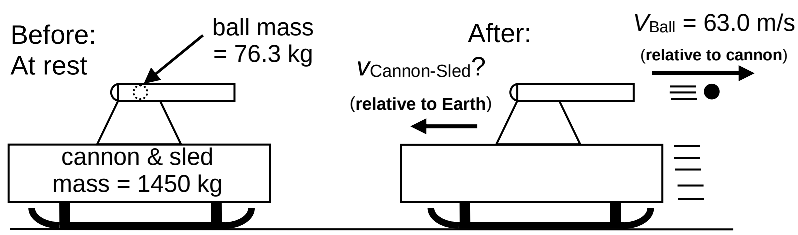
a. -3.00×10^5 b. -281 c. -6.89×10^3 d. -1.38×10^4 e. -1.50×10^5

18. A small bead of mass 0.400 kg slides with speed, V_o = 6.00 m/s, along a frictionless, horizontal wire which bends upward (at point *A*) into a semi-circular curve of radius, R = 0.250 m. A relaxed (uncompressed) spring of negligible mass is anchored at point *B* and is coiled around the wire, extending down along the semi-circle to point *A,* as shown. As the bead contacts the spring at point *A*, it compresses the spring, eventually coming to rest momentarily one-half the way up the semi-circle. Using energy concepts, what is the effective **spring constant** of the spring, assuming that the spring force is proportional to its arc length compression?



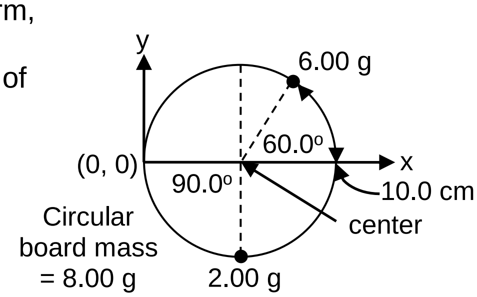
a. 167 N/m
b. 15.8 N/m
c. 40.3 N/m
d. 93.4 N/m
e. 80.7 N/m

19. A cannon is mounted on top of a sled which is able to slide freely along the surface of a frozen lake. The mass of the cannon plus sled is 1450 kg. In addition to this mass, the cannon is loaded with a cannon ball of mass 76.3 kg. The sled is initially at rest. If the cannon then fires the ball horizontally and parallel to the sled's runners with a speed (**relative to the cannon**) of $v_{Ball\ r.t.\ Cannon}$ = 63.0 m/s, what will the Earth-frame speed of the cannon-sled be? ($v_{\text{Cannon-Sled r.t. Earth}}$ = ?)



a. 3.15 m/s
b. 3.32 m/s
c. 3.00 m/s
d. 3.50 m/s
e. 3.71 m/s

20. Two small masses are attached to the face of a uniform, circular board, as shown. If the mass of the board is 8.00 g, what is the x coordinate of the center of mass of the system?



a. 3.44 cm
b. 4.44 cm
c. 5.94 cm
d. 6.62 cm
e. 8.44 cm

21. Beginning from rest, a grindstone rotates through an angle of 8.50 revolutions in a time of 15.0 s. Assuming that the angular acceleration of the wheel was constant during this interval of time, what was the magnitude of this angular acceleration in rad/s^2?
a. 0.487 b. 0.275 c. 0.689 d. 0.475 e. 0.0756

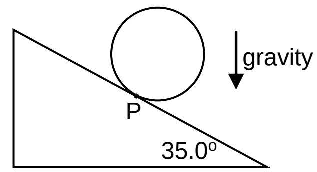
22. A 4.50 kg object undergoes an acceleration given by $\vec{a} = (-12.0\hat{i} + 16.0\hat{j})\,m/s^2$, where $\hat{i}$ and $\hat{j}$ are unit vectors in the x and y directions, respectively. Measured counter clockwise from the positive x axis, what is the **direction of the net force** acting on the object?

a. -36.9^o b. -53.1^o c. 143^o d. 127^o e. 233^o

23. For the situation in problem 22, what is the magnitude of the net force acting on the object?

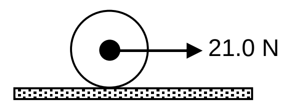
a. 20.0 N b. 126 N c. 18.0 N d. 47.6 N e. 90.0 N

24. A uniform disk of diameter 36.0 cm and mass 2.45 kg rolls without slipping down a plane inclined at an angle of 35.0^o with respect to a horizontal table surface on the Earth. How much torque does Earth's gravity produce with respect to point P, the contact point between the disk and plane?



a. 2.48 Nm b. 3.54 Nm c. 4.32 Nm d. 4.96 Nm e. 13.8 Nm

25. A constant, horizontal force of 21.0 N is applied to a wheel of radius 0.250 m and mass 15.0 kg, as shown. If the wheel rolls without slipping, and the acceleration of the wheel's center of mass is $0.800\ m/s^2$, what amount of frictional force must the pavement exert on the wheel?

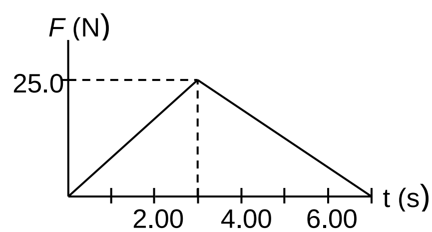


a. 6.00 N b. 9.00 N c. 2.25 N d. 12.0 N e. 3.00 N

26. If the wheel in problem 25 started from rest, what is its angular speed 3.00 seconds later?

a. 9.60 rad/s b. 3.20 rad/s c. 4.80 rad/s d. 6.40 rad/s e. 2.40 rad/s

27. Acting in a constant direction, the force on an 18.0 kg object increases linearly from zero to 25.0 N in 3.00 s, then in the next 4.00 s, the force decreases linearly back to zero. What is the speed of the object after the 7.00 s, assuming that the object started from rest?



a. 0.00 m/s b. 87.5 m/s c. 4.86 m/s d. 9.72 m/s e. 0.694 m/s

28. 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

29. An adiabatic process is a process in which

a. the system's volume is constant.
b. the system does not exchange heat with its surroundings.
c. the temperature of the system remains constant.
d. the volume of the system is constant.
e. the entropy of the system decreases.

30. A traveling wave has a wavelength of 2.80 m and a speed of 365 m/s. What is the angular frequency of the wave?

a. 130 rad/s b. 819 rad/s c. 20.7 rad/s d. 163 rad/s e. 1.02 krad/s

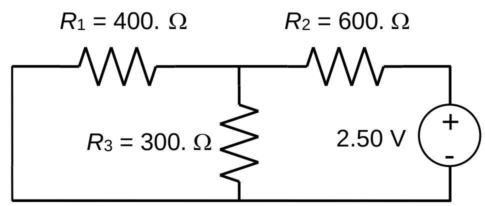
31. When one of NASA's crawler-transporters carries the space shuttle assembly and the mobile launch platform, the total weight, including the crawler-transporter, is about 18 million pounds. The crawler-transporter moves on 8 tracks, each of which is about 10. feet wide by 41 feet long. Assuming that the weight forces are evenly distributed over the full dimension of each track, how does the pressure this assembly exerts on the ground compare to the pressure exerted by a 180 pound person whose shoes **each** measure 0.750 ft long by 0.250 ft in wide? $P_{crawler} / P_{person} = ?$

a. 100,000 b. 45.7 c. 5.7 d. 1600 e. 11

32. According to Bernoulli, if the speed of air flow past the upper surface of an airplane wing is 145 m/s, what must the speed of the air past the lower surface be to cause the pressure on the lower surface to be 1210 Pa greater than the pressure on the upper surface? Assume the density of air to be 1.28 kg/m^3.

a. 148 m/s b. 142 m/s c. 151 m/s d. 138 m/s e. 188 m/s

33. How much power does the voltage source deliver to the following circuit?

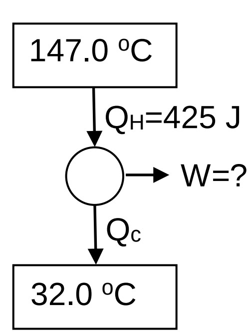


a. 3.24 mW
b. 46.9 mW
c. 4.81 mW
d. 10.4 mW
e. 8.10 mW

34. A wire of length 15.0 m and mass 332 g is stretched under a tension of 454 N. How long does it take a transverse pulse generated at one end of the wire to return to that same end?

a. 0.105 s b. 0.731 s c. 0.209 s d. 6.62 s e. 1.46 s

35. A Carnot cycle engine operates between a hot reservoir temperature of 147.0 ^oC and a cold reservoir temperature of 32.0 ^oC. If the engine absorbs 425 J per cycle from the hot reservoir, how much work per cycle does the engine perform?



a. 332 J
b. 92.5 J
c. 309 J
d. 116 J
e. 76.0 J