2014 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. 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)
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)
Stefan-Boltzmann constant	σ	5.6703×10^{-8} W/(m^2·K^4)

Other information:

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

0.00 ^{o}C = 273.15 K

1 eV = 1.602×10^{-19} J

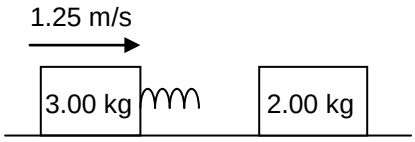
WYSE – Academic Challenge
Physics Test (Sectional) – 2014

1. In the SI system, what are the units of torque divided by power?

   a. [m]
   b. [m]/[s]
   c. $[s]^{-1}$
   d. [s]/[m]
   e. [s]

2. A 3.00 kg block, which is moving to the right at a speed of 1.25 m/s along a frictionless, horizontal surface, has a massless, horizontal spring, with a spring constant of 345 N/m, attached to its right face, as shown. When the spring encounters a 2.00 kg block which is initially at rest, the spring begins to compress. At some instant, the two blocks are found to have the same velocity. At this instant, what is the common speed of the two blocks?

   a. 1.25 m/s
   b. 0.500 m/s
   c. 0.833 m/s
   d. 0.750 m/s
   e. 0.968 m/s



3. During the collision in problem 2, which one of the following statements is true?

   a. The momentum of the 3.00 kg block is conserved.
   b. The total kinetic energy of the two blocks is conserved.
   c. The momentum of the two block system is not conserved because of the spring force.
   d. The total kinetic energy of the two block and one spring system is conserved.
   e. The sum of the kinetic energies of both blocks plus the elastic potential energy of the spring is constant.

4. A projectile is launched with a speed of 56.0 m/s at an angle of 65.1^{o} above the horizontal. Ignoring air friction, what is the ratio of the projectile's speed at the top of its trajectory to the launch speed?

   a. 1.00 b. 0.907 c. 0.421 d. 0.000 e. 0.464

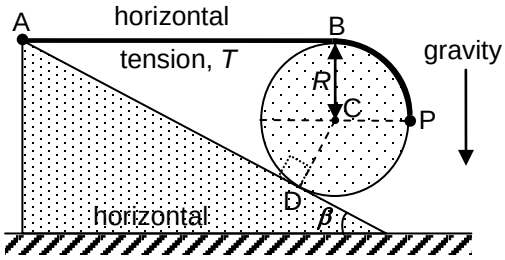
5. Initially the potential energy of a 3.00 kg object in free flight is 46.0 J with respect to the reference level, while its kinetic energy at this instant is 74.0 J. A little later the potential energy of the object is 72.0 J. What is the speed of the object at this later time?

   a. 4.16 m/s b. 7.02 m/s c. 4.00 m/s d. 5.66 m/s e. 16.0 m/s

6. Referring to the same situation as in problem 5, what is the change in elevation of the object, assuming that the object is near the earth's surface?

   a. 0.884 m b. 1.33 m c. 2.65 m d. 8.67 m e. 2.07 m

7. A uniform cylinder of mass *m* and radius *R* rests on an inclined plane, held in static equilibrium by a cord which wraps ¼ of the way around the cylinder and anchors at P, as shown, and by the static friction between the cylinder and the inclined plane which makes an angle β with the horizontal. Which of the following statements must be true?

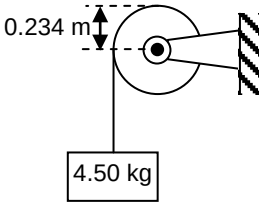


a. With respect to a line perpendicular to the page through point C, the magnitude of the torque produced by the frictional force must be equal to the product, *RT*.
b. With respect to a line perpendicular to the page through point C, the magnitude of the torque produced by gravity is *mgR.*
c. With respect to a line perpendicular to the page through point C, the magnitude of the torque produced by gravity is $mgR\sin(\beta)$.
d. With respect to a line perpendicular to the page through point D, the magnitude of the torque produced by gravity is $mgR\cos(\beta)$.
e. None of the statements above are correct.

8. For the situation in problem 7, which of the following statements must be true? (Note: *f* denotes the magnitude of the friction between cylinder and plane, *N* denotes the magnitude of the normal force between cylinder and plane, and *T* denotes the magnitude of the tension in the cord.)

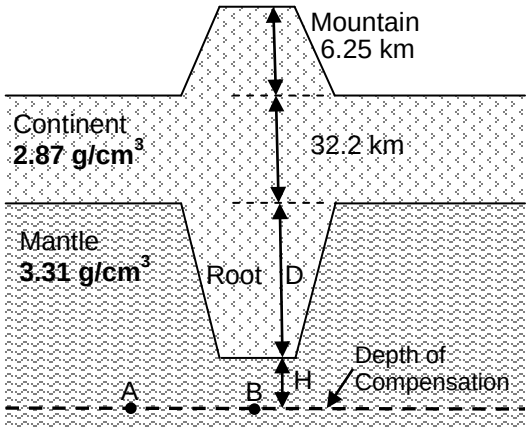
a. $T + mg + f + N = 0$
b. $N - mg\cos(\beta) - T\sin(\beta) = 0$
c. $N - mg\cos(\beta) - T\sin(\beta + \frac{\pi}{2}) = 0$
d. $-T - f\cos(\beta) + N\sin(\beta) + mg\cos(\beta)\sin(\beta) = 0$
e. None of the above are correct statements.

9. A 4.50 kg block is suspended by a thin, massless rope which is wrapped around a wheel of radius 0.234 m that is free to rotate about a frictionless, horizontal axle, as shown. Assuming the rope does not slip on the wheel, if the acceleration of the block is 2.00 m/s^2 downward, what is the moment of inertia of the wheel?



a. 1.21 kg·m^2
b. 1.05 kg·m^2
c. 0.246 kg·m^2
d. 0.961 kg·m^2
e. 4.11 kg·m^2

10. The diagram at right shows a typical situation that occurs in the earth. In order for a mountain to rise above the continent, a "root" must also form underneath. Assuming that the pressure at point A equals the pressure at point B, and that pressure depends on depth as it would in static fluids, what is the depth, D, of the root? (Note that H will cancel from your equation(s).)



a. 40.8 km b. 5.42 km c. 33.3 km d. 8.57 km e. 47.1 km

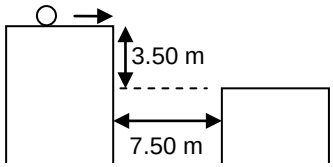
11. A 5.00 kg object has an acceleration of $2.00\ \text{m/s}^2\ \mathbf{i}$ (along the positive x-axis of a coordinate system). What additional force acting on the object would cause the object to have an acceleration of $(1.50\,\mathbf{i} + 1.82\ \mathbf{j})\ \text{m/s}^2$?

    a. $(12.50\,\mathbf{i} + 9.10\ \mathbf{j})\ \text{N}$
    b. $(7.50\,\mathbf{i} + 9.10\ \mathbf{j})\ \text{N}$
    c. $(-3.50\,\mathbf{i} + 1.82\ \mathbf{j})\ \text{N}$
    d. $(-0.500\,\mathbf{i} + 1.82\ \mathbf{j})\ \text{N}$
    e. $(-2.50\,\mathbf{i} + 9.10\ \mathbf{j})\ \text{N}$

12. After spotting a police car, you brake your auto from 78.0 km/h to 42.0 km/h over a distance of 92.0 m. What is the acceleration of your auto, assuming it to be constant?

    a. $1.81\ \text{m/s}^2$ b. $1.96\ \text{m/s}^2$ c. $-1.81\ \text{m/s}^2$ d. $-1.96\ \text{m/s}^2$ e. $-3.62\ \text{m/s}^2$

13. A ball is rolled across the horizontal roof of a building that is 3.50 m higher than the building next to it. If the building next to it is 7.50 m away, how fast must the ball be rolling in order to just make it to the next roof?



    a. 12.5 m/s b. 8.87 m/s c. 10.5 m/s d. 9.79 m/s e. 7.34 m/s

14. In a certain nuclear reaction a deuterium atom reacts with a tritium atom producing an atom of helium-4 and a neutron. How much energy is released in this reaction? Use the following masses: deuterium: 2.0135532 u; tritium: 3.0160493 u; helium-4: 4.0026032 u; neutron: 1.0086649 u; u: $1.6605389 \times 10^{-27}$ kg.

    a. $18.3 \times 10^{-3}\ \text{eV}$
    b. $17.1 \times 10^{6}\ \text{eV}$
    c. $19.0 \times 10^{-11}\ \text{eV}$
    d. $57.0 \times 10^{-3}\ \text{eV}$
    e. $8.54 \times 10^{6}\ \text{eV}$

15. According to the equipartition of energy theorem, the average energy of a gas molecule in a gas that is at a temperature of 154°C, and which contains molecules having 6 degrees of freedom, is

    a. $1.28 \times 10^{-20}\ \text{J}$.
    b. $5.90 \times 10^{-21}\ \text{J}$.
    c. $3.54 \times 10^{-20}\ \text{J}$.
    d. $6.38 \times 10^{-21}\ \text{J}$.
    e. $1.77 \times 10^{-20}\ \text{J}$.

16. Three protons are fixed at the corners of a 3.00 mm, 4.00 mm, 5.00 mm triangle. What is the magnitude of the force on the proton located at the intersection of the 3.00 mm side and the 5.00 mm side?

a. 3.85×10^{-23} N
b. 3.49×10^{-23} N
c. 3.20×10^{-23} N
d. 3.12×10^{-23} N
e. None of the above.

17. The equation of a transverse wave propagating along a taut, uniform string is $y = 0.0352\text{ m}\cos\left[\left(1.45\text{ m}^{-1}\right)x + \left(28.4\text{ s}^{-1}\right)t\right]$. If the density of the string is 1.67×10^{-4} kg/m, what is the tension in the string?

a. 306 N b. 1.62 mN c. 342 N d. 135 mN e. 64.1 mN

18. A camera with a single thin lens of focal length 65.0 mm creates a sharp image of a 175 cm tall person standing 12.0 m in front of the lens. What is the height of the person's image on the film?

a. -65.4 mm b. -9.53 mm c. -9.48 mm d. 9.48 mm e. 65.4 mm

19. An object is thrown vertically upward with a speed 30.0 m/s from an initial height of 2.0 m above the ground. What is the greatest height above the ground reached by the object?

a. 2.96 m b. 30.0 m c. 32.0 m d. 47.9 m e. 91.8 m

20. In the situation described in problem 19, what is the speed of the object 2.00 s after it is released?

a. 0.00 m/s b. 10.4 m/s c. 20.0 m/s d. 16.0 m/s e. 39.6 m/s

21. A car moves around a level 270. m radius curve in a road while its speed is decreasing at a constant rate of 0.400 m/s^2. What is the magnitude of the car's acceleration at the moment its speed is 9.00 m/s?

a. 0.100 m/s^2 b. 0.300 m/s^2 c. 0.400 m/s^2 d. 0.500 m/s^2 e. 0.700 m/s^2

22. An object moves in the x-direction from x = 2.00 m to x = 4.00 m as it is acted on by a force in the positive x-direction with a magnitude F that has a dependence on x given by

$$F = \left(3.00\text{ N/m}\right)x, \text{ for } x \geq 0.$$

What is the work done on the object by the force?

a. 6.00 J b. 8.00 J c. 12.0 J d. 15.0 J e. 18.0 J

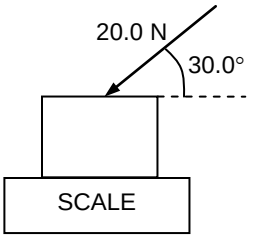
23. An object is initially moving North at a speed 10.0 m/s. After an impulse 80.0 N·s toward the South acts on the object, the object is moving South at 40.0 m/s. What is the mass of the object?

a. 0.375 kg b. 0.625 kg c. 1.60 kg d. 2.00 kg e. 2.33 kg

24. A 50.0 kg block is dragged across a horizontal surface by a 60.0 N force at an angle 20.0° above horizontal. If the block is moving at constant velocity, what is the coefficient of kinetic friction between the block and the horizontal surface?

a. 0.0893 b. 0.120 c. 0.155 d. 0.179 e. 0.875

25. A scale sits on the floor of an elevator near the surface of the earth and is oriented to measure the vertical component of the force on its surface. An 8.00 kg block rests on the scale, and a constant force with magnitude 20.0 N is applied to the top surface of the block as shown. The scale reads 100.0 N under the stated conditions. What is the vertical acceleration of the elevator?



a. 0.00 m/s^2
b. 1.45 m/s^2 upward
c. 3.80 m/s^2 downward
d. 11.3 m/s^2 upward
e. 11.3 m/s^2 downward

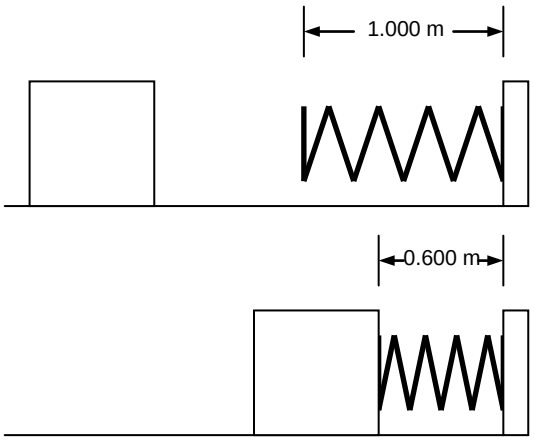
26. A door is initially opened 90.0° degrees from being closed and is at rest. A constant torque 9.00 N·m about an axis parallel to the door hinges acts on the door to close it. If the moment of inertia of the door about its hinges is 5.00 kg·m^2, how much time does it take the door to close?

a. 0.742 s b. 1.09 s c. 1.32 s d. 1.80 s e. 2.25 s

27. Which of the following is not equal to a Joule?

a. N·m b. W·s c. kg·m^2/s^2 d. Pa·m^3 e. N·s/kg

28. A 6.00 kg block is sliding to the right at 3.00 m/s on the level, frictionless surface as shown in the upper diagram. It strikes the end of the spring and compresses it as shown in the lower diagram. When the block is in the position shown in the lower diagram, its speed is 2.00 m/s. What is the spring constant of the spring?



a. 16.7 N/m
b. 37.5 N/m
c. 83.3 N/m
d. 133. N/m
e. 188. N/m

29. The moment of inertia of a 2.00 kg object is 20.0 kg·m^2 about axis A, which passes through the object's center of mass. The moment of inertia is 28.0 kg·m^2 about a second axis B which is parallel to axis A. What is the distance from axis A to axis B?

a. 2.00 m b. 4.00 m c. 8.00 m d. 8.40 m e. 16.0 m

30. The moment of inertia of the body of a helicopter about the main rotor axis is 2.00×10^3 kg·m^2, and the moment of inertia of the main rotor is 1.00×10^2 kg·m^2 about its axis. The main rotor of the helicopter initially spins with angular speed 2.00×10^2 rad/s while the body of the helicopter is not rotating. If both the main rotor and the tail rotor (with negligible angular momentum) lock up simultaneously, what will be the common rotation rate of the body and the main rotor of the helicopter?

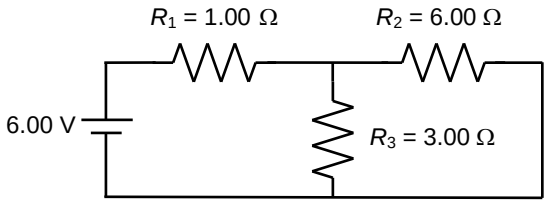
a. 0.00 rad/s b. 4.27 rad/s c. 9.52 rad/s d. 10.0 rad/s e. 11.6 rad/s

31. The ratio of the amplitude of the sinusoidal voltage across a capacitor to the amplitude of the sinusoidal current into the capacitor is called

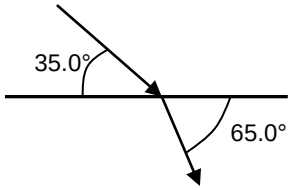
a. resistance b. reactance c. compliance d. capacitance e. susceptance

32. What is the current that flows through the 3.00 Ω in the circuit shown in the diagram?

a. 1.33 A
b. 1.67 A
c. 2.00 A
d. 2.33 A
e. 3.00 A



33. A light ray is incident on a flat surface, traveling from air, with refractive index 1.00, into an unknown material. The light is transmitted through the surface and continues to propagate in the direction indicated. What is the refractive index of the unknown material?



a. 1.11 b. 1.36 c. 1.44 d. 1.58 e. 1.94

34. The surface of a blackbody radiator emits a total power of 1.00 W when the surface is at a temperature 0.00 ºC. What is the total power emitted by the surface when the surface is at a temperature 273.15 ºC?

a. 2.00 W b. 4.00 W c. 16.00 W d. 272.15 W e. 544.30 W

35. In the following fundamental particle decay process, which particle is represented by the ? symbol?

$$n_1^0 \rightarrow ?_1^1 + e_0^{-1} + \overline{\nu}$$

a. electron b. positron c. proton d. neutron e. neutrino