ACADEMIC CHALLENGE FOR ACES ENGINEERING AND SCIENCE

EASTERN ILLINOIS UNIVERSITY

2020 Academic Challenge

PHYSICS TEST – SECTIONAL

Physics Test Production Team

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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 Number of Questions: 35

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 = 9.80 m/s^2

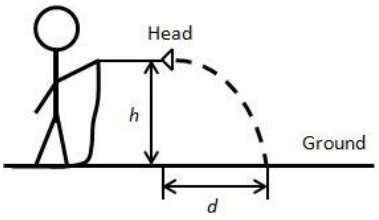
0.00 ^{o}C = 273.15 K

Academic Challenge
2020 Sectional Physics Exam

1. How many milliseconds in one 30 day month?

   a. 2.59×10^3 ms b. 2.59×10^6 ms c. 2.59×10^9 ms d. 1.12×10^5 ms
   e. 1.12×10^8 ms

2. Katie is watering plants in her garden using a wand that is attached to a hose, as shown in the diagram. When the head of the wand is a vertical distance *h* above the ground, water hits plants a horizontal distance *d* from the head. In order to reach plants twice as far, how high should Katie hold the head of the wand above the ground? Assume that water is projected horizontally from the head of the wand and that the flow speed of water at the head remains the same. Ignore air resistance.



   a. 2*h* b. 4*h* c. 6*h* *d.* *h*/2 e. *h*/4

3. The human heart pumps about 50 cm^3 of blood with each pump. Approximately how much blood has the heart of an average 50 year old person pumped in their lifetime?

   a. $9 \times 10^4 l$ b. $9 \times 10^7 l$ c. $9 \times 10^{10} l$ d. $9 \times 10^{12} l$ e. $9 \times 10^{14} l$

4. Consider 4 vectors, all with magnitude 2.50. They have the following angles measured from the +x axis: 65.0˚, 90.0˚, 180˚, and 245˚. What is the vector sum of these 4 vectors?

   a. 10.0 at 0.00˚ b. 3.54 at –45.0˚ c. 3.54 at 45.0˚ d. 3.54 at 135˚ e. 3.54 at 225˚

5. Consider the vectors **A** and **B** where $\vec{A} = 3.00\hat{x} + 2.00\hat{y}$ and $\vec{B} = -1.00\hat{x} + 3.00\hat{y}$. What is the angle between **A** and **B**?

   a. 37.9˚ b. 68.2˚ c. 74.7˚ d. 90.0˚ e. 105˚

6. A Normal Force in physics is

   a. The force exerted on an object by any surface with which it is in contact acting perpendicular to the surface.
   b. The force exerted on an object by a surface acting parallel to the surface.
   c. The pulling force exerted by a rope on an object.
   d. Any force that counteracts the weight of an object whether acting in direct contact or when separated by a long distance.
   e. The force needed to keep an object moving in a circle when in uniform circular motion.

7. A projectile is shot with an initial speed of 55.0 m/s from the top of a building 35.0 m high at an angle of 65.0˚ above the horizontal. Assuming no air resistance, find the highest point above the ground reached by this projectile.

   a. 127 m b. 136 m c. 162 m d. 178 m e. 200 m

8. In the situation described in problem 7, what will be the horizontal distance traveled by the projectile before it reaches the ground?

   a. 236 m b. 252 m c. 274 m d. 295 m e. 320 m

9. Consider a 20.0 kg dog, Daisy, on a leash. Daisy decides to stop the walk and sits on level ground without moving. The coefficient of static friction between Daisy and the ground is 0.631. The leash makes an angle of 18.0˚ with the horizontal. How much force will be needed to pull on the leash to get Daisy to move?

   a. 108 N b. 124 N c. 130 N d. 136 N e. 171 N

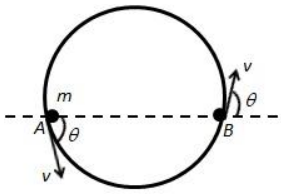
10. A 1200 kg car is being pulled up a hill. The hill makes an angle of 10.0˚ with the horizontal. The chain pulling the car (attached to the tow truck) makes an angle of 25.0˚ above the surface of the hill. The force of the pull is 3000 N. Neglecting friction, what is the acceleration of the car up the hill?

    a. 0.562 m/s^2 b. 0.798 m/s^2 c. 1.68 m/s^2 d. 3.97 m/s^2 e. 7.39 m/s^2

11. A cannon launches a 1.48 kg projectile with an initial velocity of 17.3 m/s at 56.3˚ above the horizontal. Consider the launch point to be the origin. What is the velocity of the projectile the second time that it passes the height of 7.55 m?

    a. 7.69 m/s at 56.3˚ b. 7.69 m/s at 304˚ c. 9.60 m/s at 0.00˚ d. 12.3 m/s at 38.7˚
    e. 12.3 m/s at 321˚

12. A small object of mass *m* moves from *A* to *B* along a circular path, as shown in the diagram. At point *A*, the object is moving at speed *v* at an angle of θ below the horizontal; at point *B*, the object is moving at speed *v* at an angle of θ above the horizontal. If it takes time *t* for the object to move from *A* to *B*, what is the average force that acts on the object during this time?

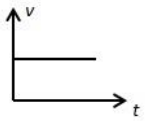


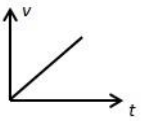
    a. $2mv/t$, upward b. $2mv\cos\theta/t$, upward c. $2mv\cos\theta/t$, downward
    d. $2mv\sin\theta/t$, upward e. $2mv\sin\theta/t$, downward

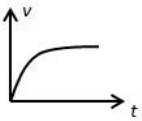
13. The magnitude of air resistance *f* that an object encounters while moving through air can be modeled as $f = (1/2)C\rho Av^2$, where *C* is the drag coefficient, ρ is the density of air, *A* is the frontal area of the object, and *v* is the speed of the object. What are the dimensions of the coefficient *C*?

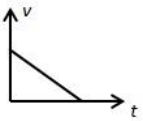
    a. Dimensionless b. [M][L]/[T]^2 c. [M][L]/[T] d. [M][T]/[L]^2 e. [M][L]^2/[T]

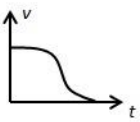
14. Consider the downward fall of a bungee jumper before the bungee cord becomes taut. If the air resistance the jumper encounters is directly proportional to the speed of the jumper, which diagram below correctly shows the relationship between the jumper's speed *v* and time *t* ?

    a. 

    b. 

    c. 

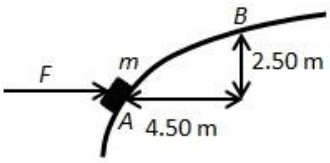
    d. 

    e. 

15. For simplicity assume that the planet Mercury has a circular orbit about the Sun and it rotates about an axis perpendicular to the plane of the orbit. The orbital period of Mercury is 7.60×10^6 s. The rotational period of Mercury is 5.07×10^6 s. The orbital radius of Mercury is 5.79×10^{10} m. What is the speed relative to the Sun, of an object at the north pole of Mercury?

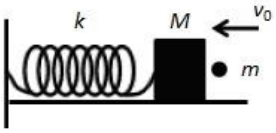
    a. 3.02 m/s b. 464 m/s c. 7.62×10^3 m/s d. 4.79×10^4 m/s e. 7.18×10^4 m/s

16. An object of mass *m* starts at rest at *A* and moves horizontally 4.50 m and vertically upwards a distance of 2.50 m to *B* along a frictionless curved path. A constant horizontal force of magnitude *F* is applied to the object. If *m* = 0.300 kg and *F* = 10.0 N, what is the speed of the object at *B* given the information shown in the diagram?



    a. 18.7 m/s b. 15.8 m/s c. 12.6 m/s d. 10.5 m/s e. 8.66 m/s

17. A small projectile of mass *m* is fired with initial speed v_0 into a block of mass *M* that is initially at rest, as shown in the diagram. The block is attached to one end of a light spring of force constant *k* and can move along a frictionless, horizontal surface. The other end of the spring is attached to a wall. At the moment when the projectile is fired, the spring is at its natural length. The projectile is quickly caught inside the block. If *m* = 5.00 g, *M* = 10.0 g, v_0 = 5.00 m/s, and *k* = 20.0 N/m, what is the speed of the block at the instant when the projectile is stopped inside the block?

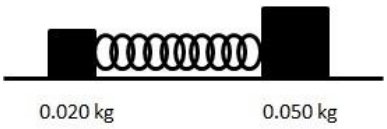


    a. 1.67 m/s b. 1.96 m/s c. 2.57 m/s d. 3.45 m/s e. 4.66 m/s

18. In the situation described in problem 17, what is the maximum compression of the spring?

    a. 8.50 cm b. 7.32 cm c. 6.06 cm d. 4.57 cm e. 3.88 cm

19. Two objects, one of 0.020 kg and the other 0.050 kg, are connected by a light spring and are placed on a frictionless, horizontal surface, as shown in the diagram. The two objects are released from rest when the spring is in a stretched position. What is the speed of the 0.050 kg object when the 0.020 kg object is moving at 3.00 m/s?

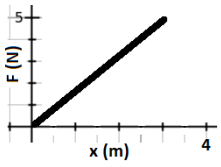


    a. 0 m/s b. 1.20 m/s c. 2.40 m/s d. 3.00 m/s e. 7.50 m/s

20. The planet Romulus is discovered orbiting a star of mass 3.67×10^{30} kg in a circular orbit at a distance of 2.21×10^8 km from the star. How long is the period of one orbit for Romulus? (the Romulan year)

    a. 1.32×10^3 s b. 4.15×10^3 s c. 6.64×10^6 s d. 4.17×10^7 s e. 2.77×10^{14} s

21. Consider this graph of force vs position for an object of mass 2.50 kg. What is the magnitude of the work done in going from x = 1.00 m to x = 3.00 m?



a. 1.60 J b. 4.00 J c. 5.00 J d. 6.00 J e. 6.67 J

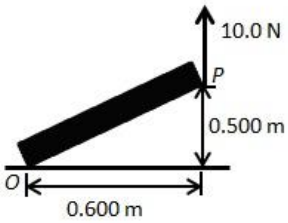
22. In circular motion, the time rate of change of the direction of motion is given by

a. the angular velocity b. the linear velocity c. the linear acceleration
d. the angular acceleration e. the radial component of the linear acceleration

23. A 850 kg Cessna 172 airplane has an engine that is producing 2090 N of thrust to maintain a constant speed of 51.4 m/s. What is the power output of this engine in that situation?

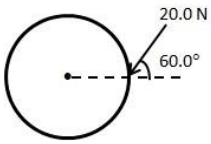
a. 4.37×10^4 W b. 1.07×10^5 W c. 2.14×10^5 W d. 2.25×10^6 W e. 9.10×10^7 W

24. A person supports one end of a bookcase at point *P* with an upward force of 10.0 N. The other end of the bookcase rests on the floor at point *O*. The horizontal and vertical distances from point *P* to point *O* are 0.600 m and 0.500 m, respectively, as shown in the diagram. What is the torque applied by the 10.0 N upward force about point *O*?



a. 0 Nm b. 5.00 Nm c. 6.00 Nm d. 7.81 Nm e. 10.0 Nm

25. The 0.300 m diameter wheel shown in the diagram has a moment of inertia 4.00 kg·m^2 about the axis through the center of the wheel and is acted on by the 20.0 N force, as shown. If the wheel is initially spinning counterclockwise about the axis through the center of the wheel with an angular velocity 20.0 revolutions per second, what will be the angular velocity 50.0 s later? Ignore friction.

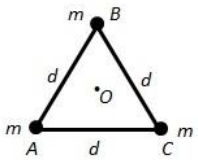


a. 20.0 rev/s clockwise b. 25.2 rev/s clockwise c. 14.8 rev/s clockwise
d. 25.2 rev/s counterclockwise e. 14.8 rev/s counterclockwise

26. A small statue of a ballerina is located 1.50 m from a converging lens. The image of the ballerina has a magnification of −0.113. What is the focal length of the lens?

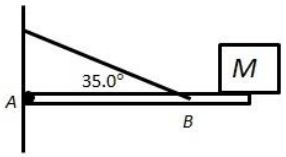
a. 10.5 cm b. 15.2 cm c. 17.0 cm d. 19.1 cm e. 135 cm

27. A machine part consists of three weights, *A*, *B*, and *C*, of equal mass *m* and three light connecting rods of equal length *d*, as shown in the diagram. The moment of inertia about the axis through center *O* is I_1 and that about the axis through the center of weight *A* is I_2. Both axes are perpendicular to the page. What is the relationship between I_1 and I_2?



a. $I_2 = I_1$ b. $I_2 = 2I_1$ c. $I_2 = 3I_1$ d. $I_1 = 2I_1$ e. $I_1 = 3I_2$

28. The left end of a 20.0 kg horizontal uniform beam of length 2.00 m is attached to the vertical wall by a frictionless pin at point *A*. The beam is also supported by a 35.0° cable attached to the wall and to point *B*, which is a distance 1.50 m from the left end of the beam. The cable will break if the tension in the cable exceeds 450 N. What will be the maximum mass *M* placed at the end of the beam that this structure will support?



a. 6.55 kg b. 7.86 kg c. 9.75 kg d. 12.8 kg e. 20.0 kg

29. Three charges, 3.15 μC, 1.25 μC, and −2.65 μC are located at (0.00, 2.50 m), (−1.75 m, 0.00), and (2.00 m, 0.00) respectively. What is the magnitude and direction of the resulting electric field at the origin?

a. 5.08×10^3 N/C at 24.3° b. 5.08×10^3 N/C at 63.2° c. 5.10×10^3 N/C at 0.00°
d. 1.07×10^4 N/C at 25.2° e. 1.07×10^4 N/C at 335°

30. In the Bohr model of the Hydrogen atom what is the wavelength of the electromagnetic radiation given off in the transition from $n = 11$ to $n = 4$? The Rydberg constant is 1.097×10^7 m^{-1}.

a. 365 nm b. 573 nm c. 638 nm d. 1290 nm e. 1680 nm

31. Gauss' Law states that:

a. The total electric flux through a closed surface equals a constant times the total charge enclosed by the surface.
b. The algebraic sum of all the electric charges in any closed system is constant.
c. The magnitude of the electric force between two point charges is inversely proportional to the square of the distance between them.
d. The algebraic sum of the currents into any circuit junction must be zero and the algebraic sum of the potential differences around any circuit loop must be zero.
e. The line integral of the magnetic field around any closed path is equal to a constant times the net current through the area enclosed by the path.

32. What speed would a muon, of rest mass 1.89×10^{-28} kg, need in order to have a total energy equal to the rest energy of a proton, 938 MeV?

a. 0.897*c* b. 0.942*c* c. 0.987*c* d. 0.994*c* e. 4.21*c*

33. Consider a steel support for a bridge standing vertically in seawater with a depth of 30.0 m. A scuba diver is inspecting it at a depth of 25.0 m. A sharp noise is created at the surface of the water in the steel so that the sound from the noise travels to the scuba diver through the steel but also through the water. What is the time between when the scuba diver hears the sound through the steel and when she hears it through the water? The bulk modulus of steel is 163×10^9 Pa and of seawater is 2.34×10^9 Pa. The density of steel is 8050 kg/m^3 and of seawater is 1029 kg/m^3.

a. 5.56×10^{-3} s b. 6.10×10^{-3} s c. 1.11×10^{-2} s d. 1.66×10^{-2} s e. 7.29×10^{-2} s

34. Consider a coal power plant operating as a Carnot engine with a hot reservoir at 349 ˚C. The power plant uses coal with a heat of combustion of 2.65×10^7 J/kg to produce 1500 MW continuously. The efficiency of this plant is 40.8%. What is the temperature of the cold reservoir?

    a. 95.0 K b. 207 K c. 317 K d. 368 K e. 480 K

35. As a continuation of problem 34: How much coal does this plant use in one day?

    a. 56.0 kg b. 1.20×10^4 kg c. 4.89×10^6 kg d. 8.26×10^6 kg e. 1.20×10^7 kg