Mu

Math in Physics

Test #133

Directions:

1. Fill out the top left section of the scantron. Do not abbreviate your school name.

2. In the Student ID Number grid, write your 9-digit ID# and bubble.

3. In the Test Code grid, write the 3-digit test# on this test cover and bubble.

4. Scoring for this test is 5 times the number correct plus the number omitted.

5. TURN OFF ALL CELL PHONES.

6. No calculators may be used on this test.

7. Any inappropriate behavior or any form of cheating will lead to a ban of the student and/or school from future National Conventions, disqualification of the student and/or school from this Convention, at the discretion of the Mu Alpha Theta Governing Council.

8. If a student believes a test item is defective, select "E) NOTA" and file a dispute explaining why.

9. If an answer choice is incomplete, it is considered incorrect. For example, if an equation has three solutions, an answer choice containing only two of those solutions is incorrect.

10. If a problem has wording like "which of the following could be" or "what is one solution of", an answer choice providing one of the possibilities is considered to be correct. Do not select "E) NOTA" in that instance.

11. If a problem has multiple equivalent answers, any of those answers will be counted as correct, even if one answer choice is in a simpler format than another. Do not select "E) NOTA" in that instance.

12. Unless a question asks for an approximation or a rounded answer, give the exact answer.

Assume $g = \frac{GM_e}{r_e^2} = 10m/s^2$ unless specified otherwise.

1. A ball with mass *m* projected horizontally off the end of a table with an initial speed *V*. At a time *t* after it leaves the end of the table it has twice the kinetic energy. What is *t*? Neglect air resistance.

   A. $\frac{V}{g\sqrt{2}}$ B. $\frac{V}{g}$ C. $\frac{V\sqrt{2}}{g}$ D. $\frac{2V}{g}$ E. NOTA

2. A parallel-plate capacitor has a capacitance C_o. A second parallel-plate capacitor has plates with twice the area and twice the separation. Which of these is the closest to the capacitance of the second capacitor?

   A. ¼ C_o B. ½ C_o C. C_o D. 2 C_o E. NOTA

3. A uniform disk starts from rest on the y-axis at $(0, 1)$ and rolls without slipping down an incline of length $\sqrt{5}$ which meets the x-axis at $(2, 0)$. The disk then continues across a smooth horizontal surface of length 1 and up a long frictionless $45°$ incline. What is the maximum product of its coordinates?

   A. 3 B. 4 C. 22/9 D. 16/3 E. NOTA

4. If I is current, t is time, E is electric field intensity, and x is distance, then the ratio of $\int I\,dt$ to $\int E\,dx$ has units equivalent to which of these?

   A. coulombs B. joules C. farads D. henrys E. NOTA

5. Taking the earth to be a uniform sphere with radius 6,400km, then what would be the magnitude of the gravitational field due to earth at a location 3,200km above the surface?

   A. 40/9 N/kg B. 60/9 m/s^2 C. 0 N/kg D. 10 m/s^2 E. NOTA

6. For the same earth described in the previous question what would be the gravitational field at a location with half of the separation to the center as defined in Newton's Universal Law of Gravitation?

   A. 160/9 N/kg B. 240/9 m/s^2 C. 0 N/kg D. 7.5 m/s^2 E. NOTA

7. A solid insulating sphere with constant charge density ρ C/m^3 is electrically isolated. The distance to the center of the sphere from some point inside its surface is "r". In the function that describes the electric field inside the sphere what is the exponent on "r"?

A. -2 B. -1 C. 0 D. 1 E. NOTA

8. Two conducting spheres share the same center. The inner sphere is solid with radius 1 cm and the outer sphere is a shell with inner radius 3cm and outer radius 4cm. The total charge on the inner sphere is 1 nC and the total charge on the outer sphere is –4nC. What is the charge on the outer surface of the outer sphere?

A. –5nC B. –4nC C. –3nC D. 0nC E. NOTA

9. A particle with charge 2 C is at position x=0 and in an electric field E(x) = X^2-1. What is the work required to move the particle to position x=2 at constant velocity?

A. 4 J B. 7 J C. 8 J D. 14 J E. NOTA

10. Given a solid uniform sphere with mass 1kg and radius 2m is rotating such that it completes 1 revolution every minute, then how long would it take to complete a revolution if it is compressed into a sphere with radius 1m in the absence of an external torque?

A. 30 s B. 15 s C. 7.5 s D. 60 s E. NOTA

11. An equilateral triangle has sides of length s and charges x, $2x$, and $3x$ on its vertices. What is the electric potential due to these charges at its centroid? k is coulomb's constant.

A. 0 B. $\frac{2kx}{s\sqrt{3}}$ C. $\frac{6kx\sqrt{3}}{s}$ D. $\frac{6kx}{s}$ E. NOTA

12. If the centroid of the triangle in the previous question were placed at the center of a hollow conducting sphere with radius s, then what would be the total electric flux through the surface of the sphere? ϵ_0 is the permittivity of free space.

A. 0 B. $\frac{3x}{\epsilon_0}$ C. $-\frac{3x}{\epsilon_0}$ D. $\frac{6x}{\epsilon_0}$ E. NOTA

13. A conducting sphere with radius r has surface charge density σ and a second conducting sphere with radius 2r has surface charge density .75σ. If a wire from the surface of each sphere is connected to opposite sides of a parallel plate capacitor with capacitance C, then what would be the magnitude of the electric potential between the capacitor plates when it has reached equilibrium?

A. $-\sigma 6\pi kr$ B. $\sigma 6\pi kr$ C. $\sigma 4\pi kr$ D. $\sigma 2\pi kr$ E. NOTA

14. For the same situation from the previous question what total charge magnitude would accumulate on the capacitor plates when it has reached equilibrium?

A. 0 B. $C\sigma 6\pi kr$ C. $C\sigma 4\pi kr$ D. $C\sigma 2\pi kr$ E. NOTA

15. A cannon is on the ground pointing straight up and another cannon is on a 150m building pointed straight down towards the first cannon. The first cannon fires a ball at 100 m/s while the second cannon fires a ball at 50 m/s at the same time. At what height above the first cannon do these shots meet?

A. 75 m B. 55 m C. 100 m D. 95 m E. NOTA

16. Positive charge Q is uniformly distributed over a thin ring of radius a that lies in a plane perpendicular to the x-axis. with its center at the origin 0. The potential V at points on the x-axis is represented by which of the following functions?

A. $V(x) = \frac{kq}{x^2+a^2}$ B. $V(x) = \frac{kQ}{\sqrt{x^2+a^2}}$

C. $V(x) = kQ/x^2$ D. $V(x) = \frac{kQ}{x}$ E. NOTA

17. A circuit contains an initially uncharged 1F capacitor, 1Ω resistor and a 9V battery in series. V(t) is the voltage across the capacitor as a function of time. What is the instantaneous rate of change of voltage across the capacitor at time 2s?

A. $9e^2$ B. $-9e^2$ C. $9e^{-2}$ D. $-9e^{-2}$ E. NOTA

18. Two 2kg blocks are stacked one top of another and at rest on a table. If the coefficients of friction for all surfaces are 2 then what is the maximum force that can be applied to the bottom block without the top block slipping?

A. 40N B. 160N C. 80N D. 120N E. NOTA

19. A 10kg box is moving 30 m/s up a rough incline, which makes an angle of 45° with the horizon. The coefficient of friction between the box and the slope is 1. How far will the box move along the incline before ever coming to rest?

A. $\frac{30}{10\sqrt{2}-5}$ B. $\frac{30}{10\sqrt{2}}$ C. 6 D. 10 E. NOTA

20. What is the time constant for a DC circuit containing a 3V battery, a 1F capacitor, a 2F capacitor, a 3F capacitor, a 2Ω resistor and a 3 Ω resistor all connected in series?

A. 30/11 s B. 15/11 s C. 30 s D. 5/11 s E. NOTA

21. The emf of a battery is 9V. When the battery is connected to a load it delivers a current of 1A and the terminal voltage is 6V. What is the internal resistance of the battery?

A. 0 Ω B. 1.5 Ω C. 3 Ω D. 6 Ω E. NOTA

22. A long wire, fixed in space, carries current I and a proton a distance d away moves at speed v in the same direction as I. The force of attraction has magnitude F. What change will give an attractive force of magnitude 4F?

A. The proton is changed to an alpha particle. B. d is changed to 4d.

C. v is changed to 4v. D. I doubles. E NOTA

23. If a new planet has twice the density of Earth but only 2/5 of the radius then which of these is closest to the surface gravitational field of the new planet?

A. 4 m/s^2 B. 3.2 m/s^2 C. 8 m/s^2 D. 62.5 m/s^2 E. NOTA

24. If a planet in an elliptical orbit around a star is moving 29.25 km/s at the point closest to the star and 13 km/s at the point farthest away then how fast will it move when it is at the point in its orbit closest to the center of its orbit?

A. $13\sqrt{2}$ km/s B. $10\sqrt{6}$ km/s C. 19.5 km/s D. 25 km/s E. NOTA

25. Capacitors X, Y, and Z with capacitances $C_X, C_Y,$ and C_Z respectively with $C_Y = 2C_X$ and $C_Z = 3C_X$. If they are in a circuit so that X and Y are parallel to each other while they are in series with Z and C_{eq} is the equivalent capacitance of the three, then what is C_{eq}/C_X?

A. 1 B. 6 C. 4 D. 5/6 E. NOTA

26. A wire of radius R has a current I uniformly distributed across its cross-sectional area. Ampere's law is used with a concentric circular path of radius r, with r < R, to calculate the magnitude of the magnetic field B at a distance r from the center of the wire. Which of the following equations results from a correct application of Ampere's law to this situation?

A. $B(2\pi r)=\mu_o I$ B. $B(2\pi r)=\mu_o I(r^2/R^2)$ C. $B(2\pi r)=0$ D. $B(2\pi R)=\mu_o I$ E NOTA

27. A circular current-carrying loop lies so that the plane of the loop is perpendicular to a constant magnetic field of strength B. Suppose that the radius R of the loop could be made to increase with time t so that $R = at$, where a is a constant. What is the magnitude of the emf that would be generated around the loop as a function of t?

A. $2\pi Ba^2t$ B. $2\pi Bat$ C. $2\pi Bt$ D. πBa^2t E. NOTA

28. A loop of wire with area $2m^2$ and current in amps $I(t) = 1 + t$ is in a magnetic field $B(t) = 1 + t^2$ measured in teslas. If the field and moment of the loop are always perpendicular, then what is the magnitude of the rate of change of the torque on the loop due to the magnetic field as a function of time at time t=2s?

A. 0 B. 34 C. 48 D. 24 E. NOTA

29. What is the rate at which a planet of mass M and radius r is doing work on a small ball of mass m falling without drag from far far away and starting at rest at the point when the ball is 5r away from the center of the planet?

A. $\sqrt{\frac{2G^3M^3m^2}{3125r^5}}$ B. $\sqrt{\frac{2G^3M^3m^2}{25r^5}}$

C. $GMm/25r^2$ D. $\frac{2GMm}{25r^2}$ E. NOTA

30. What is the acceleration of a ball in m/s^2 as a function of time near the Earth's surface. The ball has mass M, constant drag coefficient b so that the drag force $F_D = bV$ and terminal velocity V_t? The ball starts from rest at time t=0.

A. 10 B. $10M - bV$

C. $10e^{-\frac{bt}{M}}$ D. $10 - 10e^{\frac{V}{V_t}}$ E. NOTA