Important: The first question identifies the version of the test you have.

1. Enter the answer **b** for this question on your answer sheet.

2. The potential energy of a 2.5 kg particle moving along the x-axis is given by $U(x) = 10x^2 - 30x$, where U is in Joules and x is in meters. When the particle is at position $x = 1.0$ m, its acceleration is (in m/s^2):

   a. 0 b. -10 c. -4 d. 4 e. 10

3. At time $t = 0$ a particle starts moving along the x-axis. If its kinetic energy increases linearly with t, the net force acting on it must be:

   a. constant b. proportional to t c. proportional to $1/t$
   d. proportional to $\sqrt{t}$ e. proportional to $1/\sqrt{t}$

4. A circular ring of radius R lies in the x-y plane, centred on the origin. The ring is uniformly charged, with linear charge density λ. If the ring creates an electric field of $E_z = -26$ N/C at position $z = 3R$ on the z-axis, the electric field at $z = -2R$ on the z-axis is approximately (in N/C):

   a. 49 b. 35 c. -35 d. -39 e. -49

5. An infinite plane of surface charge density σ lies in the xy-plane, i.e. the $z = 0$ plane. A second infinite plane of surface charge density -2σ lies in the $z = d$ plane, i.e. parallel to the xy-plane but shifted in z. If $\sigma > 0$ and $d > 0$, then the z-component of the electric field at $z = -d$ is:

   a. $\sigma/2\epsilon_0$ b. σ/ϵ_0 c. $-3\sigma/2\epsilon_0$ d. e. $-\sigma/\epsilon_0$ $-\sigma/2\epsilon_0$

6. A disc of radius 10 cm carries a uniform surface charge density of 6.0×10^{-8} C/m^2. The electric field on the axis of the disc at a distance of 10 cm is (in N/C)

   a. 3.4×10^3 b. 6.8×10^2 c. 9.9×10^2 d. 5.4×10^3 e. 1.8×10^2

7. An 0.25 kg block oscillates on the end of a spring with a spring constant of 200 N/m. If the system has an energy of 6.0 J, then the maximum speed of the block is:

   a. 0.06 m/s b. 0.17 m/s c. 0.24 m/s d. 4.9 m/s e. 6.9 m/s

8. Let the displacement of the mass on the spring in the above question be $x(t) = x_m \cos(\omega t + \phi)$. If the velocity and displacement of the mass are both negative at time $t = 0$, then the value of the constant ϕ (in radians) is between

   a. 0 and $\pi/2$ b. $\pi/2$ and π c. π and $3\pi/2$ d. $3\pi/2$ and 2π
   e. None of the above; ϕ is exactly 0, $\pi/2$, π, or $3\pi/2$.

9. A positive charge $q/2$ is uniformly distributed on a thin, spherical, hollow shell of radius R. A point charge $-q/2$ is placed at the centre of the cavity. The magnitude of the electric field in the cavity at a distance r from the centre is
   a. $q/(2\pi\epsilon_0 r^2)$ b. $q/(4\pi\epsilon_0 r^2)$ c. $q/(4\pi\epsilon_0 R^2)$ d. 0 e. $q/(8\pi\epsilon_0 r^2)$

10. A 20 kg block on a horizontal surface is attached to a light spring of force constant 8.0×10^3 N/m. The block is pulled 10 cm to the right from its equilibrium position and released from rest. When the block has moved 2.0 cm toward its equilibrium position, its kinetic energy is 13 J. How much work is done by the frictional force on the block as it moves the 2.0 cm?
    a. -2.5 J b. -1.4 J c. -3.0 J d. -1.9 J e. 1.9 J

11. A small object of mass m, on the end of a light cord, is held horizontally at a distance r from a fixed support as shown. The object is then released. What is the tension force of the cord when the object is at the lowest point of its swing?
    

    a. $3mg$ b. $2mg$ c. mg d. $mg/2$ e. mgr

12. Chooose the correct statement concerning electric field lines:
    a. field lines may cross
    b. field lines are closer together at positive charges than at negative charges
    c. field lines point away from negative charge
    d. a point charge released from rest moves along a field line
    e. none of these are correct

13. Particles 1 and 2 have charge q_1 and q_2, respectively. The two particles lie on the x-axis, with particle 1 at $x = -a$ and particle 2 at $x = -2a$. For the net force to be zero on a third charged particle placed at the origin, the ratio q_2/q_1 must be:
    a. 2 b. 4 c. -2 d. -4 e. $1/4$

14. Consider Gauss' law: $\oint \vec{E}\cdot d\vec{A} = q/\epsilon_0$. Which of the following is true?
    a. $\vec{E}$ must be the electric field due to the enclosed charge.
    b. If $q = 0$, then $\vec{E} = 0$ everywhere on the Gaussian surface.
    c. If the charge inside consists of an electric dipole, then the integral is zero.
    d. On the surface $\vec{E}$ is everywhere parallel to $d\vec{A}$.
    e. If a charge is placed outside the surface, then it cannot affect $\vec{E}$ at any point on the surface.

15. An infinite line charge $\lambda = 0.30\ \mu$C/m lies along the z-axis and a point charge $q = 6.0\ \mu$C lies on the y-axis at $y = 2.0$ m. The x-component of the electric field at position $x = 3.0$ m on the x-axis is (in N/C)
    a. 1.8×10^3 b. 4.2×10^3 c. 0.96×10^3 d. 5.3×10^3 e. 0.64×10^{-3}

2. (d) $F_x = -\frac{dU(x)}{dx} = -\frac{d}{dx}(10x^2-30x) = -(20x-30)$ at $x=1.0\,m$
$= -(20\cdot 1-30) = 10\,N$

$a_x = \frac{F_x}{m} = \frac{10N}{2.5\,kg} = 4.0\,m/s^2$

3. (e) $K = ct$ with $c>0$ const. ∵ "at $t=0$ particle starts moving" and "kinetic energy increases linearly with t"

$\therefore \frac{1}{2}mv^2 = ct \Rightarrow v = \left(\frac{2ct}{m}\right)^{1/2}$

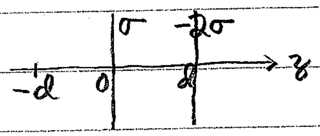
$\therefore F = m\frac{dv}{dt} \propto t^{-1/2}$

4. (a) $E_z = \frac{qz}{4\pi\varepsilon_0(R^2+z^2)^{3/2}} \Rightarrow \frac{E(z_2)}{E(z_1)} = \frac{z_2}{(R^2+z_2^2)^{3/2}}\frac{(R^2+z_1^2)^{3/2}}{z_1}$ with $z_1 = 3R$, $z_2 = -2R$

$\frac{E(z_2)}{E(z_1)} = \frac{-2R}{(R^2+(2R)^2)^{3/2}}\frac{(R^2+(3R)^2)^{3/2}}{3R} = -\frac{2}{3}\left(\frac{10}{5}\right)^{3/2} = -1.89$

$\therefore E(z_2) \cong -1.89\,E(z_1) = -1.89(-26\,N/C) \cong 49\,N/C$

5. (a)



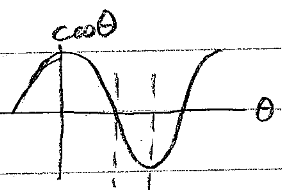
$E_z(-d) = -\frac{\sigma}{2\varepsilon_0} - \frac{(-2\sigma)}{2\varepsilon_0} = -\frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{\varepsilon_0} = \frac{\sigma}{2\varepsilon_0}$

6. (c) $E_z = \frac{\sigma}{2\varepsilon_0}\left(1-\frac{z}{(R^2+z^2)^{1/2}}\right) = \frac{(6\cdot 10^{-8}\,C/m^2)}{2\cdot 8.85\cdot 10^{-12}\,C^2/Nm^2}\left(1-\underbrace{\frac{0.1}{(0.1^2+0.1^2)^{1/2}}}_{1/\sqrt{2}}\right) = 9.9\cdot 10^2\,\frac{N}{C}$

7. (e) $E = U + K = \frac{1}{2}kx^2 + \frac{1}{2}mv^2 \Rightarrow \frac{1}{2}mv_{max}^2 = E$

$v_{max} = \left(\frac{2E}{m}\right)^{1/2} = \left(\frac{2\cdot 6.0\,J}{0.25\,kg}\right)^{1/2} = 6.9\,m/s$

8. (b)



here $\cos\theta < 0$ and $\frac{d\cos\theta}{d\theta} < 0$ where $\theta = \omega t + \phi = \phi$ for $t=0$

$\therefore x(t) < 0$ $\quad \therefore \frac{dx}{dt} = x_m \underbrace{\frac{d\theta}{dt}}_{\omega}\frac{d\cos\theta}{d\theta} < 0$

i.e. $\frac{\pi}{2} < \phi < \pi$

9. Uniformly charged shell gives no contribution to $\vec{E}$ <u>inside</u>.

(e) $\therefore$ $\vec{E}$ inside is due to point charge $-q/2$ at origin only.

$\therefore \vec{E} = E\hat{r}$ where $|E| = \left|\dfrac{-q/2}{4\pi\varepsilon_0 r^2}\right| = \dfrac{q}{8\pi\varepsilon_0 r^2}$

10. $E_i = \frac{1}{2}m\underbrace{v_i^2}_{0} + \frac{1}{2}kx_i^2 = \frac{1}{2}(8\cdot10^3\,\frac{N}{m})(0.1\,m)^2 = 40\,J$

(b) $U_f = \frac{1}{2}kx_f^2 = \frac{1}{2}(8\cdot10^3)(0.08\,m)^2 = 25.6\,J$

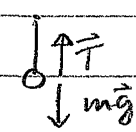
$E_f = K_f + U_f = 13 + 25.6 = 38.6\,J$

$W_{Friction} = \Delta E = E_f - E_i = 38.6 - 40 = -1.4\,J$.

11. $\frac{1}{2}mv^2 + mg\underbrace{(-r)}_{y=-r \text{ at lowest point}} = E = E_i = 0$ with $U = mgy$ and $y = 0$ initially at rest.

(a)

$\therefore$ $mv^2 = 2mgr$ where v is at lowest point:

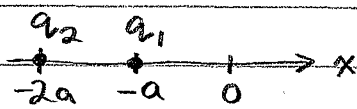


$m\underbrace{a_y}_{v^2/r} = T - mg \Rightarrow T = mv^2/r + mg = 2mg + mg$
$= 3mg$

12. None of the statements (a)–(d) are correct.

(e)

13.



$0 = E_x(0) = \dfrac{kq_2}{(2a)^2} + \dfrac{kq_1}{a^2} \Rightarrow \dfrac{q_2}{4} + q_1 = 0$

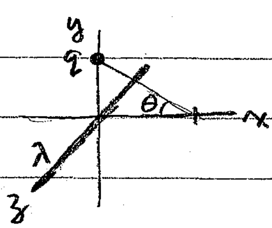
(d)

$\therefore$ $q_2/q_1 = -4$

14. Since an electric dipole has net charge $= 0$, $\therefore \oint \vec{E}\cdot d\vec{A} = \frac{q}{\varepsilon_0} = 0$ in this case.

(c)

15.



$E_x = \left.\dfrac{\lambda}{2\pi\varepsilon_0 r_1}\right|_{r_1=x} + \left.\dfrac{q}{4\pi\varepsilon_0 r_2^2}\right|_{r_2^2=x^2+y^2}\cos\theta$ where $\cos\theta = \dfrac{x}{\sqrt{x^2+y^2}}$
$= \dfrac{3}{\sqrt{3^2+2^2}}$

(d)

$\therefore E_x = \dfrac{0.3\cdot10^{-6}\,C/m}{(2\pi)(8.85\cdot10^{-12}\,C^2/Nm^2)(3\,m)} + \dfrac{(6\cdot10^{-6}\,C)\left(\frac{3}{\sqrt{3^2+2^2}}\right)}{4\pi(8.85\cdot10^{-12}\,C^2/Nm^2)(3^2+2^2)\,m^2} = 5.25\cdot10^3\,N/C$

$(1.80\cdot10^3\,N/C)$ $\qquad$ $(3.45\cdot10^3\,N/C)$