UCLA Physics 1B

Practice Final Exam

Fall 2019, Version A

Spenser Talkington

1	/5
2	/5
3	/5
4	/5
5	/5
6	/10
7	/5
8	/5
9	/5
10	/5
11	/15
12	/15
13	/10
14	/30
15	/20
16	/10
17	/15
18	/10
19	/10
20	/10
Total	/200

Problem 1. (5 Points)

What is the fastest speed that a block in a spring-block system will reach if its natural frequency is $\omega = 0.3$ [Hz], and it begins at 0 displacement at a speed of 1.5 [m/s]? (2 points) What is its maximum displacement? (3 points)

Problem 2. (5 Points)

Suppose that power is given by $P(x,t) = F\partial_x y(x,t)\partial_t y(x,t)$. Find the maximum power at $x = 0$ and the time at which it occurs for a rope stretched with a force of 50 [N], and a wave given by $y(x,t) = A\sin(kx - \omega t)$, for an amplitude of 0.1 [m], a wavevector of 2 [m^{-1}], and an angular frequency of 4.71 [rad/s].

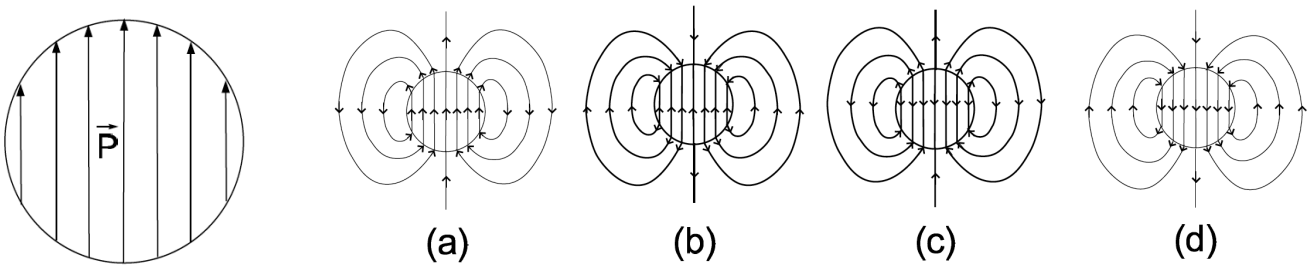
Problem 3. (5 Points)

Identify the following waves as transverse, longitudinal, or neither (1 point each)

- The sound transmitted along a string in a game of telephone
- The electrical pulses transmitted along a telephone wire
- Shaking a "battle rope" up and down for exercise
- The motion of a snake
- The motion of a worm

Problem 4. (5 Points)

A sphere is uniformly polarized as shown in the diagram. Circle the case below that shows the correct electric field lines.



Problem 5. (5 Points)

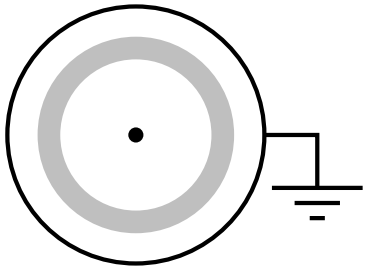
Suppose that a marching band is marching across a bridge with footfalls 120 times per minute.

(a) If we assume there are 40 band members each of mass 60 [kg], and their entire weight is pressed down with each step, what is the magnitude of the driving force? You may assume that $g = 10$ [m/s^2]. (2 points)

(b) If we assume that the bridge weighs 10^5 [kg] and has a spring constant of 10^6 [N], and a damping constant of $b = 10^4$ [kg/s], what is the maximum amplitude the bridge reaches? (3 points)

Problem 6. (10 Points)

Consider a point charge of magnitude $+q$ surrounded by a uniformly charged insulating shell of inner radius r_1 and outer radius r_2 of total charge $-2q$, surrounded by a thin conducting shell of radius r_3 that is grounded:



What is the total charge on the metal shell? (4 points)

What is the electric field in the regions $r < r_1$, $r_2 < r < r_3$, and $r_3 < r$ (2 points each).

Problem 7. (5 Points)

Suppose that we are told that the radiant intensity 3 [m] away from a light is 1 [W/m^2].

(a) What is the power emitted by the light? (3 points)

(b) What is the radiant intensity at 1 [m]? (2 points)

Problem 8. (5 Points)

When can a point charge be in stable mechanical equilibrium in the electric field of other charges? That is, is there some arrangement of point charges so that if we fix all but one of them, the other one is in a stable equilibrium? If so, what configurations are possible? Please show sufficient reasoning for your answer.

Note 1: A mathematical proof is sufficient reasoning. So is a good proof by example. So is a sound physical argument. So is any other technique that shows you have a good grasp of the concept at hand. Note 2: A stable equilibrium is one where if we move the charge in any direction, there is a restoring force directed opposite to the displacement.

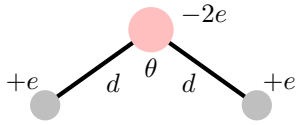
Problem 9. (5 points)

If the pressure is currently 1.01×10^5 [Pa], and we approximate your head as a sphere of radius 0.1 [m], what is the total force pressing on your head? (2 points)

What would this force be if you decided to go to the pool to relax, and dive to the bottom at 3 [m]? (3 points)

Problem 10. (5 Points)

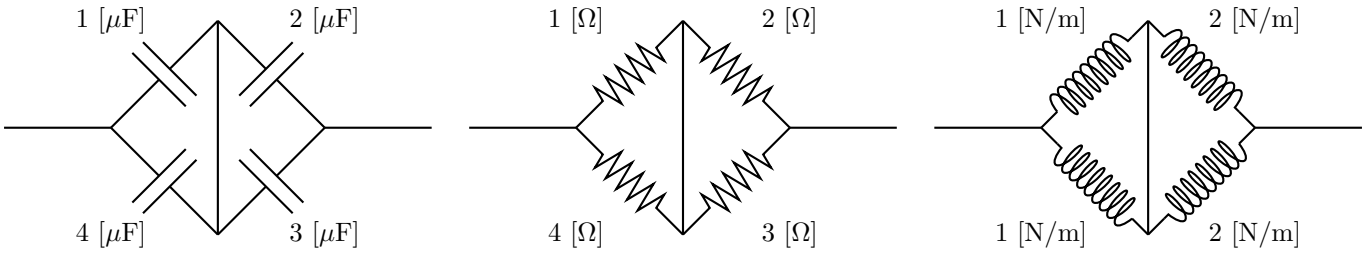
Find the dipole moment of water using the figure below. Hint: superimpose two dipoles of total strength $p = ed$. (4 points)



Now, consider a stream of water falling, and deflected by an electric charge. If this deflection results from the dipole moments, calculate the force. If the deflection does not come from the dipole moments, propose an alternate mechanism fro the deflection. (1 point)

Problem 11. (15 Points)

Calculate the equivalent capacitance (4 points), resistance (4 points), and spring constant for small displacements (7 points):



Problem 12. (15 Points)

What is the period of a physical pendulum composed of a disc of radius a connected to rod of length $4a$? Both of mass m. Hint: for a disc, $I = mr^2/2$, and for a rod about its end $I = ml^2/3$. Don't forget to use the parallel axis theorem!

Problem 13. (10 Points)

What is the resistance of a cylinder of radius r and length l of resistivity $\rho = \rho_0 \sin(\pi x/l)$? x runs along the length of the cylinder. (7 points)

If $\rho_0 = 1$ [Ω m], $r = 1$ [cm] and $l = 20$ [cm], then what voltage is needed to generate a current of 5 [A]? (2 points)

If $I = 5$ [A], how much power does the cylinder dissipate? (1 point)

Problem 14. (30 Points)

Consider a spherical charge distribution where for $r < r_1$, $\rho = c_1 r/r_1$, and at r_2 one has $\sigma = c_2(r/r_2)^2$, where $r_1 < r_2$.

(a) What are the units of c_1 and c_2? (4 points)

(b) Find the electric field for $r < r_1$. (4 points)

(c) Find the electric field for $r_1 < r < r_2$. (3 points)

(d) Find the electric field for $r_2 < r$. (3 points)

(e) Graph the electric field as a function of r. Is the electric field continuous everywhere? Is this ok? (3 points)

(f) Find the electric potential in all space. (10 points)

(g) Graph the electric potential as a function of r. Is the electric potential continuous everywhere? Is this ok? (3 points)

Problem 15. (20 Points)

Two flat, square metal plates have sides of length L, and thickness $s/2$, are arranged parallel to each other with a separation of s, where $s \ll L$ so you may ignore fringing fields. A charge Q is moved from the upper plate to the lower plate. Now a force is applied to a third uncharged conducting plate of the same thickness so that it lies between the other two plates to a depth x, maintaining the same spacing $s/4$ between its surface and the surfaces of the other two.

(a) Find the electric field in the wide region. (2 points)

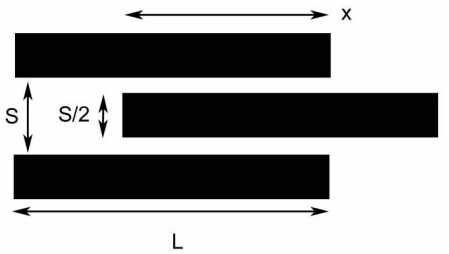
(b) Find the electric field in the narrow region. (2 points)

(c) Find the surface charge in the wide region, and in the narrow region. (4 points)

(d) What is the potential difference between the upper and lower plates? (4 points)

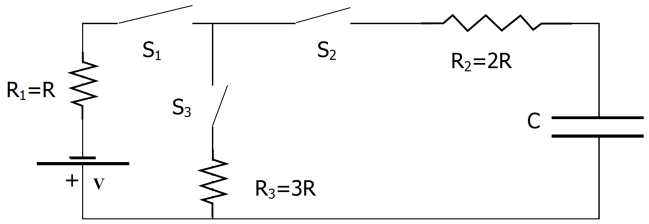
(e) Find the capacitance of the system. (4 points)

(f) What is the energy stored in the electric field? (4 points)



Problem 16. (10 Points)

Consider the following circuit:



Initially all switches are open and the capacitor C is discharged.

- At time $t = t_0$, we close S_1 and S_2 simultaneously
- At time $t = t_1 \gg t_0$ we close S_3 (with S_1 and S_2 still closed)
- At time $t = t_2 \gg t_1$ we open S_1 (S_2 and S_3 still closed)

Sketch how the following quantities vary over time ($3.\bar{3}$ points each):

(a) V_C (potential across capacitor)

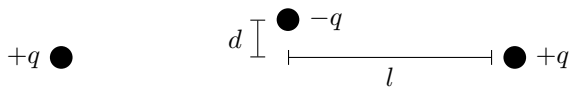
(b) I_{R_2} (current flowing through R_2)

(c) V_{R_3} (potential across R_3)

Specify asymptotic values and time constants. You don't need to solve differential equations or write down functions explicitly.

Problem 17. (15 Points)

Consider oscillations for *small* displacement $d \ll l$, on short time scales so the energy radiated is insignificant. Find the frequency of oscillation of the negatively charged particle if it is released from rest a distance d from equilibrium. Assume that the positively charged particles are fixed.



Problem 18. (10 Points)

Consider a runner crossing the finish line of a race at 6 [m/s], and yelling in excitement at 300 [Hz]. At what frequency does a stationary observer in front of the runner hear the yell? (5 points)

Now, the observer responds and shouts at a frequency of 250 [Hz]. What frequency does the runner hear? (5 points)

Problem 19. (10 Points)

Find the electric field at a point p on the z-axis, if a charge $+q$ is spread on the x-axis from $-a$ to 0, and a charge $-q$ is spread on the x-axis from 0 to $+a$. Hint: The x components of the electric field don't cancel.

Problem 20. (10 points)

Stone Canyon Reservoir is at a height of 258 [m] and provides water to UCLA, elevation 96 [m]. If water starts in a tube at rest, and the tube breaks into 10000 faucets each 1 [cm] in diameter, how much power can a hydroelectric motor extract if the water leaves the faucets at 5 [m/s]?