Solutions

Common themes:
Theme 1: Coulomb's law, the electric field of a point charge
Theme 2: The electromagnetic force $\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B})$
Theme 3: Gauss' law and Ampere's law alone can be used to find the electric and magnetic field in situations with enough symmetry (spherical, cylindrical planar).
Theme 4: Capacitors in series and parallel, energy stored in a capacitor $U = Q^2/C = CV^2$
Theme 5: The principle of superposition
Theme 6: Faraday's law

Problem 1:
(D) The electromagnetic force
$\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B}) = 0$, B is proportional to I. (theme 2)

Problem 2:
(C) Gauss' law and Ampere's law
Both the electric and the magnetic force drop off as 1/r. (theme 3)

Problem 3:
(C) Electrostatic energy
$W = [1/(4\pi\varepsilon_0)]\int_0^Q q\,dq/R^2 = [1/(8\pi\varepsilon_0)]Q^2/R$.
or: $C = Q/V$, $= Q/(kQ/r) = r/k$, $U = ½\, Q^2/C$. (theme 4)

Problem 4:
(D) Temperature dependence of resistivity of metals at ordinary temperatures

Problem 5:
(D) Coulomb's law
$F = kQ_1Q_2/r^2$ is the magnitude of the initial force. Initially $Q_1 = Q_2 = Q$.
After the touching sequence $Q_1 = Q/2$, $Q_2 = 3Q/4$, $F = 3F/8$. (theme 1)

Problem 6:
(E) Capacitors in parallel (theme 4)

Problem 7:
(E) The principle of superposition
The net electrostatic force on the charge Q at the center is zero since the force on Q due to each negative charge is balanced by the force due to the negative charge at the diagonally opposite corner of the cube. (theme 5)

Problem 8:
(C) Motional emf
The section of the wire extending from the bottom center of the cylinder radially outward to radius R rotates with angular frequency $\omega = N2\pi$ rad/sec in the magnetic field. The force on an electron in this section is has magnitude $qvB = q\omega rB$. The magnitude of the potential difference is $(1/q) \int_0^R F dr = \pi NBR^2$.
or
$d\Phi_B/dt$ (filamentary circuit with moving parts, constant B) = motional emf.
Period = (1/N)s. The flux through the circuit changes by $B\pi R^2$ in one period.

Problem 9:
(E) The electromagnetic force
The particle starts from rest. It accelerates in a direction parallel or anti-parallel to **E** and always moves parallel or anti-parallel to **B**. (theme 2)

Problem 10:
(A) The electromagnetic force
$\mathbf{F} = q\mathbf{v}\times\mathbf{B}$. (theme 2)

Problem 11:
(C) Capacitors in parallell
$Q_1 = C_1V$, $Q_2 = C_2V$, $V = 5V$.
$Q_f = Q_2 - Q_1 = (C_2 - C_1)V$. $V_f = Q_f/C_f = (C_2 - C_1)V/(C_2 + C_1) = 5/3$. (theme 4)

Problem 12:
(A) Ampere's law and the principle of superposition
Right hand rule: $\mathbf{B} = B\mathbf{j}$. Each conductor contributes B/2.
$2\pi(d/2)B/2 = \mu_0 I_{\text{through}\Gamma} = \mu_0 J\pi(d/2)^2$. (themes 3 and 5)

Problem 13:
(C) Faraday's law
Flux = $B\pi R^2\cos\omega t$
emf = $\omega B\pi R^2\sin\omega t = E_0\sin\omega t$
$\omega = E_0/(B\pi R^2)$. (theme 6)

Problem 14:
(C) Self inductance L
$|\varepsilon| = L|dI/dt| = |dF/dt|$
$F = NBA$, $B = \mu_0(N/L)I$, $L \propto N^2$.

Problem 15:
(E) RC circuits
$Q/C + RdQ/dt = 0$ $dQ/dt = -Q/(RC)$, $Q = Q_0\exp(-t/(RC))$,
$E = Q^2/C = E_0\exp(-2t/(RC))$, $½ = \exp(-2t_{1/2}/(RC))$, $t_{1/2} = \ln(2)RC/2$. (theme 4)