

PHY 2005 Applied Physics 2 - Summer 2011
Solutions to Suggested Homework Problems (Chapter 23)

1. Magnetic flux through a surface is given by $\Phi = BA\cos\theta$, where θ is the angle between the normal to the surface and the magnetic field. The area of the rectangular board is $A = 0.2 \times 0.3 = 0.06 \text{ m}^2$ a) $\Phi = BA\cos 0^\circ = 9 \times 10^{-3} \text{ T}\cdot\text{m}^2$ b) $\Phi = BA\cos 90^\circ = 0$ c) $\Phi = BA\cos 40^\circ = 6.89 \times 10^{-3} \text{ T}\cdot\text{m}^2$

5. The solenoid has number of turns per unit length $n = N/L = 1200 \text{ turns/m}$. The magnetic field in the solenoid is $B = k_m B_v = k_m \mu n I = 9.05 \times 10^{-2} \text{ T}$. The magnetic field is perpendicular to the cross section of the solenoid. Therefore, the magnetic flux is $\Phi = BA = Bn(D/2)^2 = 2.30 \times 10^{-5} \text{ Wb}$, where D is the diameter of the solenoid.

7. a) The change in flux is $\Delta\Phi = BA(\cos 60^\circ - \cos 0^\circ) = -4.0 \times 10^{-5} \text{ Wb}$. Faraday's law yields $\epsilon_{ind} = -\Delta\Phi/\Delta t = 8.0 \times 10^{-5} \text{ V}$. b) The change in flux is $\Delta\Phi = BA(\cos 40^\circ - \cos 30^\circ) = -8.0 \times 10^{-6} \text{ Wb}$. Faraday's law yields $\epsilon_{ind} = -\Delta\Phi/\Delta t = 1.6 \times 10^{-5} \text{ V}$.

9. If two coils are wound on a common ferromagnetic core, we can assume the same magnetic flux passes through both of the coils. We apply Faraday's law to obtain $\epsilon_{ind} = -N(\Delta\Phi/\Delta t) = N(\Delta B n r^2/\Delta t) = 0.519 \text{ V}$.

12. Since the vertical component of Earth's field is considered constant over the small region where the experiment is performed, there is no *change* in the magnetic flux passing through the horizontal loop. Therefore, no emf is induced in the loop. The voltmeter reads zero. If you flop around the loop, then the component of the magnetic field perpendicular to the loop changes, thus an emf is induced in the loop.

14. Only a part of the loop is in the uniform magnetic field and the area of this part is changing by amount $Lv\Delta t$ in the time interval Δt , where $L = 0.045 \text{ m}$ & $v = 0.2 \text{ m/s}$. The induced voltage is $\Delta V = \Delta\Phi/\Delta t = B\Delta A/\Delta t = BLv$. Solving this expression for B , we obtain $B = \Delta V/Lv = 0.152 \text{ T}$.

16. The induced emf in a coil rotating in a uniform magnetic field with angular frequency ω is given by $\epsilon_{ind} = NBA\omega\cos\omega t$. The angular frequency and frequency are related as $\omega = 2\pi f$. Since the cosine function changes from -1 to 1, the maximum induced emf is $\epsilon_{ind} = NBA(2\pi f)$. We solve the equation for f to obtain $f = \epsilon_{ind}/(2\pi NBA) = 442 \text{ Hz}$.

18. a) The ratio of the number of turns is the same as the ratio of voltages. We have $N_p/N_s = \Delta V_p/\Delta V_s = 120/14000 = 9.29 \times 10^{-3}$. b) If the transformer is connected backwards, the turn ratio is inverted. The induced voltage in the secondary coil is $N_p/N_s = \Delta V_s/\Delta V_p \Rightarrow \Delta V_s = (N_p/N_s)\Delta V_p = 1.21 \text{ V}$.

21. a) Applying Kirchhoff's loop rule to the circuit, we obtain $\epsilon - \epsilon_{back} - IR = 0 \Rightarrow \epsilon_{back} = \epsilon - IR = 108.6 \text{ V}$. b) The motor starts from rest. Thus there is no back emf induced in the motor at the instant it is turned on. The loop rule yields $\epsilon - IR = 0 \Rightarrow I = \epsilon/R = 21.1 \text{ A}$.

23. Converting hp to W, we obtain $1/4 \text{ hp} = 1/4 \text{ hp} \times 746 \text{ W/1 hp} = 186.5 \text{ W}$. a) The conservation of energy tells you that the input energy is equal to the output energy plus the energy lost in the internal resistor. We solve the energy conservation equation for the current: $I\epsilon = P + I^2 r \Rightarrow I = P/(\Delta V - r^2) = 1.70 \text{ A}$. b) The loop rule yields $\epsilon - \epsilon_{back} - Ir = 0 \Rightarrow \epsilon_{back} = \epsilon - Ir = 109.2 \text{ V}$.

26. Motional emf induced in a rod moving with velocity v in a uniform magnetic field B perpendicular to the rod is $\epsilon_{ind} = B_\square l v$, where B_\square is the component of field perpendicular to the velocity. The substitution of given values yields $\epsilon_{ind} = B_\square l v = 2.1 \times 10^{-3} \text{ V}$. The polarity is obtained by the right hand rule. Point your thumb in the direction of velocity (downward) while

pointing your fingers in the direction of the field (to the north). Your palm faces to the east. The east end is positive.

29. a) Solving the motional emf equation $\varepsilon_{ind} = B_{\square}l v$ for v , we get $v = \varepsilon_{ind}/B_{\square}l = 1.67 \times 10^5$ m/s. b) To light lights, you have to connect the straight wire across lightbulbs, making a closed circuit. Since the magnetic flux through the closed circuit does not change, the lights don't turn on. This means that the induced emf in the wire and that in the other part of the circuit exactly cancel. The ingenious person's proposal *never* works!

30. a) The angle between the velocity vector and the magnetic field is $90 - 30 = 60^\circ$, thus the component of the field perpendicular to the velocity is $B \sin 60^\circ$. The induced emf is $B l v \sin 60^\circ$. b) Ohm's law gives the current: $I = \varepsilon/R = B l v \sin 60^\circ/R$. c) The right hand rule tells you the direction of the magnetic force on a positive charge in the rod. The force is toward the back of the wedge. Thus the current flows in the clockwise direction. d) The direction of the induced current is perpendicular to the field. Thus the magnitude of the magnetic force on the current-carrying rod is $F = I v B = (B l v \sin 60^\circ/R) v = B^2 l v^2 \sin 60^\circ/R$. e) The right hand rule yields the direction of the force. The force is horizontal and into the incline. The force tends to slow down the rod.