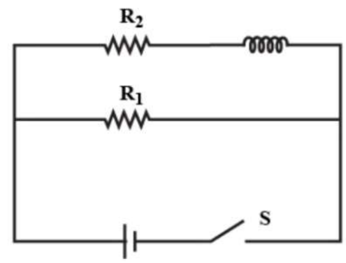
Physics 2

11. Fig. … shows a circuit with two identical resistors and an ideal inductor. Comparison between the current through the central resistor R_1 and the other resistor R_2, a long time after that?



A. $I_1 = I_2$.

B. $I_1 > I_2$.

C. $I_1 < I_2$.

D. Not enough data.

A long time after closing the switch S, the inductor had reached its steady state and it start to act like a simple conducting wire. Since two given resistances are parallel and both are identical. Thus, the current coming from the battery splits equally between both resistors.

Therefore, the current in both the resistors is the same.

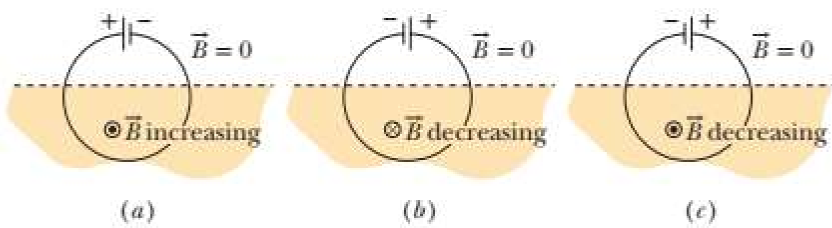
12. Fig. 12 shows three situations in which a wire loop lies partially in a magnetic field. The magnitude of the field is either increasing or decreasing, as indicated. In each situation, a battery is part of the loop. In which, situations are the induced emf and the battery emf in the same direction along the loop?

A. in situation (b).

B. in situation (a).

C. in situation (c).

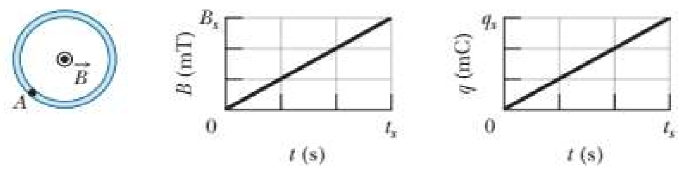
D. all in 3 situations.



Applying Lenz's law in Fig.12(a), the direction of induced current i_{ind} is clockwise but the direction of current from the battery i_{bat} is counterclockwise.
Applying Lenz's law in Fig.12(b), the direction of induced current i_{ind} is clockwise and the direction of current from the battery i_{bat} is also clockwise.
Applying Lenz's law in Fig.12(c), the direction of induced current i_{ind} is counterclockwise but the direction of current from the battery i_{bat} is clockwise.

Therefore, in (b) situation, the induced emf and the battery emf are in the same direction along the loop.

13. In Fig. …a, a uniform magnetic field $\vec{B}$ increases in magnitude with time t as given by Fig. …b, where the vertical axis scale is set by $B_s = 9.0\ mT$ and the horizontal scale is set by $t_s = 3.0\ s$. A circular conducting loop of area 8.0 x 10^{-4} m^2 lies in the field, in the plane of the page. The amount of charge q passing point A on the loop is given in Fig. … as a function of t, with the vertical axis scale set by $q_s = 6.0\ mC$ and the horizontal axis scale again set by $t_s = 3.0\ s$. What is the loop's resistance?



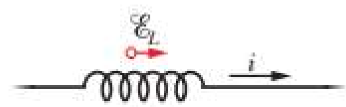
(a) (b) (c)

Figure b demonstrates that dB/dt (the slope of that line) is $0.003\,T/s$. Thus, in absolute value, Faraday's law becomes $\varepsilon = -\frac{d\Phi_B}{dt} = -\frac{d(BA)}{dt} = -A\frac{dB}{dt}$ where $A = 8\times10^{-4}\,m^2$.

We related the induced emf to resistance and current using Ohm's law. The current is estimated from Fig. c to be $i = dq/dt = 0.002\,A$ (the slope of that line). Therefore, the resistance of the loop is

$$R = \frac{|\varepsilon|}{i} = \frac{A\,|dB/dt|}{i} = \frac{(8.0\times10^{-4}\,m^2)(0.0030\,T/s)}{0.0020\,A} = 0.0012\Omega$$

14. At a given instant the current and self-induced emf in an inductor are directed as indicated in Fig. … The induced emf is 17 V, and the rate of change of the current is 25 kA/s, find the inductance?



From Eq. $\mathcal{E}_L = -L\frac{di}{dt}$ (self-induced emf) (in absolute value) we get

$$L = \left|\frac{\varepsilon}{di/dt}\right| = \frac{17\,V}{2.5kA/s} = 6.8\times10^{-4}\,H$$

17. A coil is connected in series with a 10.0 $k\Omega$ resistor. An ideal 50.0 V battery is applied across the two devices, and the current reaches a value of 2.00 mA after 5.0 ms. Find the inductance of the coil.

(a) If the battery is applied at time t=0 the current is given by $i = \frac{\varepsilon}{R}\left(1 - e^{-t\tau_L}\right)$

where ε is the emf of the battery, R is the resistance, and τ_L is the inductive time constant (L/R).

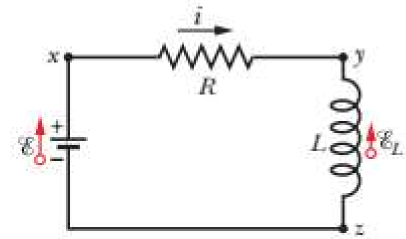
This leads to $e^{-t\tau_L} = 1 - \frac{iR}{\varepsilon} \Rightarrow -\frac{t}{\tau_L} = \ln\left(1 - \frac{iR}{\varepsilon}\right)$

since $\ln\left(1 - \frac{iR}{\varepsilon}\right) = \ln\left[1 - \frac{(2.00\times10^{-3}\,A)(10.0\times10^{3}\,\Omega)}{50.0\,V}\right] = -0.5108$

The inductive time constant is $\tau_L = t/0.5108 = (5.00\times10^{-3}\,s)/0.5108 = 9.79\times10^{-3}\,s$ and the inductance is

$$L = \tau_L R = (9.79\times10^{-3}\,s)(10.0\times10^{3}\,\Omega) = 97.9H$$

18. For the circuit of Fig. …, assume that *E = 10.0 V*, *R = 6.70 Ω,* and *L = 5.50 H.* The ideal battery is connected at time *t = 0 s.* How much energy is delivered by the battery during the first 2.0 s?



(a) The energy delivered by the battery is the integral of Eq. $P = \varepsilon i$ (where we use Eq.$i = \frac{\varepsilon}{R}(1 - e^{-t/\tau_L}$ (rise of current) for the current

$$\int_0^t P_{battery}\,dt = \int_0^t \frac{\varepsilon^2}{R}\left(1 - e^{-\frac{R}{L}t}\right)dt = \frac{\varepsilon^2}{R}\left[t + \frac{L}{R}\left(e^{-\frac{R}{L}t} - 1\right)\right]$$

$$= \frac{(10.0\text{ V})^2}{6.70\Omega}\left[2.00\text{ s} + \frac{(5.50\text{H})\left(e^{-(6.70\Omega)(2.00\text{ s})/3.50\text{H}} - 1\right)}{6.70\Omega}\right]$$

$$= 18.7\text{ J}$$

Module 2: Electromagnetic field; Electromagnetic oscillations and waves (17 questions)

25. Calculate the inductance of an LC circuit that oscillates at 120 Hz when the capacitance is 8.00 μF.

$$X_L = X_C \Rightarrow \omega L = \frac{1}{\omega C}$$

$$\Rightarrow L = \frac{1}{\omega^2 C} \text{ and } \omega = 2\pi f = 240\pi \text{rad/s}$$

$$\Rightarrow L = \frac{1}{240^2 \times \pi^2 \times 8.00 \times 10^{-6}} \Rightarrow L = 0.22\text{H}$$

28. What resistance R should be connected in series with an inductance $L = 220\ mH$ and capacitance $C = 12.0\ \mu F$ for the maximum charge on the capacitor to decay to 99.0% of its initial value in 50.0 cycles?

$$t = NT$$
$$\text{or,} \quad t = \frac{2\pi N}{\omega}, \omega = \frac{1}{\sqrt{LC}}$$
$$\text{So,} \quad t = 2\pi N\sqrt{LC}$$

Subsitute with the givens to get:

$$t = 2\pi(50.0)\sqrt{(220 \times 10^{-3}\text{H})(12.0 \times 10^{-6}\text{ F})}$$
$$t = 0.5104\text{sec}$$

The charge over the Capacitor at any instant is given by:

$$q = Qe^{-tR/2L}\cos(\omega t + \phi)$$

the maximum charge on the Capacitor decay as follow:

$$q_{\max} = Qe^{-t\ \ /2L}$$

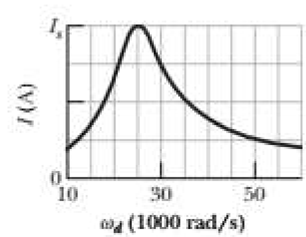
Where the maximum occurs when $\cos(\omega t + \phi) = 1$, solve for R

$$e^{-t\ \ /2L} = \frac{q_{\max}}{Q}$$

take the natural logarithm to get: $R = \frac{-2L}{t}\ln\left(\frac{q_{\max}}{Q}\right)$

Substitute with the Sirens to get: $R = -\frac{2(220\times10^{-3}\text{H})}{8.6660.5104\text{ s}}\ln(0.99)$
$= 8.66 \times 10^{-3}\Omega$

30. The current amplitude I versus driving angular frequency ω_d for a driven RLC circuit is given in Fig. …, where the vertical axis scale is set by $I_s = 4.00$ *(A)*. The inductance is 200 µH, and the emf amplitude is 8.0 V. What are C and R?



(a) The graph shows that the resonance angular frequency is 25000rad/s, which means, $C = \frac{1}{\omega^2 L} = \frac{1}{(25000)^2 \times 200\times10^{-6}} = 8.0\mu\text{F}$

(b) The graph also shows that the current amplitude at resonance is 4.0A, but at resonance the impedance Z becomes purely resistive $(Z = R)$ so that we can divide the emf amplitude by the current amplitude at resonance to find $R = 8.0/4.0 = 2.0\Omega$

32. Which of the following statements are true regarding electromagnetic waves traveling through a vacuum?

A. All waves have the same wavelength.

B. All waves have the same frequency.

C. All waves travel at 3.00×10^8 m/s.

D. The speed of the waves depends on their frequency.

34. A electromagnetic wave with a peak magnetic field magnitude of 1.50×10^{-7} T has an associated peak electric field of what magnitude?

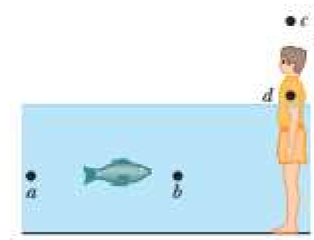
The peak values of the electric and magnetic field components of an electromagnetic wave are related by $E_{max} / B_{max} = c$, where c is the speed of light in vacuum. Thus, $E_{max} = cB_{max} = \left(3.00 \times 10^8 \text{ m/s}\right)\left(1.50 \times 10^{-7} \text{ T}\right) = 45.0 \text{ N/C}$

35. The red light emitted by a helium-neon laser has a wavelength of 632.8 nm. What is the frequency of the light waves?

we know that $\lambda = c/\nu \Rightarrow \nu = c/\lambda = \dfrac{3\times10^8}{632.8\times10^{-9}} = 4.7\times10^{14}$ Hz

Module 3: Light and Wave optics

38. Fig. … shows a fish and a fish stalker in water. Does the stalker see the fish in the general region of point *a* or point *b* while the fish can see the eyes of the stalker in the general region of point *c* or *d*?



A. a & c .

B. b & c.

C. a & d .

D. b & d .

The stalker sees the fish in the region of point a, and the fish sees the stalker in the region of point c.

As the image of the fish passes from the water to the air, it bends away from the normal because the index of refraction is greater for water than air.

As the image of the stalker enters the water, it bends towards the normal, because it is passing into a medium of greater index of refraction.

43. Fig. … shows a pencil partially immersed in a cup of water. Why does the pencil appear to be bent?

A. Refraction.

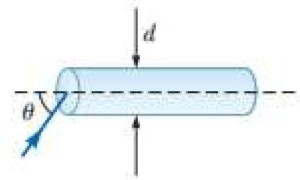
B. Reflection.

C. Interference.

D. Diffraction.

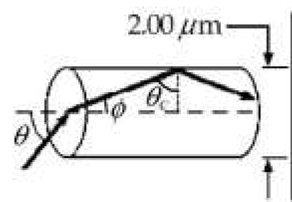
Light rays coming from parts of the pencil under water are bent away from the normal as they emerge into the air above. The rays enter the eye (or camera) at angles closer to the horizontal, thus the parts of the pencil under water appear closer to the surface than they actually are, so the pencil appears bent.

47. Assume a transparent rod of diameter $d = 2.00\ \mu m$ has an index of refraction of 1.36. Determine the maximum angle θ for which the light rays incident on the end of the rod in Fig. … are subject to total internal reflection along the walls of the rod. Your answer defines the size of the cone of acceptance for the rod.



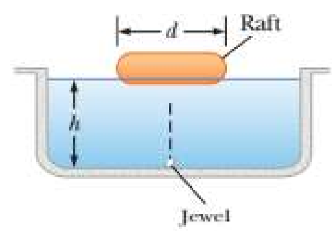
At the upper surface, $\sin\theta_c = \frac{n_{air}}{n_{pipe}} = \frac{1.00}{1.36} = 0.735 \rightarrow \theta_c = 47.3^\circ$

Geometry shows that the angle of refraction at the end is $\phi = 90.0^\circ - \theta_c = 90.0^\circ - 47.3^\circ = 42.7^\circ$



Then, by Snell's law at the end, $1.00\sin\theta = 1.36\sin 42.7^\circ$

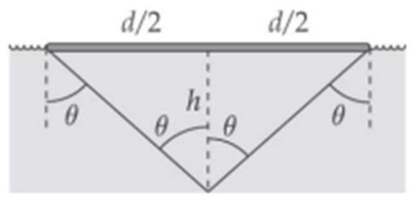
gives $\theta = 67.2^\circ$



48. A thief hides a precious jewel by placing it on the bottom of a public swimming pool. He places a circular raft on the surface of the water directly above and centered over the jewel as shown in Fig. … . The surface of the water in calm. The raft, of diameter $d = 4.54\ m$, prevents the jewel from being seen by any observer above the water, either on the raft or on the side of the pool. What is the maximum depth h of the pool for the jewel to remain unseen? ($n_{water} = \frac{4}{3}$ and $n_{\text{air}} = 1$.)

Light from the diamond reflects totally at the water's surface at incident angles greater than the critical angle θ_c . The circular raft must cover the area of the surface through which light from the diamond could emerge. Thus, it must form the base of an inverted cone (with the apex at the diamond) whose halfangle is at least the critical angle.

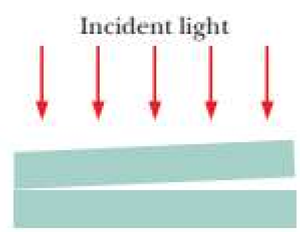
$$\theta \geq \theta_c$$
$$\tan\theta \geq \tan\theta_c$$
$$\frac{d/2}{h} \geq \tan\theta_c$$
$$\rightarrow h \leq \frac{d}{2\tan\theta_c}$$



The critical angle at the water-air boundary is $\theta_c = \sin^{-1}\left(\frac{n_{air}}{n_{water}}\right) = \sin^{-1}\left(\frac{1.000}{1.333}\right) = 48.61^\circ$

Thus, the maximum depth of the water is $h_{max} = \frac{d}{2\tan\theta_c} = \frac{4.54\,m}{2\tan 48.61^\circ} = 2.00\,m$

55. In Fig. …, two microscope slides touch at one end and are separated at the other end. When light of wavelength 500 nm shines vertically down on the slides, an overhead observer sees an interference pattern on the slides with the dark fringes separated by 1.2 mm. What is the angle between the slides?



We find that the (vertical) change between the center of one dark and the next is

$$\Delta y = \frac{\lambda}{2} = \frac{500\,nm}{3} = 250\,nm = 2,50\times10^{-4}\,mm$$

Thus, with the (hosizontal) separation of dark bands given by $\Delta x = 1.2\,nm$, we have

$$\theta \approx \tan\theta = \frac{\Delta y}{\Delta x} = 2.08\times10^{-4}\,rad.$$

56. A mixture of light, consisting of wavelength 590 nm and an unknown wavelength, illuminates Young's double slit and gives rise to two overlapping interference patterns on the screen. The central maximum of both lights coincide. Further, it is observed that the third bright fringe of known light coincides with the 4th bright fringe of the unknown light. From this data, the wavelength of the unknown light is:

We know that n^{th} maxima occurs at a distance $\frac{n\lambda D}{d}$ from the central maxima. for the known light 3rd maxima will occur at a distance $\frac{3\times 590\times D}{d}\times 10^{-9}$ m from the central maxima

for the unknown wavelength λ, the 4^{th} maxima will occur at a distance $\frac{4\lambda D}{d}$ from the central maxima If both coincide $\frac{3\times 590\times 1}{d}\times 10^{-9}\,\text{m} = \frac{4\lambda D}{d}$

Solving this we get $\lambda = 442.5\,\text{nm}$

Module 4. Modern physics

74. A monochromatic light beam is incident on a barium target that has a work function of 2.50 eV. If a potential difference of 1.00 V is required to turn back all the ejected electrons, what is the wavelength of the light beam?

$$\text{KE} = \frac{\text{hc}}{\lambda} - \phi \Rightarrow \text{e}V_C = \frac{\text{hc}}{\lambda} - \phi$$

$$1\text{eV} = \frac{\text{hc}}{\lambda} - 2.5\text{eV}$$

$$\frac{\text{hc}}{\lambda} = 3.5\text{eV} = 3.5 \times 1.6 \times 10^{-1}$$

$$\frac{20 \times 10^{-26}}{\lambda} = 3.5 \times 1.6 \times 10^{-19}$$

$$\lambda = 355 \times 10^{-9} m$$