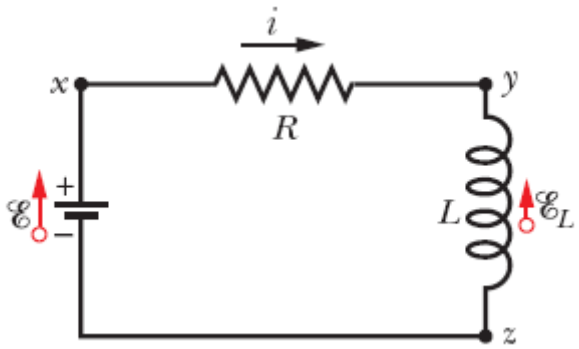
Welcome to the Physics class

Principles of Physics II

Lecture 20



$$\mathcal{E}_L = -L\frac{di}{dt}$$

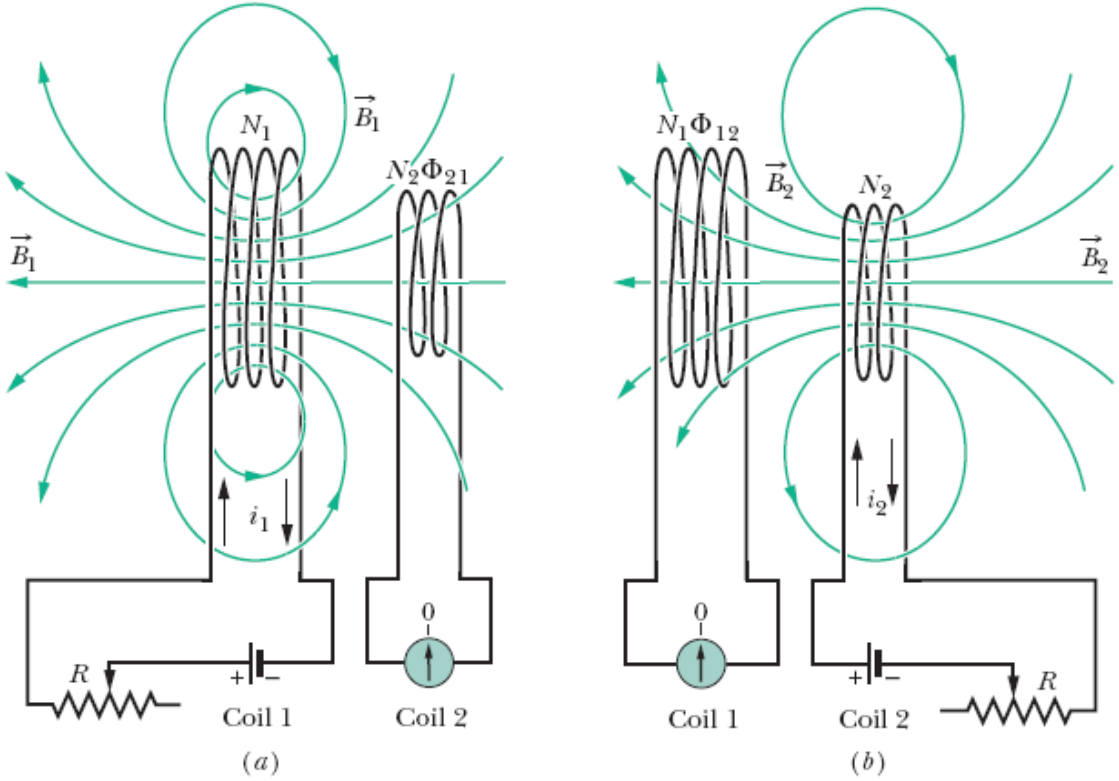


Fig. 30-19 Mutual induction. (*a*) The magnetic field $\vec{B}_1$ produced by current i_1 in coil 1 extends through coil 2. If i_1 is varied (by varying resistance R), an emf is induced in coil 2 and current registers on the meter connected to coil 2. (*b*) The roles of the coils interchanged.

$$\mathcal{E}_2 = -M\frac{di_1}{dt}$$

$$\mathcal{E}_1 = -M\frac{di_2}{dt}$$

M is the (coefficient of) mutual inductance betn the two coils.

REVIEW & SUMMARY

Magnetic Flux The *magnetic flux* Φ_B through an area A in a magnetic field $\vec{B}$ is defined as

$$\Phi_B = \int \vec{B} \cdot d\vec{A}, \qquad (30\text{-}1)$$

where the integral is taken over the area. The SI unit of magnetic flux is the weber, where 1 Wb = 1 T · m². If $\vec{B}$ is perpendicular to the area and uniform over it, Eq. 30-1 becomes

$$\Phi_B = BA \qquad (\vec{B} \perp A, \vec{B} \text{ uniform}). \qquad (30\text{-}2)$$

Faraday's Law of Induction If the magnetic flux Φ_B through an area bounded by a closed conducting loop changes with time, a current and an emf are produced in the loop; this process is called *induction*. The induced emf is

$$\mathscr{E} = -\frac{d\Phi_B}{dt} \qquad \text{(Faraday's law)}. \qquad (30\text{-}4)$$

If the loop is replaced by a closely packed coil of N turns, the induced emf is

$$\mathscr{E} = -N\frac{d\Phi_B}{dt}. \qquad (30\text{-}5)$$

Lenz's Law An induced current has a direction such that the magnetic field *due to the current* opposes the change in the magnetic flux that induces the current. The induced emf has the same direction as the induced current.

Emf and the Induced Electric Field An emf is induced by a changing magnetic flux even if the loop through which the flux is changing is not a physical conductor but an imaginary line. The changing magnetic field induces an electric field $\vec{E}$ at every point of such a loop; the induced emf is related to $\vec{E}$ by

$$\mathscr{E} = \oint \vec{E} \cdot d\vec{s}, \qquad (30\text{-}19)$$

where the integration is taken around the loop. From Eq. 30-19 we can write Faraday's law in its most general form,

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt} \qquad \text{(Faraday's law)}. \qquad (30\text{-}20)$$

A changing magnetic field induces an electric field $\vec{E}$.

Inductors An **inductor** is a device that can be used to produce a known magnetic field in a specified region. If a current i is established through each of the N windings of an inductor, a magnetic flux Φ_B links those windings. The **inductance** L of the inductor is

$$L = \frac{N\Phi_B}{i} \qquad \text{(inductance defined)}. \qquad (30\text{-}28)$$

The SI unit of inductance is the **henry** (H), where 1 henry = 1 H = 1 T · m²/A. The inductance per unit length near the middle of a long solenoid of cross-sectional area A and n turns per unit length is

$$\frac{L}{l} = \mu_0 n^2 A \qquad \text{(solenoid)}. \qquad (30\text{-}31)$$

Self-Induction If a current i in a coil changes with time, an emf is induced in the coil. This self-induced emf is

$$\mathscr{E}_L = -L\frac{di}{dt}. \qquad (30\text{-}35)$$

The direction of $\mathscr{E}_L$ is found from Lenz's law: The self-induced emf acts to oppose the change that produces it.

Series *RL* Circuits If a constant emf $\mathscr{E}$ is introduced into a single-loop circuit containing a resistance R and an inductance L, the current rises to an equilibrium value of $\mathscr{E}/R$ according to

$$i = \frac{\mathscr{E}}{R}(1 - e^{-t/\tau_L}) \qquad \text{(rise of current)}. \qquad (30\text{-}41)$$

Here τ_L (= L/R) governs the rate of rise of the current and is called the **inductive time constant** of the circuit. When the source of constant emf is removed, the current decays from a value i_0 according to

$$i = i_0 e^{-t/\tau_L} \qquad \text{(decay of current)}. \qquad (30\text{-}45)$$

Magnetic Energy If an inductor L carries a current i, the inductor's magnetic field stores an energy given by

$$U_B = \tfrac{1}{2}Li^2 \qquad \text{(magnetic energy)}. \qquad (30\text{-}49)$$

If B is the magnitude of a magnetic field at any point (in an inductor or anywhere else), the density of stored magnetic energy at that point is

$$u_B = \frac{B^2}{2\mu_0} \qquad \text{(magnetic energy density)}. \qquad (30\text{-}55)$$

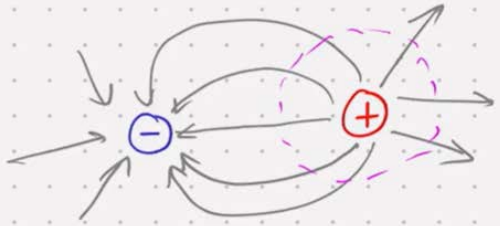
Maxwell’s Equations

L16 V2 | First two Maxwell's Equations | PHY112 | Summer 2020

First Two Maxwell's Equations

1. Gauss's Law : electric monopoles are allowed

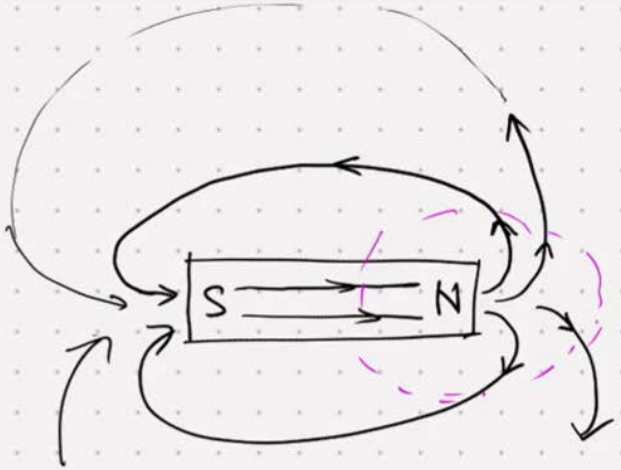
$$\oiint \vec{E}\cdot d\vec{a} = \frac{q_{enc}}{\epsilon_0}$$



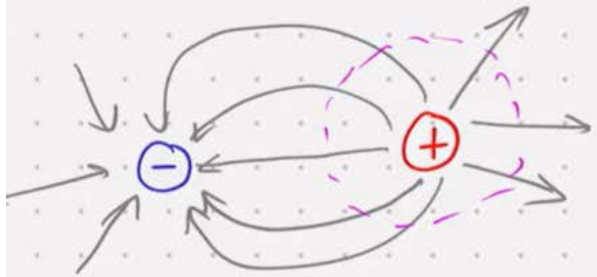
$q_{enc} = +q$

2. Magnetic Gauss's Law : No magnetic monopoles

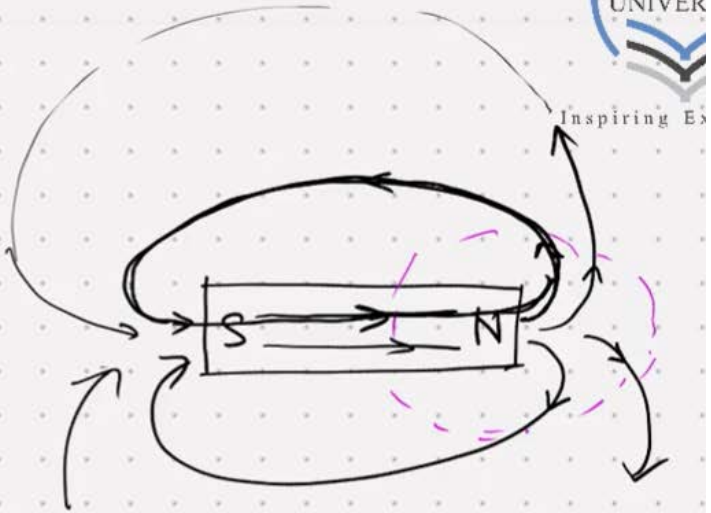
$$\oiint \vec{B}\cdot d\vec{a} = 0$$



magnetic flux

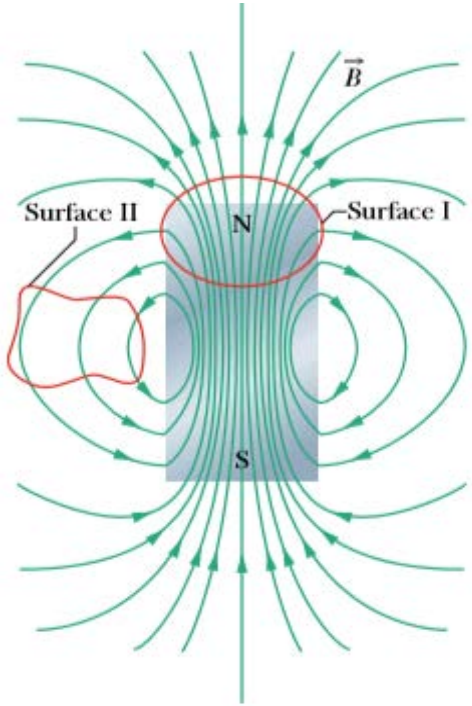


electric dipoles



magnetic dipoles

Maxwell's Equations



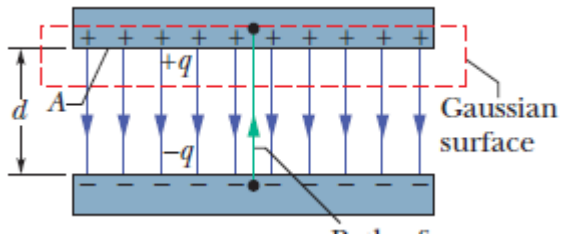
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enc},$$ (Ampere's Law of Induction)

+

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$ (Maxwell's law of induction).

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$ (Faraday's law of induction).

→



Apply Gauss law to a charging capacitor.

$$\phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$$

or $\phi_E = E \oint dA = q/\epsilon_0$

or $\phi_E = EA = q/\epsilon_0$

$$\phi_E = \frac{q}{\epsilon_0} \quad \therefore q = \epsilon_0 \phi_E$$

$$\frac{dq}{dt} = i_d = \epsilon_0 \frac{d\phi_E}{dt}$$

displacement current

The simplest magnetic structure that can exist is a magnetic dipole. Magnetic monopoles do not exist (as far as we know).

Gauss' law for magnetic fields is a formal way of saying that magnetic monopoles do not exist. The law asserts that the net magnetic flux Φ_B through any closed Gaussian surface is zero:

$$\Phi_B = \oint \vec{B} \cdot d\vec{A} = 0 \quad \text{(Gauss' law for magnetic fields).} \qquad (32\text{-}1)$$

Contrast this with Gauss' law for electric fields,

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0} \quad \text{(Gauss' law for electric fields).}$$

$\therefore$ Ampere's law as modified by Maxwell.

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{encl} + \mu_0 i_d$$

$$= \mu_0 i_{encl} + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

Maxwell's Equations[a]

Name	Equation	
Gauss' law for electricity	$\oint \vec{E} \cdot d\vec{A} = q_{enc}/\varepsilon_0$	Relates net electric flux to net enclosed electric charge
Gauss' law for magnetism	$\oint \vec{B} \cdot d\vec{A} = 0$	Relates net magnetic flux to net enclosed magnetic charge
Faraday's law	$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$	Relates induced electric field to changing magnetic flux
Ampere–Maxwell law	$\oint \vec{B} \cdot d\vec{s} = \mu_0\varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i_{enc}$	Relates induced magnetic field to changing electric flux and to current

[a]Written on the assumption that no dielectric or magnetic materials are present.

$$i_d = \varepsilon_0 \frac{d\Phi_E}{dt} \qquad \text{(displacement current).}$$

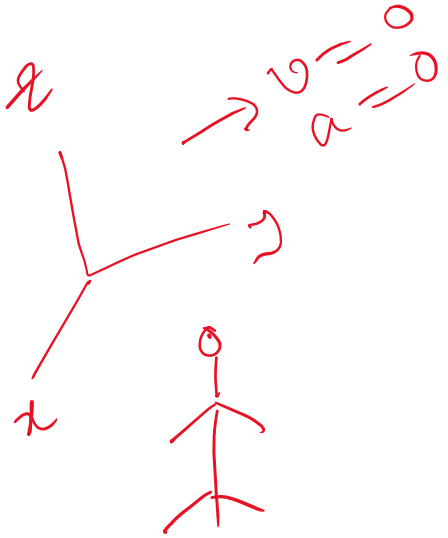
Relativity

1. Special theory of Relativity.

2. General theory of relativity

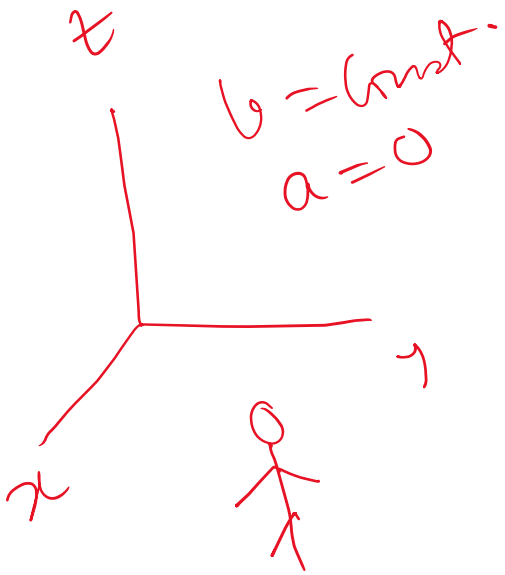
Fig. 37-1 Einstein posing for a photograph as fame began to accumulate. *(Corbis Images)*

Postulates of Special Theory of Relativity



1. The Relativity Postulate: The laws of physics are the same for observers in all inertial reference frames. No one frame is preferred over any other.

Inertial frame of reference?



2. The Speed of Light Postulate: The speed of light in vacuum has the same value c in all directions and in all inertial reference frames.

The Ultimate Speed $c = 299\,792\,458$ m/s.

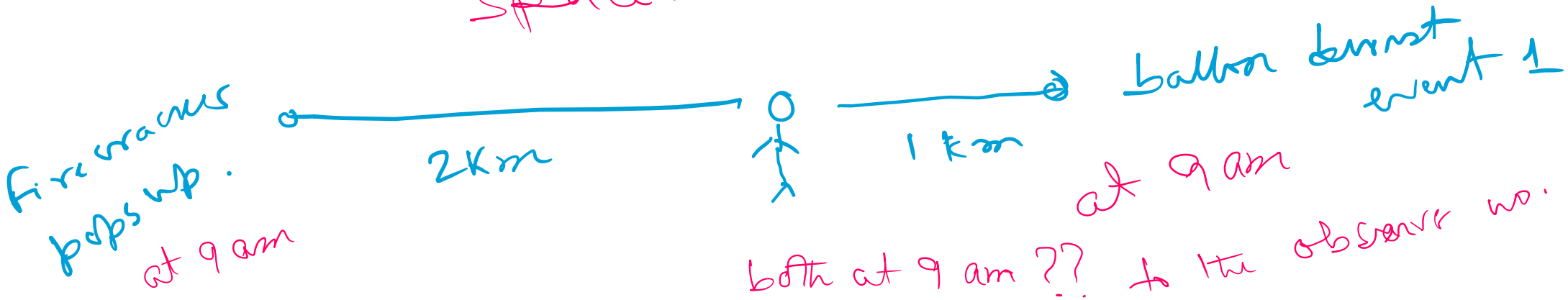
Measuring an Event

Where and when? (x, y, z, t)

In relativity space and time are entangled.

We describe these coordinates as

spacetime coordinates.



The Relativity of Simultaneity

If two observers are in relative motion, they will not, in general, agree as to whether two events are simultaneous. If one observer finds them to be simultaneous, the other generally will not.

Simultaneity is not an absolute concept but rather a relative one, depending on the motion of the observer.

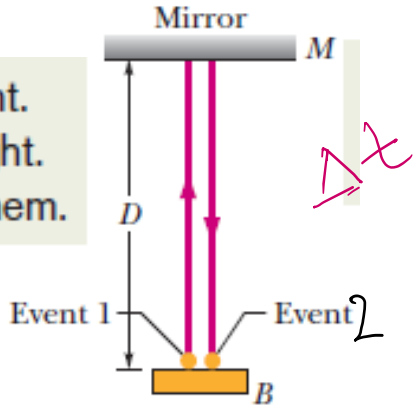
The Relativity of Time

Observers in relative motion with each other will in general find different time interval betn two events. Because the spatial separation of the events can effect the intervals measured by the two observers. Because Space and time are entangled

The time interval between two events depends on how far apart they occur in both space and time; that is, their spatial and temporal separations are entangled.

The Relativity of Time

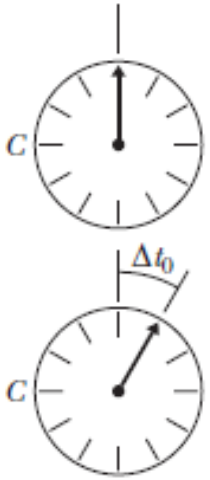
Event 1 is the emission of light.
Event 2 is the return of the light.
We want the time between them.



Δt_0

$$\Delta t_0 = \frac{2D}{c} \quad \text{(Sally)}$$

$$\therefore D = \frac{1}{2} c \Delta t_0$$

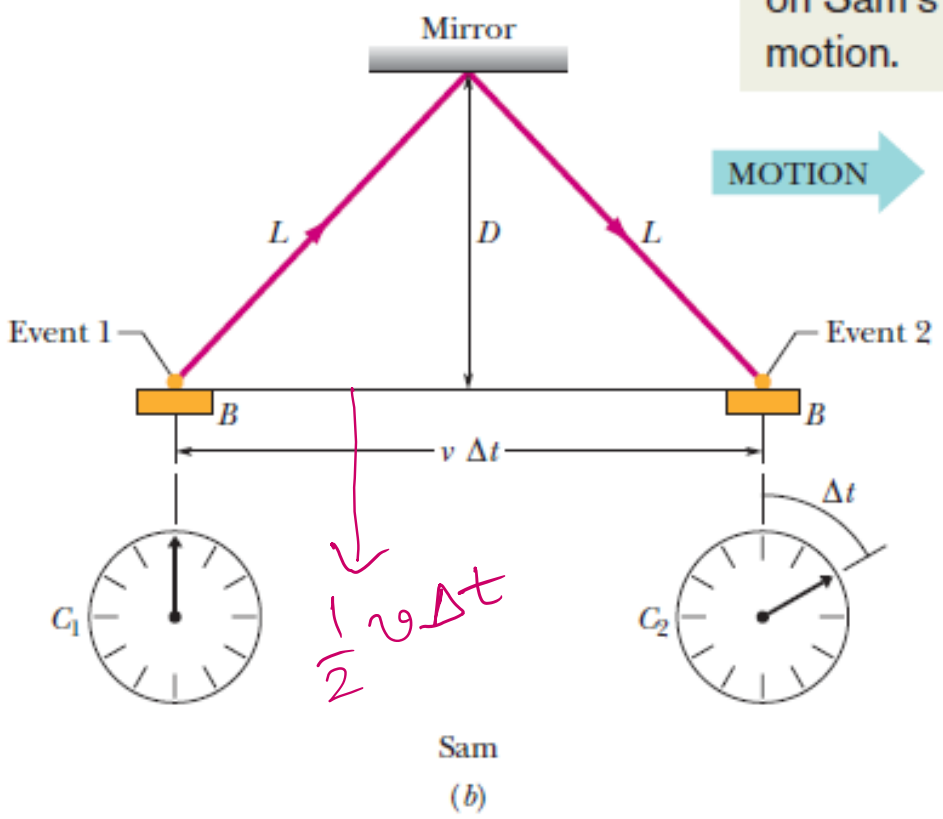


(*a*)

Figure 37-5 (*a*) Sally, on the train, measures the time interval Δt_0 between events 1 and 2 using a single clock C on the train. That clock is shown twice: first for event 1 and then for event 2. (*b*) Sam, watching from the station as the events occur, requires two synchronized clocks, C_1 at event 1 and C_2 at event 2, to measure the time interval between the two events; his measured time interval is Δt.

Event 1 is the emission of light.
Event 2 is the return of the light.
We want the time between them.

The measure of that time interval on Sally's clock differs from that on Sam's clock due to the relative motion.



$$\Delta t = \frac{2L}{c}$$

$$\therefore L = \frac{1}{2} c \Delta t$$

$$L = \sqrt{\left(\frac{1}{2} v \Delta t\right)^2 + D^2}$$

$$\text{or } L = \sqrt{\left(\frac{1}{2} v \Delta t\right)^2 + \left(\frac{1}{2} c \Delta t_0\right)^2}$$

$$\text{or } L^2 = \left(\frac{1}{2} v \Delta t\right)^2 + \left(\frac{1}{2} c \Delta t_0\right)^2$$

$$\left(\frac{1}{2} c \Delta t\right)^2 = \left(\frac{1}{2} v \Delta t\right)^2 + \left(\frac{1}{2} c \Delta t_0\right)^2$$

$$c^2 \Delta t^2 = v^2 \Delta t^2 + c^2 \Delta t_0^2$$

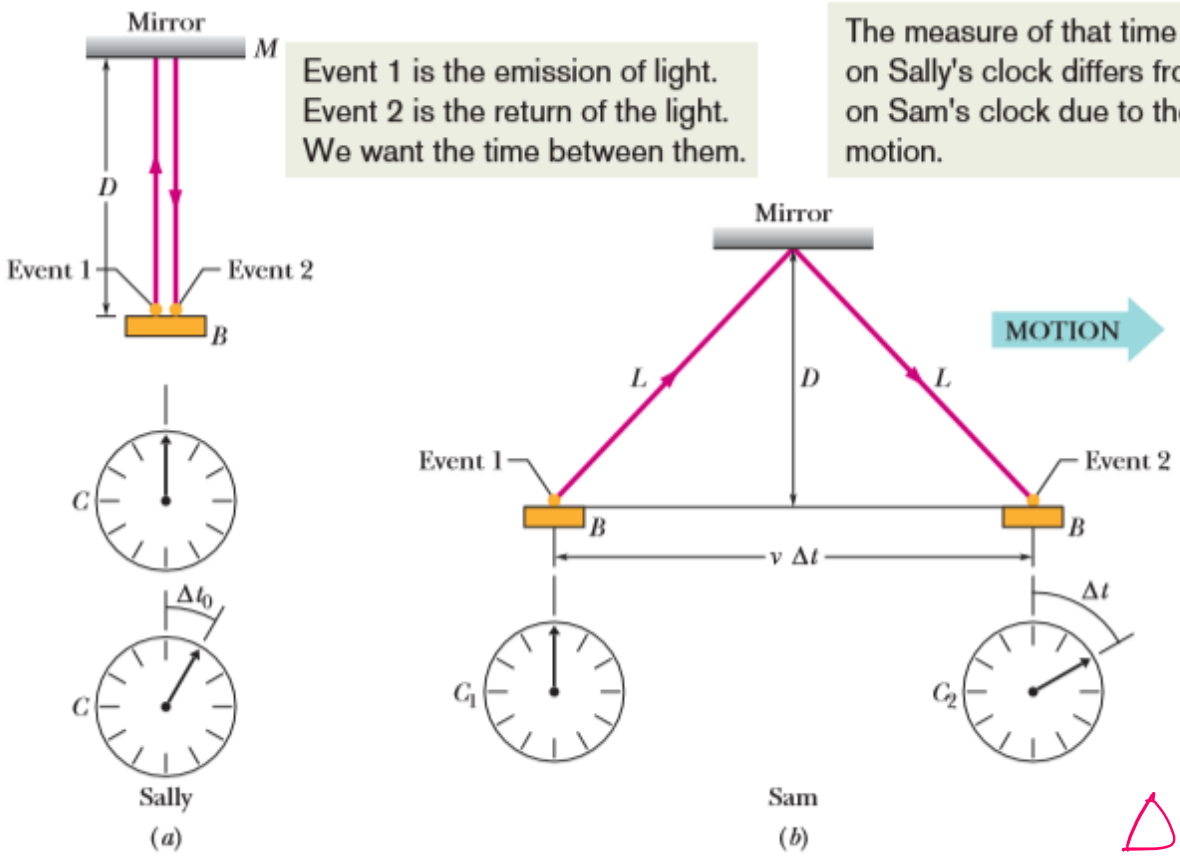


Fig. 37-5 (*a*) Sally, on the train, measures the time interval Δt_0 between events 1 and 2 using a single clock C on the train. That clock is shown twice: first for event 1 and then for event 2. (*b*) Sam, watching from the station as the events occur, requires two synchronized clocks, C_1 at event 1 and C_2 at event 2, to measure the time interval between the two events; his measured time interval is Δt.

$$\Delta t = \frac{\Delta t_0}{\sqrt{1-(v/c)^2}}.$$

$$\Delta t = \frac{\Delta t_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

$$\Delta t^2 = \left(\frac{v}{c}\right)^2 \Delta t^2 + \Delta t_0^2$$

$$\Delta t^2\left(1-\frac{v^2}{c^2}\right) = \Delta t_0^2$$

$\Delta t > \Delta t_0$ Sally will remain younger

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - (v/c)^2}}.$$

proper time

$\Delta t > \Delta t_0$

Remember

When two events occur at the same location in an inertial reference frame, the time interval between them, measured in that frame, is called the **proper time interval** or the **proper time.** Measurements of the same time interval from any other inertial reference frame are always greater.

Your starship passes Earth with a relative speed of 0.9990c. After traveling 10.0 y (your time), you stop at lookout post LP13, turn, and then travel back to Earth with the same relative speed. The trip back takes another 10.0 y (your time). How long does the round trip take according to measurements made on Earth? (Neglect any effects due to the accelerations involved with stopping, turning, and getting back up to speed.)

① 2 inertial reference frames (i) yours and (ii) the other attached to the earth.

② Two events (i) Start from the earth and (ii) End of the trip at LP13.

③ Your measurement of 10 yr betn event ① and ② is the proper time Δt_0.

because the events occur at the same location in your reference frame – namely on your ship.

④ The earth frame measurement of the time interval Δt for the trip must be greater than Δt_0 for the time dilation.

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - (v/c)^2}}$$

$$= \frac{10.0 \text{ y}}{\sqrt{1 - (0.9990c/c)^2}} = (22.37)(10.0 \text{ y}) = 224 \text{ y}.$$

On the return trip, we have the same situation and the same data. Thus, the round trip requires 20 y of your time but

$$\Delta t_{\text{total}} = (2)(224 \text{ y}) = 448 \text{ y} \qquad \text{(Answer)}$$

of Earth time. In other words, you have aged 20 y while the Earth has aged 448 y. Although you cannot travel into the past (as far as we know), you can travel into the future of, say, Earth, by using high-speed relative motion to adjust the rate at which time passes.

Often the dimensionless ratio v/c in Eq. 37-7 is replaced with β, called the **speed parameter,** and the dimensionless inverse square root in Eq. 37-7 is often replaced with γ, called the **Lorentz factor:**

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = \frac{1}{\sqrt{1-(v/c)^2}}. \tag{37-8}$$

Speed parameter $\beta = \frac{v}{c}$ (dimensionless ratio)

Syllabus for TERM FINAL Examination

PHY 112 (4) Summer Semester 2023

Exam on 7th September, 2023 at 11:00 am in room no UB 20204

Chapter 25 to Chapter 30 and, Chapter 37
Capacitance to Maxwell's Equations and Relativity
HRW 10 Edition Extended

PHY112	04	Professor Dr. A. F. M. Yusuf Haider	YUH	UB20204	ST DAY 2 Thursday	07-09-2023	11:00 am	12:30 pm

Suggested points and problems For Term Final Summer 2022

Note: This list is intended only for practice. The exam question could be similar, but may not be from this list.

The following chapter, problem number, etc. refers to the 9th edition (extended) of the Resnick, Halliday and Walker's book

Legend: CP = check point, SP = sample problem in the book (solved problems) on a particular page, Pr = unsolved problems in the book at the end of the chapter.

Chapter: 25:

SP: P665, P666, P671, P673.

CP: 1, 2, 3.

Pr **11, 15, 57**.

Chapter 26:

SP: P687, P688, P691.

CP: 1, 2, 3, 5.

Pr: 8.

Chapter 27:

SP: P716, P719, P723.

CP: 1, 2, 3, 4, 5.

Pr: *18, 33, 45,*

Chapter: 28:

CP: 1,2,3,4.

SP: P739, P746, P751, P755.

Pr: *4, 41, 42, 85.*

Chapter 29:

SP: P768, P769, P774, P778.

CP: 1,2, 3.

Pr: *4,11, 21, 45.*

Chapter 30:

SP: P793, P796, P812.

CP: 1, 2, 5, 6

Pr: *3, 15,*

Chapter 37:

SP: P1030

CP: 1, 2.

Pr: *1*, 4, *9*.