Physics 205 Test 2

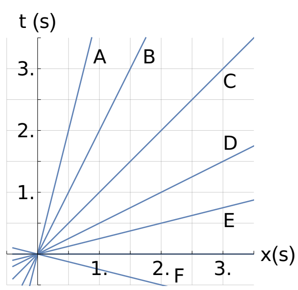
I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Name ____________________________ Signature ____________________________

Questions (7 for 7 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. A spacecraft zooms past the Earth at constant velocity. An observer on Earth measures a clock on the spacecraft is ticking at one-third the rate as an identical clock on the Earth. What does an observer see on the spacecraft for the Earth-based clock's ticking rate? Explain.

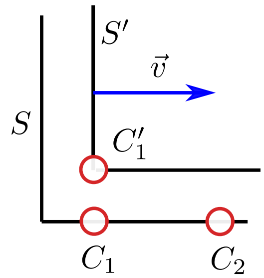
2. The *Other* frame is moving in the $+x$ direction with $x-$velocity $0.5c$. What lines in the figure correspond to the t' and and x' axes for this frame? Explain.



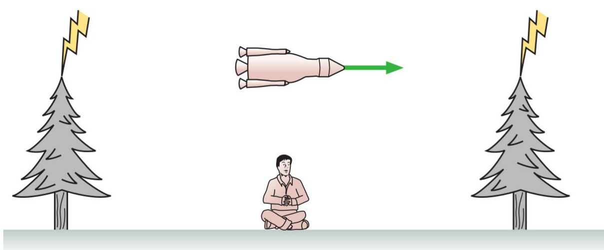
3. Two lights are 500 $light-ns$ apart along a straight road. In the ground frame, the west light flashes 600 ns before the east light flashes. Could these flashes be simultaneous in the frame of a car moving along the road at an appropriate speed? (Hint: Use a qualitative spacetime diagram.)

4. An object's length would be negative in a frame where it travels faster than the speed of light. True or False? Explain.

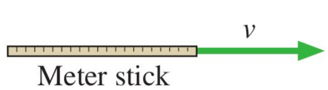
5. The figure shows two clocks in *Home* frame S that are synchronized and one clock in the *Other* frame S'. Clocks C_1 and C_1' both read zero when they pass each other. When clocks C_1' and C_2 pass each other which clock has a smaller reading and which clock measures a proper time? Explain.



6. The figure shows a rocket traveling from left to right. At the instant it is halfway between two trees, lightning simultaneously (in the rocket's frame) hits both trees. Do the light flashes reach the rocket pilot simultaneously? If not, which reaches her first? Explain.



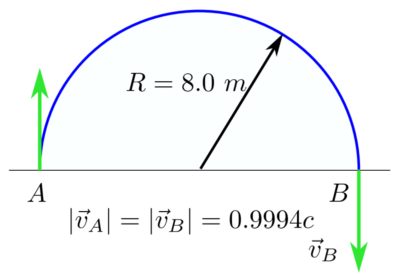
7. As the meter stick in the figure flies past you in the *Home* frame, you simultaneously measure the positions of both ends and determine that it is less than $1-m$ long. To an experimenter in the *Other* frame, the meter stick's frame, did you make your two measurements simultaneously? Explain.



Problems (4). Clearly show all reasoning for full credit. Use a separate sheet for your work.

1. 10 pts. Suppose an object with a rest length of 5 ns is at rest in the *Home* frame. The *Other* frame is moving with a speed $\beta = 0.5$ relative to the *Home* frame. (a) Draw a two-observer diagram of this situation and use it to determine the length of the object in the *Other* frame. Also calculate the same length using the appropriate equation.

2. 12 pts. The designers of particle accelerators use electromagnetic fields to boost particles to relativistic speeds while at the same time constraining them to move in a circle inside a donut-shaped evacuated cavity. Imagine a particle traveling in such an accelerator in a circular path of radius 8 m at a constant speed of $0.9994c$ as measured by laboratory observers. Let event A be the particle passing a certain point on its circular path and let event B be the particle passing the point on the circle directly opposite event A as shown in the figure. (a) What are the coordinate time Δt and the distance $|\Delta\vec{d}|$ in the lab frame? (b) What is the spacetime interval between the events? (c) What is the proper time $\Delta\tau_{SR}$ or $\Delta\tau_{SI}$ (SI units) as measured by a clock traveling with the particle?



3. 14 pts. The identical twins Speedo and Goslo join a migration from the Earth to Planet X. It is 10.0 ly away in a reference frame in which both planets are at rest. The twins, of the same age, depart at the same time on different spacecraft. Speedos craft travels steadily at 0.90c, and Goslos travels at 0.70c. What is the age difference between the twins after Goslos spacecraft lands on Planet X. Which twin is the older?

4. 15 pts. An *Other* frame moves in the positive x-direction with a velocity $v = \frac{2}{5}c$ relative to the *Home* frame. *Other* frame observers see an event at $t' = 4\ s$ and $x' = 2\ s$ in SR units. (a) Use a two-observer spacetime diagram to determine when and where this event occurs in the Home Frame. (b) Determine when and where this event occurs in the Home Frame using the Lorentz transformations.

DO NOT WRITE BELOW THIS LINE.

Physics 205 Equations

$$v = \frac{dx}{dt} \quad v = \frac{\Delta x}{\Delta t} \quad x = \frac{1}{2}at^2 + v_0 t + x_0 \quad v = at + v_0 \quad a_g = -g$$

$$\vec{F}_{net} = \sum \vec{F}_i = m\vec{a} = \frac{d\vec{p}}{dt} \quad \vec{F}_{Earth} = -mg\hat{j} \quad a_c = \frac{v^2}{r}$$

$$KE = \frac{1}{2}mv^2 \quad KE_0 + PE_0 = KE_1 + PE_1 \quad PE_{Earth} = mgh \quad PE_V = qV$$

$$\vec{p}_i = \vec{p}_f \quad \vec{p} = m\vec{v} \quad \vec{F}_C = k_e \frac{q_1 q_2}{r^2}\hat{r} \quad \vec{E} \equiv \frac{\vec{F}}{q_0} \quad d\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{s} \times \hat{r}}{r^2} = \frac{\mu_0}{4\pi}\frac{qd\vec{v} \times \hat{r}}{r^2} \qquad \vec{F}_B = q\vec{v} \times \vec{B} \qquad |\vec{F}_B| = |qvB\sin\theta|$$

Galilean Transformation SI units	Lorentz Transformation SI units	Lorentz Transformation SR units
$x' = x - vt$	$x' = \gamma(x - vt)$	$x' = \gamma(x - \beta t)$
$y' = y$	$y' = y$	$y' = y$
$z' = z$	$z' = z$	$z' = z$
$t' = t$	$t' = \gamma(t - vx/c^2)$	$t' = \gamma(t - \beta x)$
$v'_x = v_x - v_O$	$v'_x = \frac{v_x - v_O}{1 - v_x v/c^2}$	$v'_x = \frac{v_x - \beta}{1 - v_x \beta}$

Coordinate Time	Proper Time	Spacetime Interval
Time between two events in an inertial frame measured with synchronized clocks	Time between two events measured by the same clock at both events.	Time between two events measured by the same, inertial clock at both events.
$c\Delta t$,Δt	$\Delta\tau_{SI}$, $\Delta\tau_{SR}$	Δs_{SI}, Δs_{SR}
Frame dependent	Frame independent	Frame independent

$$\Delta s_{SI}^2 = c^2\Delta t^2 - \Delta d^2 = {\Delta s'_{SI}}^2 \quad \text{or} \quad \Delta s_{SR}^2 = \Delta t^2 - \Delta d^2 = {\Delta s'_{SR}}^2$$

$$\Delta\tau_{SI} = \int_{t_A}^{t_B} \sqrt{1 - \frac{v^2}{c^2}}\, dt \quad \text{or} \quad \Delta\tau_{SR} = \int_{t_A}^{t_B} \sqrt{1 - \beta^2}\, dt$$

$$\Delta\tau_{SI} = \sqrt{1 - v^2/c^2}\ \Delta t \quad \text{or} \quad \Delta\tau_{SR} = \sqrt{1 - \beta^2}\ \Delta t$$

$$L_{SI} = L_R\sqrt{1 - v^2/c^2} \quad \text{or} \quad L_{SR} = L_R\sqrt{1 - \beta^2}$$

$$\frac{d}{dx}(f(u)) = \frac{df}{du}\frac{du}{dx} \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int \frac{1}{x}dx = \ln x \quad \vec{A}\cdot\vec{B} = AB\cos\theta \quad |\vec{A}\times\vec{B}| = |AB\sin\theta|$$

$$\frac{d}{dx}(x^n) = nx^{n-1} \quad \frac{de^x}{dx} = e^x \quad \frac{d}{dx}(\ln x) = \frac{1}{x} \quad \frac{d}{dx}(\cos ax) = -a\sin ax \quad \frac{d}{dx}(\sin ax) = a\cos ax$$

$$\langle x\rangle = \frac{1}{N}\sum_i x_i \quad \sigma = \sqrt{\frac{\sum_i (x_i - \langle x\rangle)^2}{N-1}} \quad C = 2\pi r \quad A = 4\pi r^2 \quad V = Ah \quad V = \frac{4}{3}\pi r^3$$

$$\frac{df(x)}{dx} = \lim_{\Delta x\to 0}\frac{f(x+\Delta x) - f(x)}{\Delta x} \quad \int_a^b f(x)dx = \lim_{\Delta x\to 0}\sum_{n=1}^{N} f(x)\Delta x$$

$$\int \frac{1}{x}dx = \ln x \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int e^{ax}dx = \frac{e^{ax}}{a} \quad \int \frac{1}{\sqrt{x^2+a^2}}dx = \ln\left[x + \sqrt{x^2+a^2}\right]$$

$$\int \frac{x}{\sqrt{x^2+a^2}}dx = \sqrt{x^2+a^2} \quad \int \frac{x^2}{\sqrt{x^2+a^2}}dx = \frac{1}{2}x\sqrt{x^2+a^2} - \frac{1}{2}a^2\ln\left[x + \sqrt{x^2+a^2}\right]$$

$$\int \sqrt{1-ax^2}dx = \frac{x}{2}\sqrt{1-ax^2} + \frac{\arcsin(\sqrt{a}x)}{2\sqrt{a}} \quad \int \frac{x^3}{\sqrt{x^2+a^2}}dx = \frac{1}{3}(-2a^2+x^2)\sqrt{x^2+a^2}$$

Physics 205 Constants and Conversions

Avogadro's number (N_A)	6.022×10^{23}	Speed of light (c)	$3\times10^8\ m/s$
k_B	$1.38\times10^{-23}\ J/K$	proton/neutron mass	$1.67\times10^{-27}\ kg$
1 u	$1.67\times10^{-27}\ kg$	g	$9.8\ m/s^2$
Gravitation constant	$6.67\times10^{-11}\ N-m^2/kg^2$	Earth's radius	$6.37\times10^6\ m$
Coulomb constant (k_e)	$8.99\times10^9\frac{N-m^2}{C^2}$	Electron mass	$9.11\times10^{-31}\ kg$
Elementary charge (e)	$1.60\times10^{-19}\ C$	Proton/Neutron mass	$1.67\times10^{-27}\ kg$
Permittivity constant (ϵ_0)	$8.85\times10^{-12}\frac{kg^2}{N-m^2}$	1.0 eV	$1.6\times10^{-19}\ J$
1 MeV	$10^6\ eV$	atomic mass unit (u)	$1.66\times10^{-27}\ kg$
Planck's constant (h)	$6.63\times10^{-34}\ Js$	Planck's constant (h)	$4.14\times10^{-15}\ eVs$
Permeability constant (μ_0)	$1.26\times10^{-6}\ Tm/A$	Rydberg constant (R_H)	$1.097\times10^7\ m^{-1}$
Becquerel (Bq)	$1\ decay/s$	Curie (Ci)	$3.7\times10^{10}\ Bq$