University of California, San Diego
GRE Prep – Fall 2018
Practice Relativity Problems
April 18, 2022

1. A particle of rest mass M has momentum $2Mc$. Which of the following is closest to the speed of the particle?

A) $0.86c$
B) $0.90c$
C) $0.82c$
D) $0.96c$
E) $0.93c$

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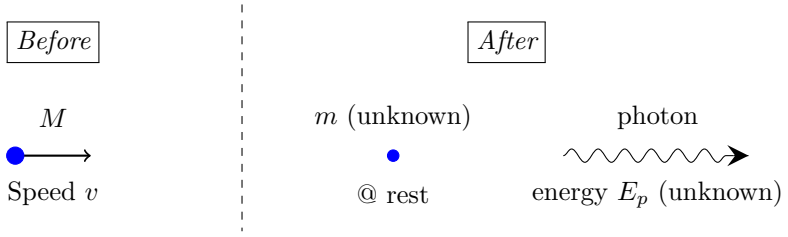
2. A particle of mass M moves at speed v in the lab frame. In order to brake to a stop, the particle can emit a photon in the forward direction and decay into a daughter particle of smaller rest-mass energy. Suppose the particle of mass M decays such that the daughter particle is at rest in the lab frame after the decay:



Which particle in the final state has the greater energy?

A) The massive particle at rest (of mass m) definitely has more energy.
B) The photon definitely has more energy.
C) The photon has more energy if $v > 0.5c$ and less energy if $v < 0.5c$.
D) The massive particle of mass m has more energy if $v > 0.5$ and less energy if $v < 0.5$.
E) None of the above.

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3. A meter stick (proper length exactly 1 meter) travels at 0.5c in the lab frame. Suppose someone (in the lab frame) has a stopwatch to measure the time it takes from the moment the front the meter stick passes by, to the moment the back of the meter stick passes by. How much time will read on the stopwatch?

A) 3.33 nanoseconds
B) 1.67 nanoseconds
C) 1.00 nanoseconds
D) 2.86 nanoseconds
E) 5.77 nanoseconds

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$E^2 = p^2 + M^2 = 5$

$v^2 = \frac{p^2}{E^2} = \frac{4}{5} = 0.8$

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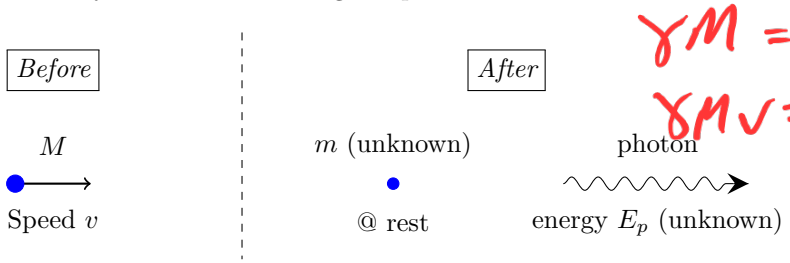

$\gamma M = m + E_p$

$\gamma M v = E_p$

$v = \frac{E_p}{m + E_p}$

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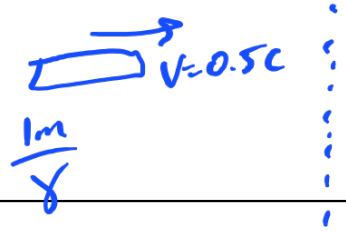


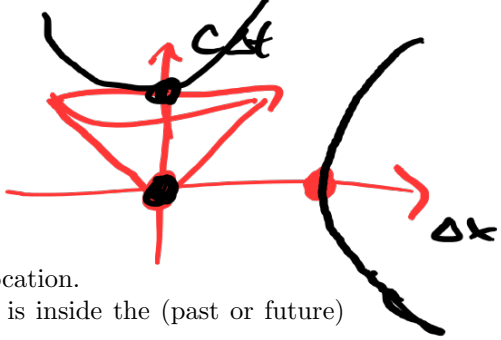
$\frac{1\text{meter}}{c} = \frac{1\text{meter}}{1\text{ft/ns}}$

$\approx 3.3\text{ns}$

$\gamma = \frac{1}{\sqrt{1 - 1/4}} = \frac{2}{\sqrt{3}}$

$t = \frac{\left(\frac{1m}{\gamma}\right)}{(0.5c)} = \frac{2\text{meters}}{\gamma c}$

$= \sqrt{3}(3.3\text{ns})$



4. Two events are space-like separated. Which of the following is true?

A) There exists an inertial frame where the two events are simultaneous.
B) There exists an inertial frame where the two events occur at the same location.
C) On a space-time diagram with one event at the origin, the other event is inside the (past or future) lightcone.
D) There exists a different frame where the events are not space-like separated.
E) None of the above are true statements.

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5. Two barn doors, separated by 10 meters in the x-direciton, are closed simultaneously (length and time as measured in a frame where the barn is at rest). A pole-vaulter runs in the $+x$ direction towards the barn doors at a speed $\beta = \sqrt{3}/2$ as measured in the barn frame. The pole-vaulter will encounter (pass through and/or break through) the front door before the back door. Which of the following is true as measured by the pole-vaulter?

A) The front barn door closes before the back door by a time $(17\,\mathrm{m})/c$.
B) The back barn door closes before the front door by a time $(17\,\mathrm{m})/c$.
C) The front barn door closes before the back door by a time $(5\,\mathrm{m})/c$.
D) The back barn door closes before the front door by a time $(5\,\mathrm{m})/c$.
E) None of the above.

---

6. A car is traveling $0.80c$ to the right as measured in the ground frame. Someone in the car throws a ball out the back window such that the ball emerges from the car traveling $0.40c$ to the right as measured in the ground frame. How fast was the ball thrown from the car, as measured in the car's frame?

A) $0.3c$
B) $0.4c$
C) $0.5c$
D) $0.6c$
E) $0.7c$

---

7. Which of the following statements is TRUE?

A) A light signal leaves a laser pointer (event A), travels a distance L, bounces 180° off a mirror, and returns to the later pointer (event B). Because light travels from event A to event B, the spacetime interval is zero.
B) A cop chases a robber, both traveling the same direction. The cop moves at speed 0.5c in the ground frame, and the robber moves at speed 0.85c in the ground frame. If the cop fires a bullet that travels at speed 0.5c with respect to the cop, then the bullet can strike the robber.
C) The time between two timelike-separated events is minimized in the inertial frame where the events occur at the same location.
D) If a system containing one photon and one massive particle has zero total momentum, then the photon has more energy than the massive particle.
E) A massive particle can decay into a single photon.

$$\left(\sum_i E_i\right)^2 - \left(\sum_i p_i\right)^2 = M^2$$

8. A particle of mass M is moving with speed $\sqrt{3}/2$ in the lab frame. It decays into two particles: particle A, of mass $M/4$, and particle B, of mass $M/2$. Particle A is at rest in the lab frame after the decay. What is the invariant mass of the two-particle system (which consists of particles A and B together)?

A) $3M/4$
B) M
C) $2M$
D) $3M/2$
E) None of the above.

inv. mass doesn't change!

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9. Without taking into account special relativity, muons created in the upper-atmosphere shouldn't make it to the Earth's surface. However, we know from special relativity that the muon's lifetime is greater in the Earth frame because of time-dilation, which explains why they make it to the ground. Which of the following is the best explanation for what happens in the muon frame?

A) The muons do not make it to the earth in the muon's frame.
B) The muons make make it to the earth in the muon's frame according to general relativity (there is a paradox if you only take into account special relativity).
C) The muons make it to the earth because there is an inverse time dilation factor for the earth coming towards the muons.
D) The muons make it to the earth because the distance from upper-atmosphere to ground is length-contracted in the muon-frame.
E) None of the above.

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10. A particle as observed in a certain reference frame F has a total energy of 7 GeV and a momentum of 5 GeV/c. What is its energy in a frame F' in which its momentum is equal to 3 GeV/c?

A) 4.2 GeV
B) 4.7 GeV
C) 5.2 GeV
D) 5.7 GeV
E) 6.2 GeV

$$E^2 - p^2 = (E')^2 - (p')^2$$
$$49 - 25 = (E')^2 - 9$$
$$E' = \sqrt{33}\ \text{GeV}$$

End of Multiple Choice Questions

University of California, San Diego
GRE Prep – Spring 2022
Practice Relativity Answers
April 25, 2022

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1. A particle of rest mass M has momentum $2Mc$. Which of the following is closest to the speed of the particle?

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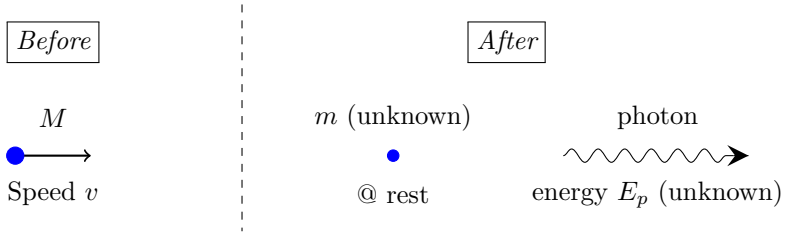

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End of Multiple Choice Questions

Questions for Faculty Panel

* What is the most impactful part of an application?
* Who can we get letters of recommendation from? Just professors who knew us well, or also managers from non-academic jobs? People we haven't explicitly worked under?