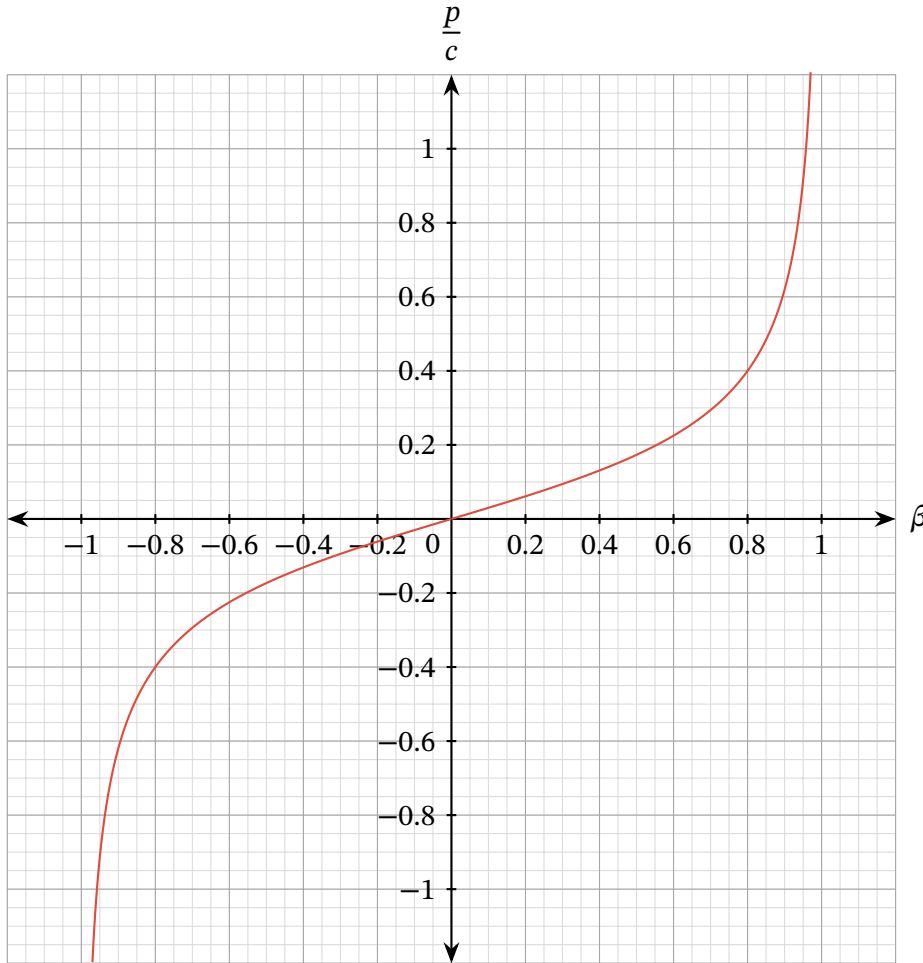


# Worksheet: Relativistic Momentum



**Q1:** The graph shows how the relativistic momentum of an object varies with speed. The  $x$ -axis shows the speed as  $\beta = \frac{v}{c}$  and the  $y$ -axis shows the momentum,  $p$ , divided by the speed of light,  $c$ . Use the formula  $m_0 = \frac{p}{c} \times \frac{1}{\gamma\beta}$  to find the rest mass of the object.



- A 0.3 kg
- B 0.4 kg
- C 0.2 kg
- D 0.5 kg
- E 0.1 kg

**Q2:** An object is traveling at 75% of the speed of light in a frame  $S$ . The object has a rest mass of 2 kg. How much greater is the relativistic momentum of the object than the classical momentum of the object? Give your answer to 3 significant figures.

A  $5.79 \times 10^8 \text{ kg}\cdot\text{m/s}$

B  $9.00 \times 10^8 \text{ kg}\cdot\text{m/s}$

C  $6.80 \times 10^8 \text{ kg}\cdot\text{m/s}$

D  $4.50 \times 10^8 \text{ kg}\cdot\text{m/s}$

E  $2.30 \times 10^8 \text{ kg}\cdot\text{m/s}$

**Q3:** At what speed is the relativistic momentum of an object equal to twice its classical momentum? Give your answer to 3 significant figures.

A  $0.577c$

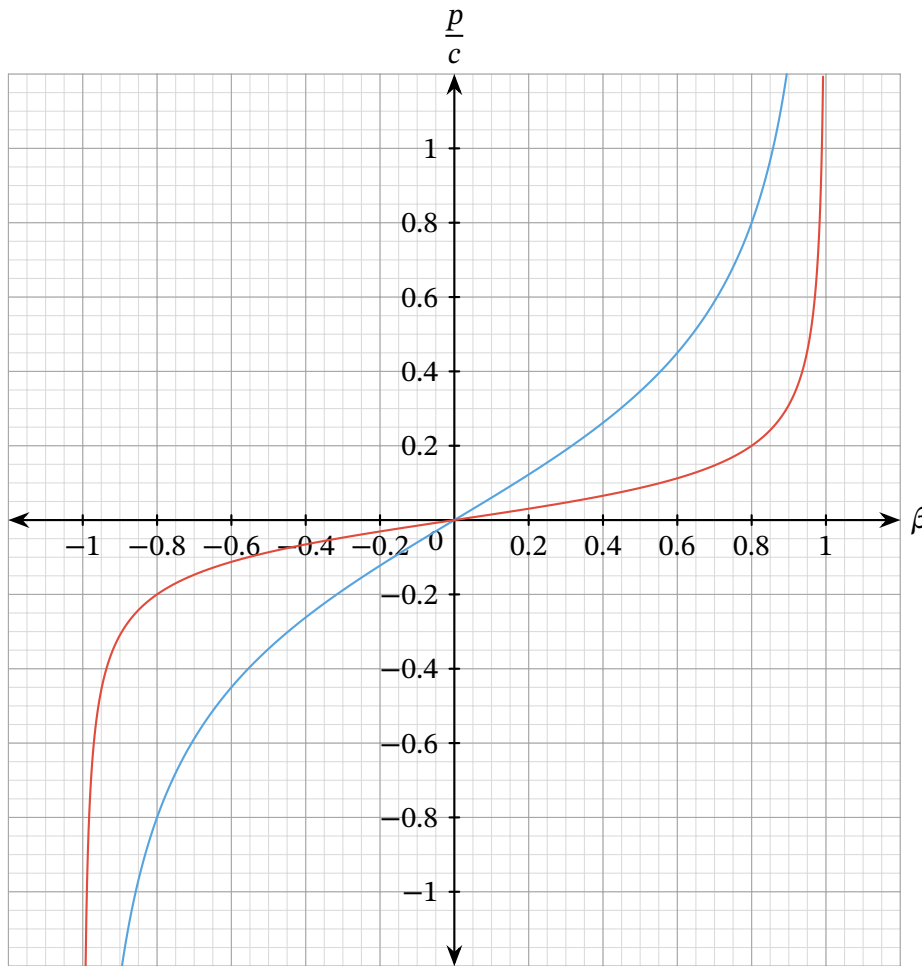
B  $0.500c$

C  $0.866c$

D  $0.707c$

E  $0.750c$

**Q4:** The graph shows how relativistic momentum varies with speed for two objects with different rest masses. The  $x$ -axis shows the speed of the objects as  $\beta = \frac{v}{c}$  and the  $y$ -axis shows the momentum of the objects,  $p$ , divided by the speed of light,  $c$ . The red line shows the relativistic momentum of object A and the blue line shows the relativistic momentum of object B. What is the ratio of the rest mass of object B to the rest mass of object A?



- A 3.0
- B 0.25
- C 4.0
- D 1.0
- E 1.2

**Q5:** A kaon in a particle accelerator has a speed of  $0.99c$  relative to the particle accelerator. Its relativistic momentum in the rest frame of the accelerator is  $1.85 \times 10^{-18} \text{ kg}\cdot\text{m/s}$ . What is the rest mass of the particle?

A  $8.79 \times 10^{-28} \text{ kg}$

B  $1.24 \times 10^{-28} \text{ kg}$

C  $6.23 \times 10^{-27} \text{ kg}$

D  $1.35 \times 10^{-27} \text{ kg}$

E  $6.25 \times 10^{-28} \text{ kg}$

**Q6:** A pion in a particle accelerator has a speed of  $0.998c$  relative to the particle accelerator. Its relativistic momentum in the rest frame of the accelerator is  $2,210 \text{ MeV}/c$ . What is the rest mass of the particle? Give your answer to 3 significant figures.

A  $140 \text{ MeV}/c^2$

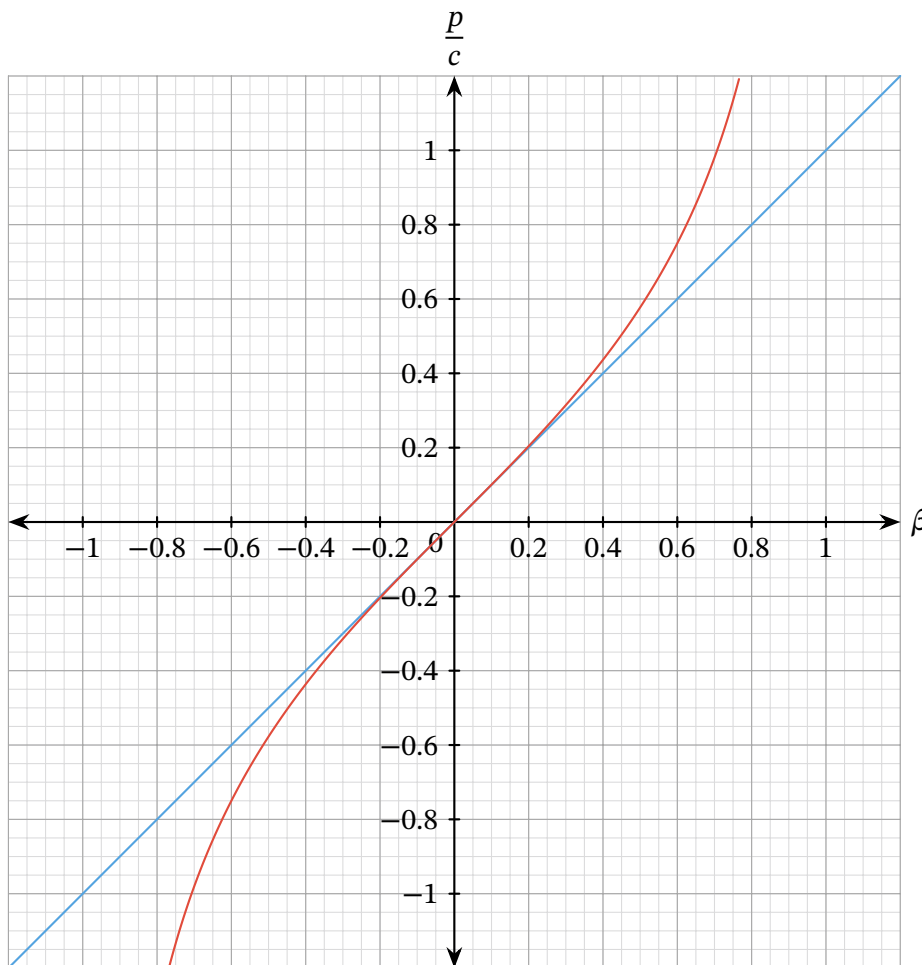
B  $309 \text{ MeV}/c^2$

C  $2,190 \text{ MeV}/c^2$

D  $315 \text{ MeV}/c^2$

E  $223 \text{ MeV}/c^2$

**Q7:** The graph shows how both the classical momentum and the relativistic momentum of an object vary with speed. The  $x$ -axis shows the speed as  $\beta = \frac{v}{c}$  and the  $y$ -axis shows the momentum divided by the speed of light,  $c$ . The object has a mass of 1 kg. The blue line shows the classical momentum of the object and the red line shows the relativistic momentum of the object.



Which of the following statements is true?

- A The magnitude of the relativistic momentum is greater than the magnitude of the classical momentum at any speed.
- B The magnitude of the relativistic momentum and the magnitude of the classical momentum are equal at any speed.
- C The magnitude of the relativistic momentum is greater than the magnitude of the classical momentum at speeds greater than  $0.2c$ . At speeds less than  $0.2c$ , the relativistic momentum is equal to the classical momentum.

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- D The magnitude of the classical momentum is greater than the

**Q8:** A spaceship traveling from Earth to the Gliese 832 system has a rest mass of 80,000 metric tons. It travels at a speed of  $0.8c$  relative to Earth. What is the relativistic momentum of the spaceship relative to Earth?

A  $9.6 \times 10^{16} \text{ kg} \cdot \text{m/s}$

B  $3.2 \times 10^{16} \text{ kg} \cdot \text{m/s}$

C  $1.2 \times 10^{17} \text{ kg} \cdot \text{m/s}$

D  $4.3 \times 10^{16} \text{ kg} \cdot \text{m/s}$

E  $5.3 \times 10^{16} \text{ kg} \cdot \text{m/s}$

**Q9:** In an inertial reference frame  $S$ , an object with a rest mass of 5 kg has a velocity of  $0.1c$ . What is the relativistic momentum of the object in frame  $S$ ? Give your answer to 5 significant figures.

A  $1.5076 \times 10^9 \text{ kg} \cdot \text{m/s}$

B  $1.5076 \times 10^8 \text{ kg} \cdot \text{m/s}$

C  $1.6667 \times 10^8 \text{ kg} \cdot \text{m/s}$

D  $1.5812 \times 10^8 \text{ kg} \cdot \text{m/s}$

E  $1.5152 \times 10^8 \text{ kg} \cdot \text{m/s}$

**Q10:** In an inertial reference frame  $S$ , an object has a speed of  $0.6c$  and a relativistic momentum of  $1.8 \times 10^8 \text{ kg}\cdot\text{m/s}$ . What is its rest mass? Answer to one significant figure.

- A 0.6 kg
- B 0.4 kg
- C 0.7 kg
- D 0.8 kg
- E 0.5 kg