# Sample Problem Set

July 24, 2024

## Physics

## 1 Asteroid Collision

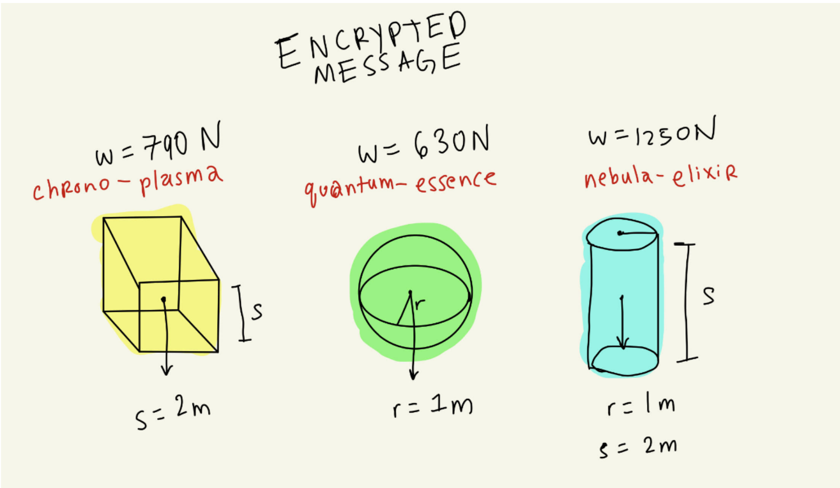
A 2200 kg asteroid enters the outer atmosphere of planet COPERNICUS at a speed of 3200 m/s and is headed straight for the planet's surface. The atmosphere of the planet is strangely made of sulfur dioxide and helium, so the asteroid experiences a constant drag force of 11,000 newtons and a constant gravitational acceleration of 2.5 $\mathrm{m/s^2}$. If the radius of the planet is 7000 km, and the outer edge of the atmosphere is 9500 km,

(a) how long would it take for the asteroid to stop?

(b) Will the planet crash into the asteroid's surface?

## 2 Peculiar Fluid

Your 550 kg spaceship is floating in a weird fluid-like substance on planet XIV. Luckily, researchers back home on Hearth have sent you an encrypted message to determine what fluid you're in. Your spaceship exerts a thrust of 1800 newtons radially outward, experiences atmospheric drag that goes as $F_{\text{drag}} = 650e^{0.25a}$ where $a$ is the acceleration of your spaceship only due to thrust, displaces a volume of 35 $\mathrm{m^3}$, and the gravitational acceleration on planet XIV is 12 $\mathrm{m/s^2}$. Under these conditions, the spaceship does not accelerate in any direction(s). Which fluid are you in? The gravitational field on Hearth is 10 $\mathrm{m/s^2}$.



# Astronomy

## 3 The habitable zone

Life on Earth requires liquid water. For this reason, a star's "habitable zone" is defined as the range of orbital distances where the surface temperature of an Earth-like planet allows for liquid water. To calculate the boundaries of the habitable zone, you might think we should require $T_{\rm eq}$ to be between 0°C and 100°C. However, this calculation neglects the greenhouse effect. To account roughly for this and other atmospheric effects, we can require $T_{\rm eq}$ to be between -95°C and 5°C. Using this criterion and assuming $A = 0.3$ (the Earth's albedo), determine the boundaries of the habitable zone (in AU) of:

- the Sun ($R = R_\odot$, $M = M_\odot$, $T = 5777$ K),
- Vega ($R = 2.26R_\odot$, $M = 2.14M_\odot$, $T = 9602$ K), and
- Proxima Centauri ($R = 0.141R_\odot$, $M = 0.123M_\odot$, $T = 3042$ K).