

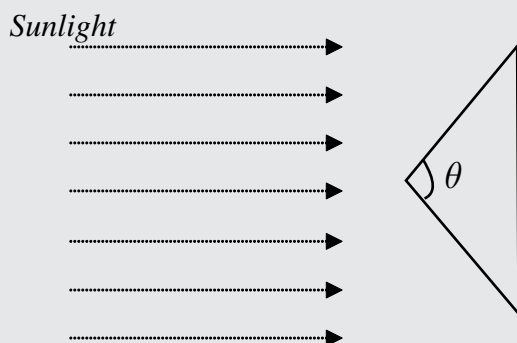
Physics Challenge for Teachers and Students

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Solution to May 2009 Challenge

► A Grand May Day Sail: 30% Off!

Challenge: A cone-shaped spaceship of the future uses the solar radiation pressure to propel itself away from the Sun as shown. The axis of the cone points directly at the Sun as shown. The conical surface of the ship is painted black. The astronauts then try to increase their acceleration by covering the conical surface with a highly reflective material. To their dismay, the acceleration actually drops 30%! Find the angle θ .

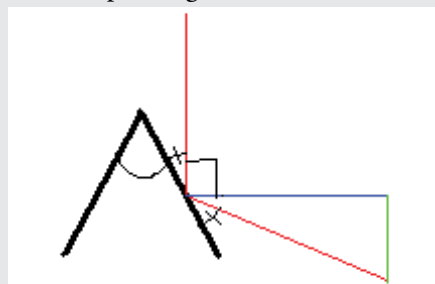


Column Editor's note: the last *Challenge* of the 2008/09 season resulted in numerous new contributors—both students and teachers—which is always exciting. Solutions arrived from Asia, Europe, and both North and South America—not to mention a historic first-ever solution by a person whose last name begins with an “O” (the last “unrepresented letter” among the solvers...).

Solution: We assume that the black painted surface has negligible reflective and transmittance properties. It is also assumed that the reflective material has negligible absorptive and transmittance properties.

Suggesting that the movement is caused by the transfer of momentum between the solar radiation and conical shape, it is clear that 100% of the momentum is transferred into the conical surface

while it is covered with a black material. This means that 70% of the momentum must be transferred while the reflective material is in use. With this we can set up a diagram:



The momenta of the incident and the reflected photons are represented by the red lines. The blue and green segments represent the X and Y components, respectively, of the momentum of the reflected photon. For the transferred momentum to be 70%, the momentum in the Y direction (green) after the collision must be 30% of the original momentum while the magnitude of the total momentum (red) must remain the same. This means that trigonometry can be used to solve for the angle of the conical shape. It can be shown that

$$\theta = 2 \frac{[180^\circ - 90^\circ - \sin^{-1}(0.3/1)]}{2}$$

or

$$\theta = 90^\circ - \sin^{-1}(0.3) \approx 72.54^\circ$$

(Submitted by William Fox, student, Downers Grove North High School, Oak Brook, IL)

We would also like to recognize the following contributors:

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Many thanks to all contributors and we hope to hear from you in the future!

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