Bicycle Gear Simulator

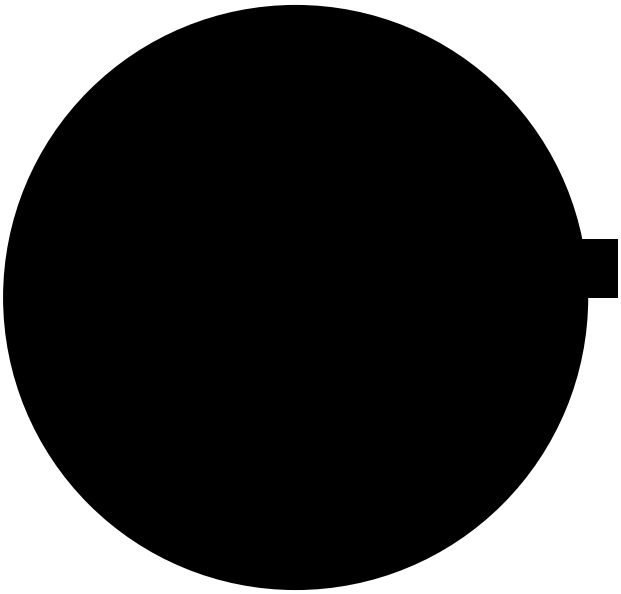
by Tom Falcone and Ivan Moore

Goal and Objective:

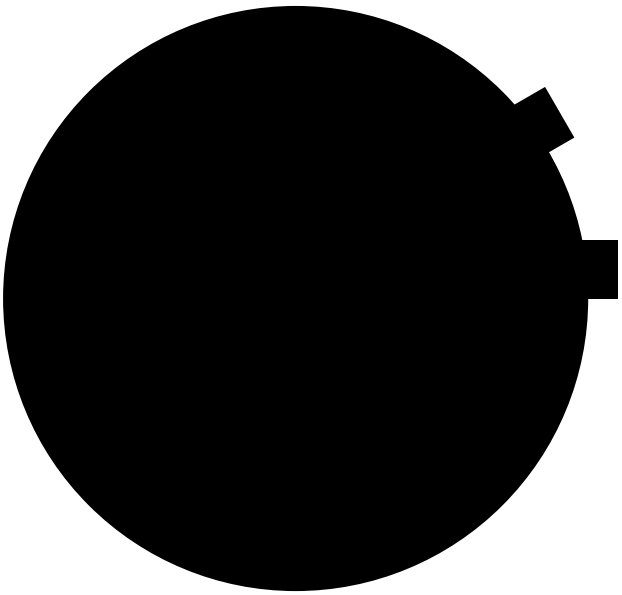
To make an interactive tool to help students investigate and gain
per understanding of fractions and ratios as found in a common setting.

the combinations of gear ratios and wheel diameters to determine how various settings
travelled and how the gears act as levers to convert the energy applied at the pedals to
ation will be an exploratory tool and an aid for students to check their own calculations.

Making the Gear
Phase 1: One tooth

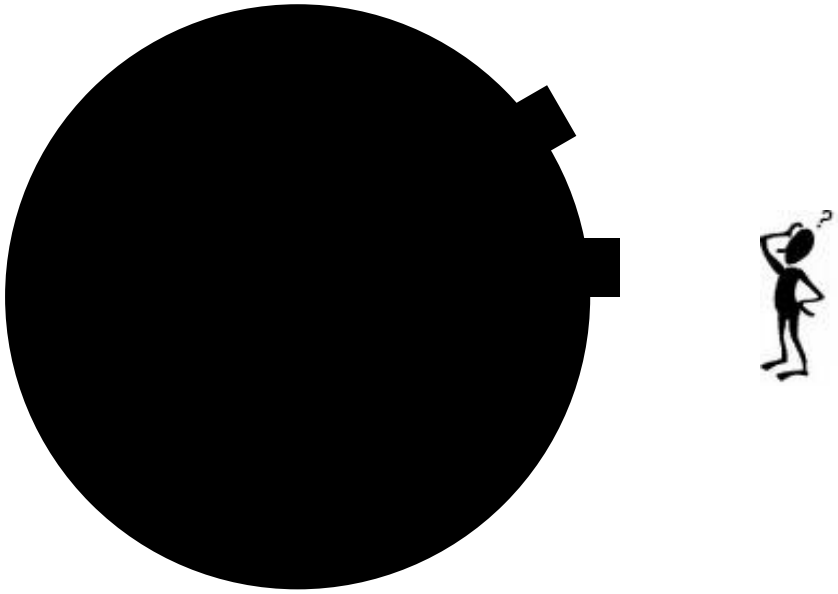


Making the Gear
Phase 2: Rotating the tooth

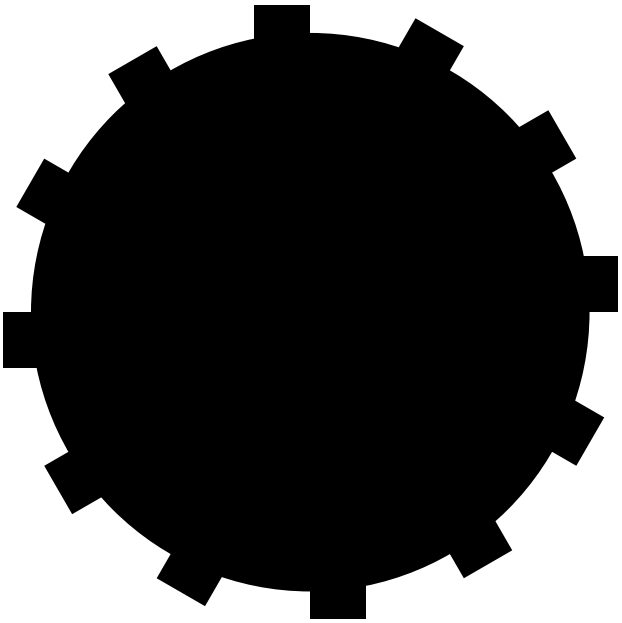


Making the Gear
Phase 2b: Simplifying

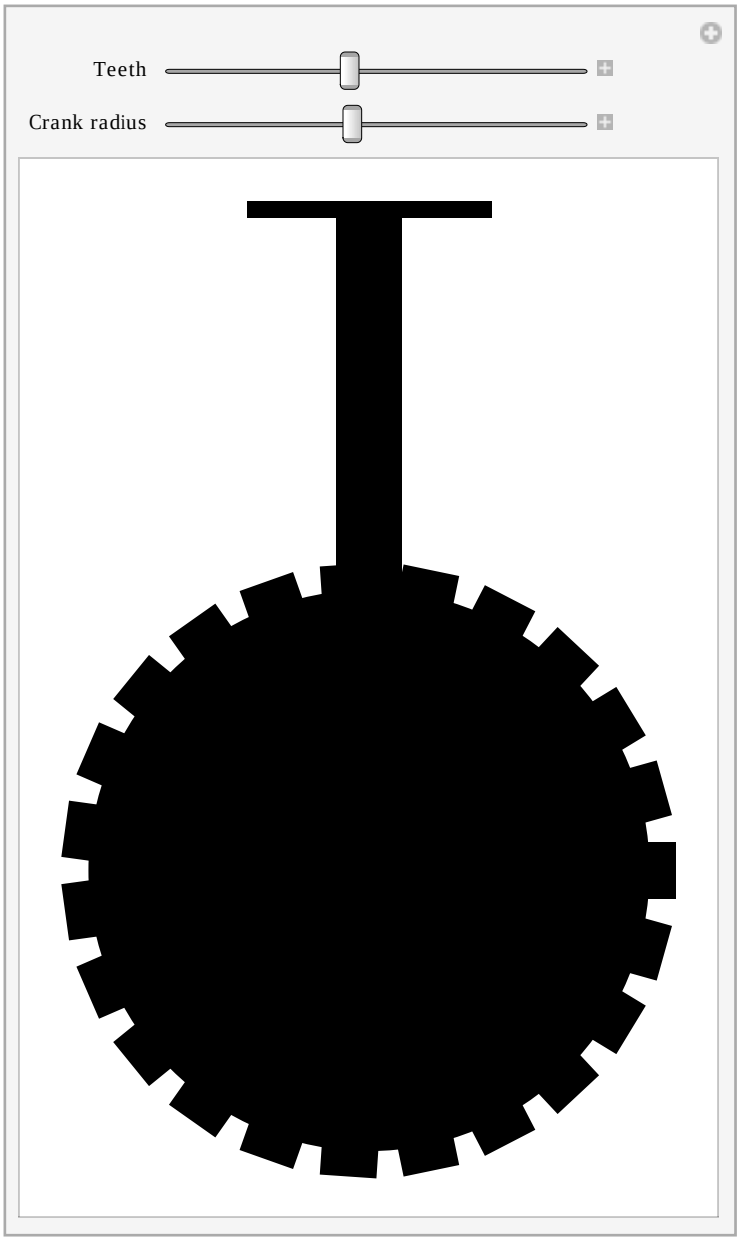
```
myRectangle = Rectangle[{0.9, 0}, {1.1, 0.2}];

Graphics[
 {Disk[{0, 0}, 1], (* makes a solid disk centered at (0,0) with radius 1 *)
  myRectangle,   (* makes a rectangle with lower right corner at (0.9,0) and upper right corner at
(1.1, 0.2) *)
  Rotate[myRectangle, 2 π/12, {0, 0}] (* rotates the rectangle 2 π/12 radians about the center (0,0)
*)
  }]
```



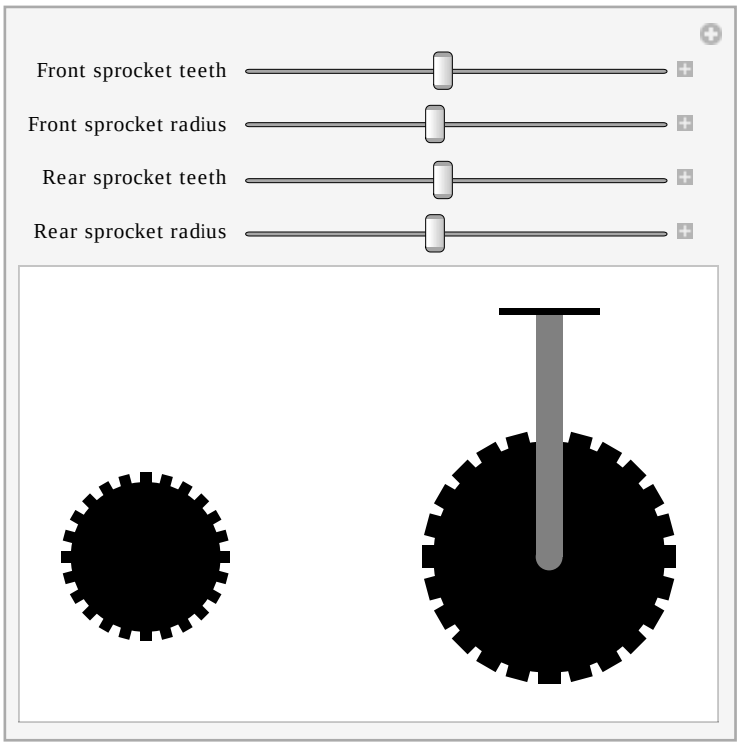
Making the Gear
Phase 3: Filling in the Teeth



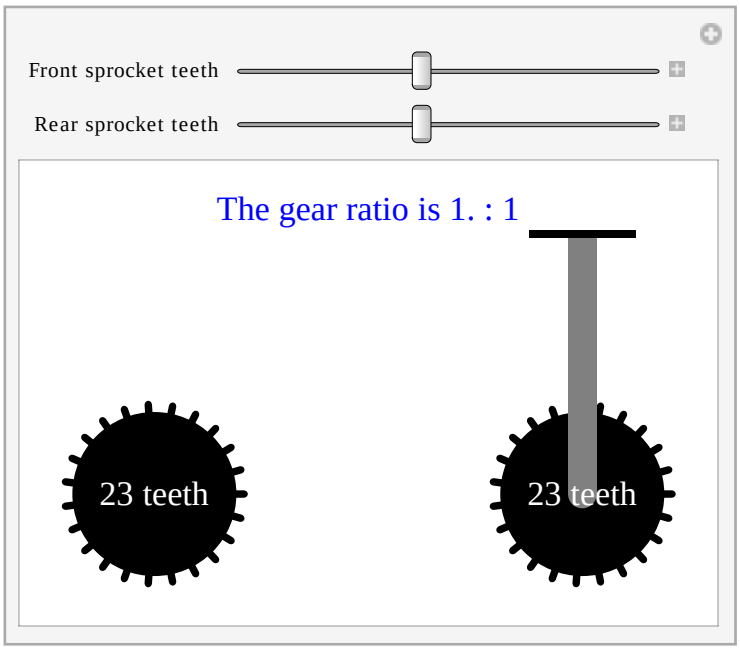
Add a Crank, Pedal, and Manipulate Controls



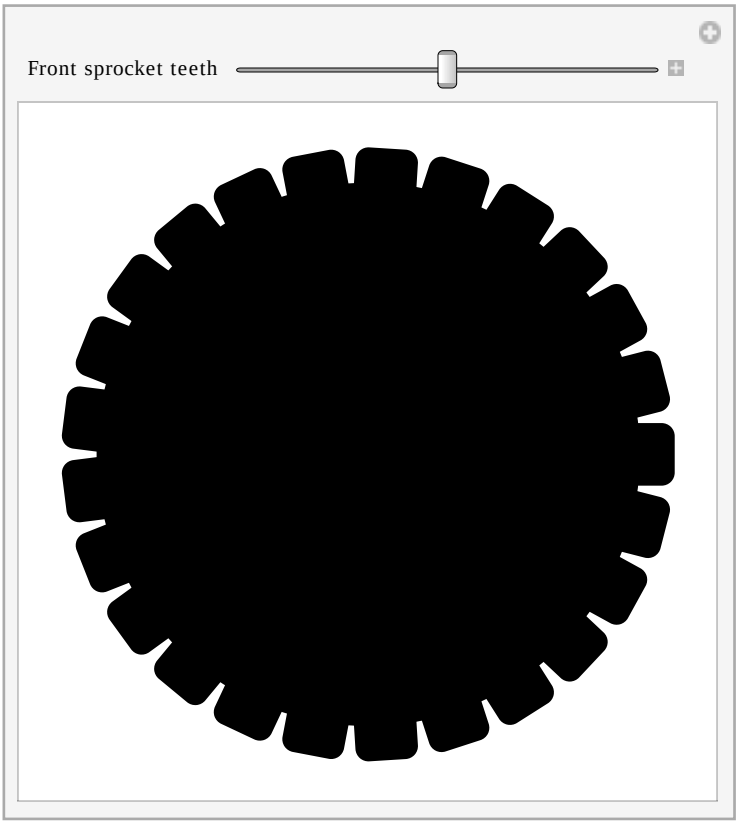
Add a Second Sprocket with Controls



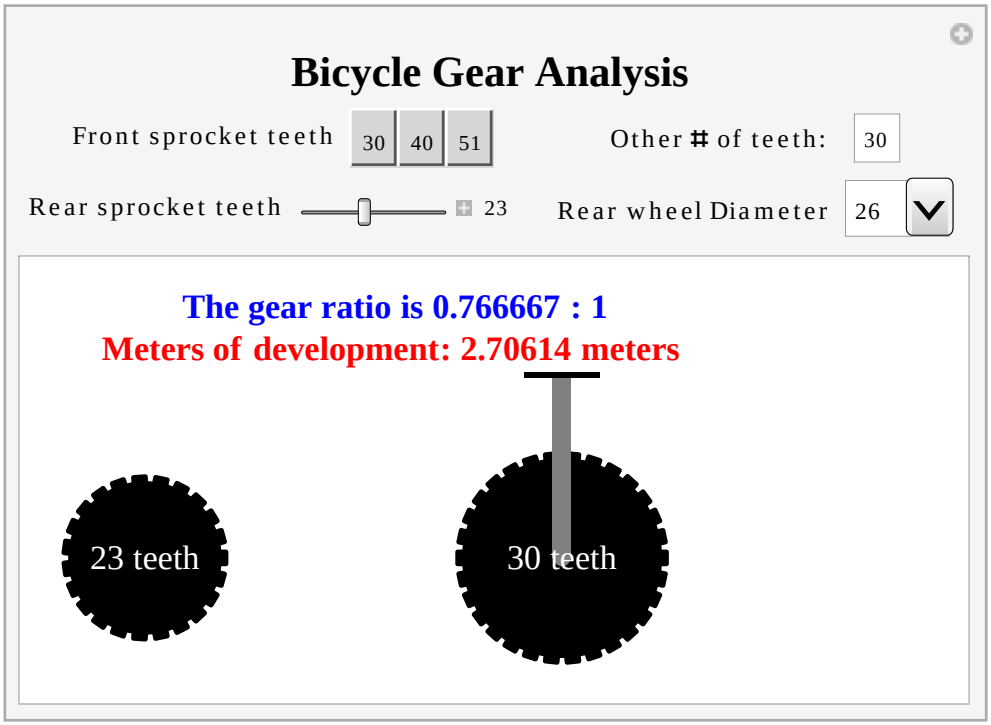
Gear Radius is a Function of Number of Teeth



Analyzing the Gear Tooth Width Problem



Teeth are Fixed / Controls and Text Added



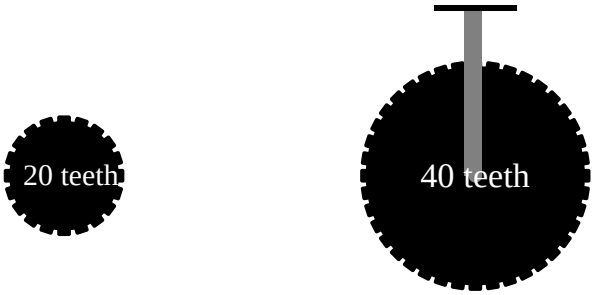
Optimizing Control Layout
Fixed the Crank Size Problem

Bicycle Gear Analysis

Front sprocket teeth 30 40 51 Other: 40 Rear wheel Diameter 26

Rear sprocket teeth 20

The gear ratio is 0.5 : 1
Meters of development: 4.14942 meters



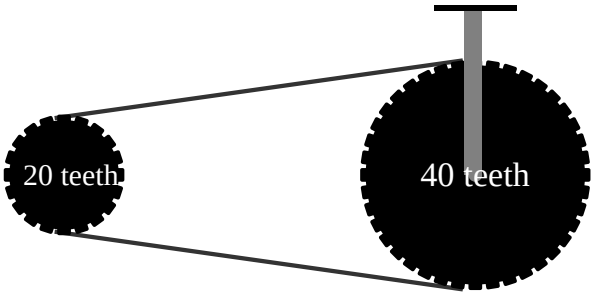
Adding a Chain

Bicycle Gear Analysis

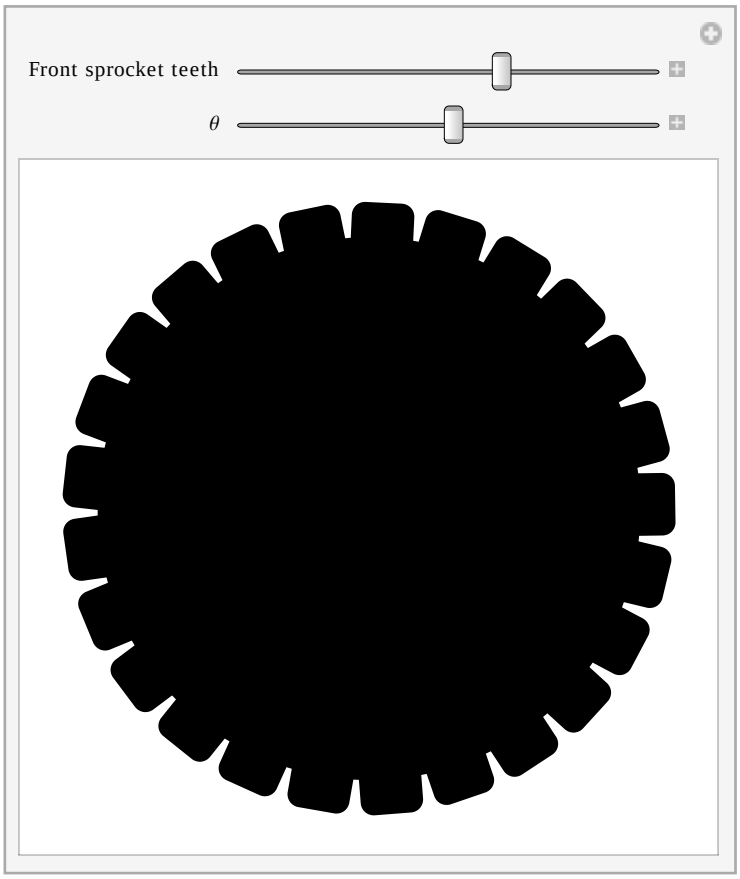
Front sprocket teeth 30 40 51 Other: 40 Rear wheel Diameter 29

Rear sprocket teeth 20

The gear ratio is 0.5 : 1
Meters of development: 4.62819 meters



Animating Gears
Phase 1: Rotate One Gear



Animation
Phase 2: Gears and Pedals Rotate

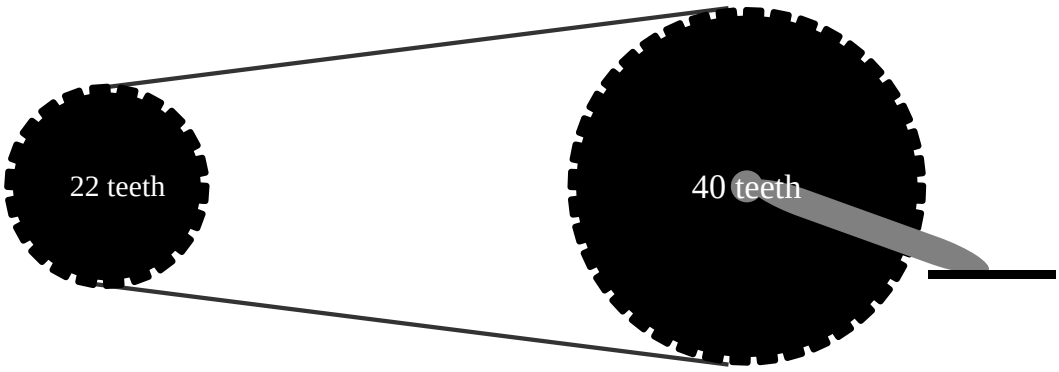
Bicycle Gear Analysis

Front sprocket teeth 30 40 51 Other: 40 Rear wheel Diameter 26

Rear sprocket teeth 22 Rotation Angle 1.916

The gear ratio is 0.55 : 1

Meters of development: 3.7722 meters



Adding a Second Pedal

Bicycle Gear Analysis

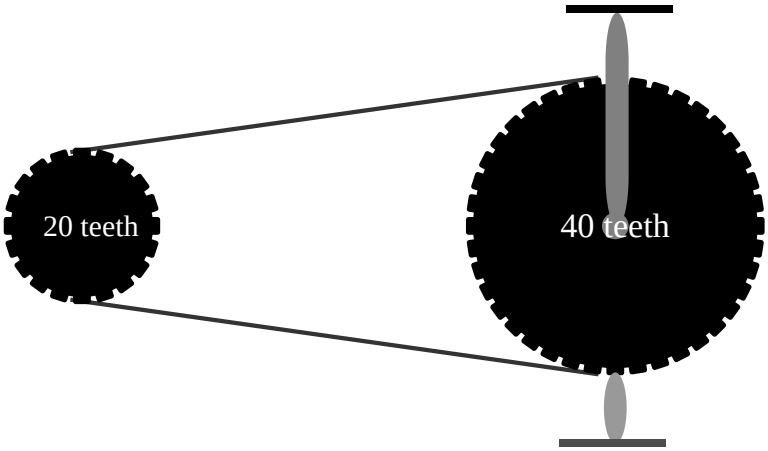
Front sprocket teeth 30 40 51

Rear wheel Diameter 26

Rear sprocket teeth 20

Rotation Angle 0

The gear ratio is 0.5 : 1
Meters of development: 4.14942 meters



A Glimpse Under the Hood

```
Manipulate [
 Deploy[  (* the Deploy command makes the output read only *)
  fMultiplier = frontSprocketTeeth/25; (* these are scaled lengths used for the radii of the gears *)
  rMultiplier = rearSprocketTeeth/25;
  (* pedalV1 & pedalV2 are the points for the corners of the rectangle
   It starts at (3,0) and its center is 1.525*fMultiplier units away
   the (sin, cos) vector rotates it in the opposite direction
   the third vector shifts from the center of rotation to the vertices  *)
  pedalV1 = {3, 0} + 1.525*fMultiplier*{Sin[θ], Cos[θ]} + {-0.375*fMultiplier, -0.025*fMultiplier};
  pedalV2 = {3, 0} + 1.525*fMultiplier*{Sin[θ], Cos[θ]} - {-0.375*fMultiplier, -0.025*fMultiplier};
  rearPedalV1 = {2.97, 0} - 1.525*fMultiplier*{Sin[θ], Cos[θ]} + {-0.375*fMultiplier,
-0.025*fMultiplier};
  rearPedalV2 = {2.97, 0} - 1.525*fMultiplier*{Sin[θ], Cos[θ]} - {-0.375*fMultiplier,
-0.025*fMultiplier};
  theta = ArcCos[N[Abs[fMultiplier - rMultiplier]/6]];  (* Calculate the angle between the horizontal
and the larger radius *)
  frontPt = {3 - fMultiplier*(N[Cos[theta]]), fMultiplier*(N[Sin[theta]] + .05)}; (* points of tangency
to form the "chain" *)
  bottomFrontPt = {3 - fMultiplier*(N[Cos[theta]]), -fMultiplier*(N[Sin[theta]] + .05)};
  rearPt = {-3 - rMultiplier*(N[Cos[theta]]), rMultiplier*(N[Sin[theta]] + .05)};
  bottomRearPt = {-3 - rMultiplier*(N[Cos[theta]]), - rMultiplier*(N[Sin[theta]] + .05)};
  myGearTooth = Rectangle[{fMultiplier + 2.92, -0.1}, {fMultiplier + 3.08, 0.1}, RoundingRadius →
0.03]; (* fMultiplier scales the gear teeth down as teeth increase *)
  myRearGearTooth =  Rectangle[{rMultiplier - 3.08, -0.1}, {rMultiplier - 2.92, 0.1}, RoundingRadius →
0.03];
   (* rMultiplier scales the gear teeth down as teeth increase, RoundingRadius rounds the edges a bit*)
  myCrank = Rotate[Rectangle[{3.15, 0}, {-0.1*fMultiplier + 3.05, 1.5*fMultiplier}, RoundingRadius →
0.55], -θ, {3, 0}];
  myRearCrank = Rotate[Rectangle[{-0.08*fMultiplier + 3, -1.53*fMultiplier}, {0.08*fMultiplier + 3,
-1.03*fMultiplier}, RoundingRadius → 0.4], -θ, {3, 0}] ;
  centerHub = Disk[{3, 0}, .15];
  myPedal = Rectangle[pedalV1, pedalV2] ;
  myRearPedal = Rectangle[rearPedalV1, rearPedalV2] ;
  minimumTeeth = 9;  (* these values are the lowest → highest values on rear "cassettes" *)
  maximumTeeth = 34;
  gearRatio = N[rearSprocketTeeth / frontSprocketTeeth];
  metersOfDevelopment = N[.0254*Pi*rearWheelDiameter*frontSprocketTeeth/rearSprocketTeeth];
  Graphics[{
    Disk[{3, 0}, fMultiplier], (* makes a solid disk centered at (3,0) with radius fMultiplier *)
    {GrayLevel[.2], Thick, Line[{rearPt, frontPt}]},  (* these are the lines for the top & bottom chain
*)
    {GrayLevel[.2], Thick, Line[{bottomRearPt, bottomFrontPt}]},
    Table[Rotate[myGearTooth, 2 π k/frontSprocketTeeth - 2* θ /fMultiplier, {3, 0}], {k, 0,
frontSprocketTeeth - 1}],
    (* rotates the rectangle 2 π/12 radians about the center (1,0) to form front sprocket teeth  *)
    {Gray, myCrank}, (* make the crank *)
    {GrayLevel[.6], myRearCrank},
    {Gray, centerHub},(* make a "bolt head" at the center of the hub *)
```

```
    myPedal,(* make the pedal *)
    {GrayLevel[.3], myRearPedal},
    Disk[{-3, 0}, rMultiplier],  (* add the rear sprocket *)
    Table[Rotate[myRearGearTooth, 2 π m/rearSprocketTeeth - 2*θ /rMultiplier, {-3, 0}], {m, 0,
rearSprocketTeeth - 1}],
     (* rotates the rectangle 2 π/12 radians about the center (-5,0) to form rear sprocket teeth   *)
    Text[Style["The gear ratio is " <> ToString[gearRatio] <> " : 1", FontSize → 20, FontColor → Blue,
Bold], {0.5, 4}],
    Text[Style["Meters of development: " <> ToString[metersOfDevelopment] <> " meters ", FontSize → 20,
FontColor → Red, Bold], {0.5, 3.5}],
    Text[Style[ToString[rearSprocketTeeth] <> " teeth", FontSize → 14, FontColor → White], {-2.9, 0}],
    Text[Style[ToString[frontSprocketTeeth] <> " teeth", FontSize → 16, FontColor → White], {3, 0}]
    },
   ImageSize → {600, 500}, PlotRange → {{-5, 7}, {-4, 5}}](* end Graphics *)
  ],(* end Deploy *)
 Text[Style["                                  Bicycle Gear Analysis", FontSize → 22, Bold]],
 Grid[{

   {
    Grid[{
      {
       Control[{{frontSprocketTeeth, 30, Style["Front sprocket teeth", Bold, FontSize → 14]}, {30, 40,
51}, SetterBar}], "                                                  ",
       Control[{{rearWheelDiameter, 26, Style["Rear wheel Diameter", Bold, FontSize → 14], FontSize →
14}, {20, 24, 26, 27, 29}, PopupMenu}]
      }
     },
     Alignment → {Left, Right}
    ]
   },
   {
    Grid[{
      {
       Control[{{rearSprocketTeeth, Floor[(minimumTeeth + maximumTeeth)/2], Style["Rear sprocket
teeth", Bold, FontSize → 14]}, minimumTeeth, maximumTeeth, 1, Appearance → "Labeled", ImageSize →
Tiny}], "                          ",
       Control[{{θ, 0, Style["Rotation Angle", Bold, FontSize → 14]}, 0, 2 Pi, Appearance → "Labeled",
ImageSize → Tiny, AnimationRate → .01*fMultiplier*rMultiplier}]
      }
     }
    ]
   }
  },
  Alignment → Left
  ]
 ]
```

Resources and References

***Mathematica* Demonstrations --http://demonstrations.wolfram.com/**

Bicycle Gear

Accompanying Worksheet

Thank You!

Special Thanks to Everyone who made the RET@ND Program Possible