Week 7 Tutorial

Tutorial Section

Tutorial Time

Tutorial TA Name

Question 1

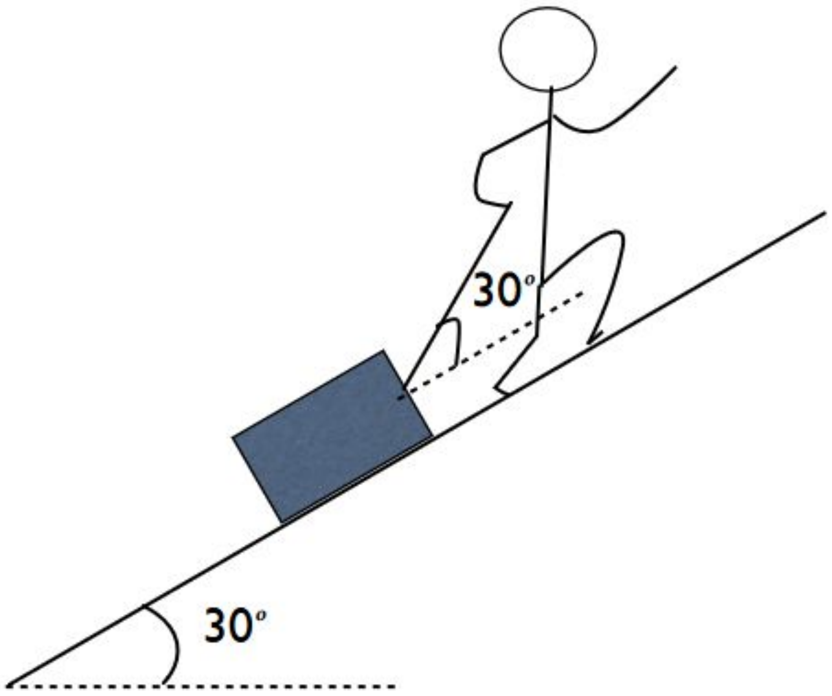


FIG. 1:

1. An environmental physicist working in the Arctic pulls her supplies up a steep (30° above the horizontal) snow-covered slope. The rope she pulls with is at an angle 30° above the angle of the slope, see Fig. 1. The coefficient of kinetic friction between the supplies and the slope is 0.20. She maintains a constant velocity up the hill.

(a) Draw a force identification diagram for her supplies. /3

Question 1

(b) Draw a free body diagram for her supplies. (*Hint: choose your axes parallel to the slope*). /6

(c) From your free body diagram write Newton's 2nd law in component form. /4

(d) If the mass of her supplies is 50 kg, solve your equations to find the normal force on the supplies. (*Hint: you will need to eliminate the tension and express* f_k *in terms of the normal force*). /3

(e) Find the magnitude of the kinetic force of friction on the supplies. /2

(f) Solve your equations to find the tension in the rope. /2

Problem Solving Framework

PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH **16,** 010123 (2020)

Template for teaching and assessment of problem solving in introductory physics

E. W. Burkholder,[1,*] J. K. Miles,[2] T. J. Layden,[2] K. D. Wang,[3]
A. V. Fritz,[4] and C. E. Wieman[1,3]

1. Framing

- Visual Representation
- Relevant Concepts
- Similar Problems
- Assumptions and Simplifications
- Information Needed

2. Planning

- Solution Plan
- Rough Estimate

3. Execution

Carry-out Plan for solving
- Work in algebra/symbols until the BITTER end
- Plug in numbers at the LAST step

4. Answer Checking

- Compare to Estimate
- Limits Test
- Units Check
- Getting (UnStuck)

Reference: Template for teaching and assessment of problem solving in introductory physics

1. Framing

2. Planning

3. Execution

4. Answer Checking

1. Framing

- Visual representation: Draw a free body diagram to illustrate all the forces at play.
- Assumptions and simplifications: Only consider this motion in only 1D.
- Relevant concept: Newton's second law, friction, dynamic equilibrium (constant velocity)
- Information needed: x and y components of each force, normal force, kinetic friction force, Tension in the rope
- Similar problems: Any problem that involves free body diagrams, equilibrium and friction

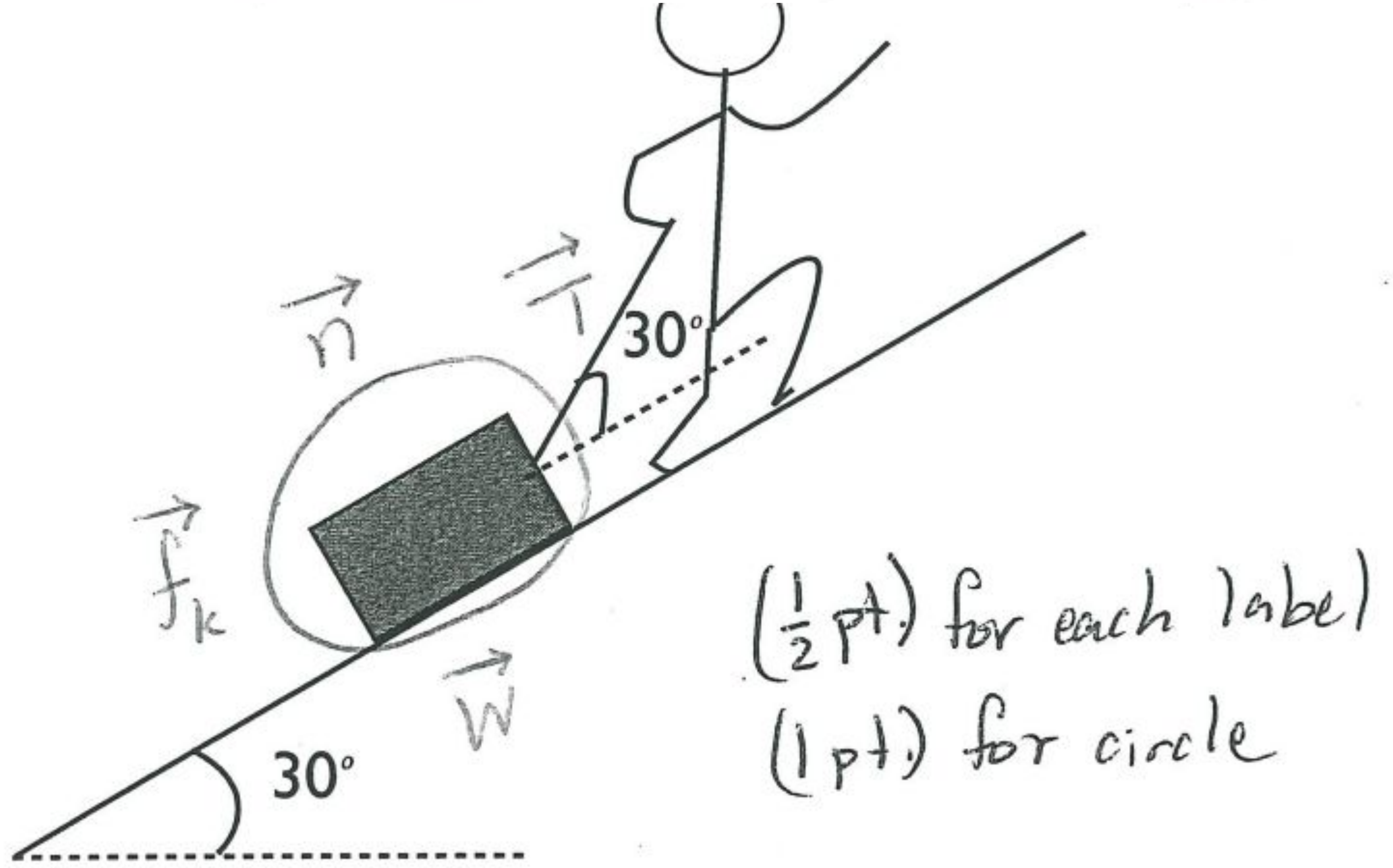
2. Planning

- Rough estimate: Since the scientist is going at a constant velocity we can already expect the sum of forces in x and y to be equal to zero. Visualize the free body diagram.

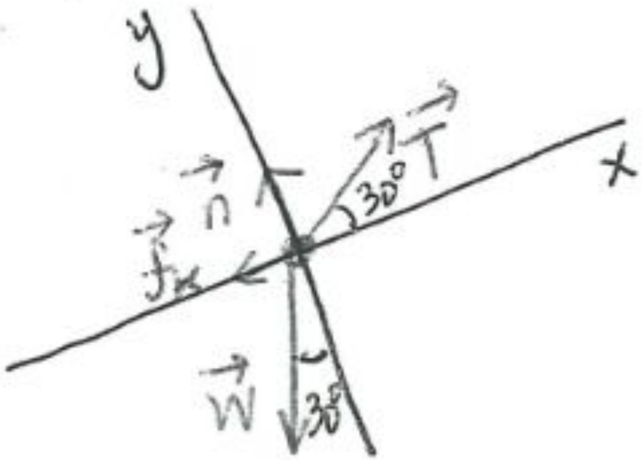
- Solution plan: Draw the FBD and find the components of each vector, then find the Sum of forces in x and y using Newton's second law

3. Execution

(a) Draw a force identification diagram for her supplies. /3



(b) Draw a free body diagram for her supplies. (*Hint: choose your axes parallel to the slope*). /6



(1pt.) axis choice

(1pt.) arrow directions

(½pt.) each arrow label

(1pt.) angles labelled

(1pt.) arrows start from a dot at centre of coordinate system.

(c) From your free body diagram write Newton's 2nd law in component form. /4

$$\sum F_x = T\cos(30^\circ) - w\sin(30^\circ) - f_k = 0$$

$\left(\frac{1}{2}\text{ pt. each}\right)$

$$\sum F_y = T\sin(30^\circ) + n - w\cos(30^\circ) = 0$$

(d) If the mass of her supplies is 50 kg, solve your equations to find the normal force on the supplies. (*Hint: you will need to eliminate the tension and express f_k in terms of the normal force*). /3

$T\sin(30^\circ) = mg\cos(30^\circ) - n$ ①

$T\cos(30^\circ) = mg\sin(30^\circ) + \mu_k n$ ②

① ÷ ② or by substitution

$$\tan 30 = \frac{mg\cos(30^\circ) - n}{mg\sin(30^\circ) + \mu_k n} \quad \text{(1pt.)}$$

$(mg\sin 30^\circ + \mu_k n)\tan(30^\circ) = mg\cos(30^\circ) - n$

$mg(\sin(30^\circ)\tan(30^\circ) - \cos 30^\circ) = n(-1 - \mu_k \tan 30^\circ)$

$$n = mg\left(\frac{\cos 30^\circ - \sin 30^\circ \tan 30^\circ}{1 + \mu_k \tan 30^\circ}\right) \underset{\text{(1pt.)}}{=} (50)(9.8)\left(\frac{0.57735}{1.11547}\right)$$

$\Rightarrow n = 254\,N$ 1pt.

(e) Find the magnitude of the kinetic force of friction on the supplies. /2

$f_k = \mu_k n = 0.20\,(253.6) = 51\,N$

(1pt.) (1pt.)

(f) Solve your equations to find the tension in the rope. /2

(1pt.)

$$T = \frac{w\cos(30^\circ) - n}{\sin(30^\circ)} = \frac{50(9.8)\cos 30^\circ - 254}{\sin(30^\circ)} = 341.5\,N$$

(or 1pt)

or $$T = \frac{w\sin(30^\circ) + f_k}{\cos(30^\circ)} = \frac{(50(9.8)\sin 30^\circ + 50.7)N}{\cos(30^\circ)} = 341.4\,N$$ (1pt.)

4. Answer Checking

Compare to estimates: compare the calculation results to your rough estimates see whether the sign matches.

Units: Think about what unit we use for each force in this problem and add them in your final answer (if not already done).

Limits: N/A

Getting (UnStuck)? If you get stuck during an exam, move on to another question and come back later to this one

Question 2

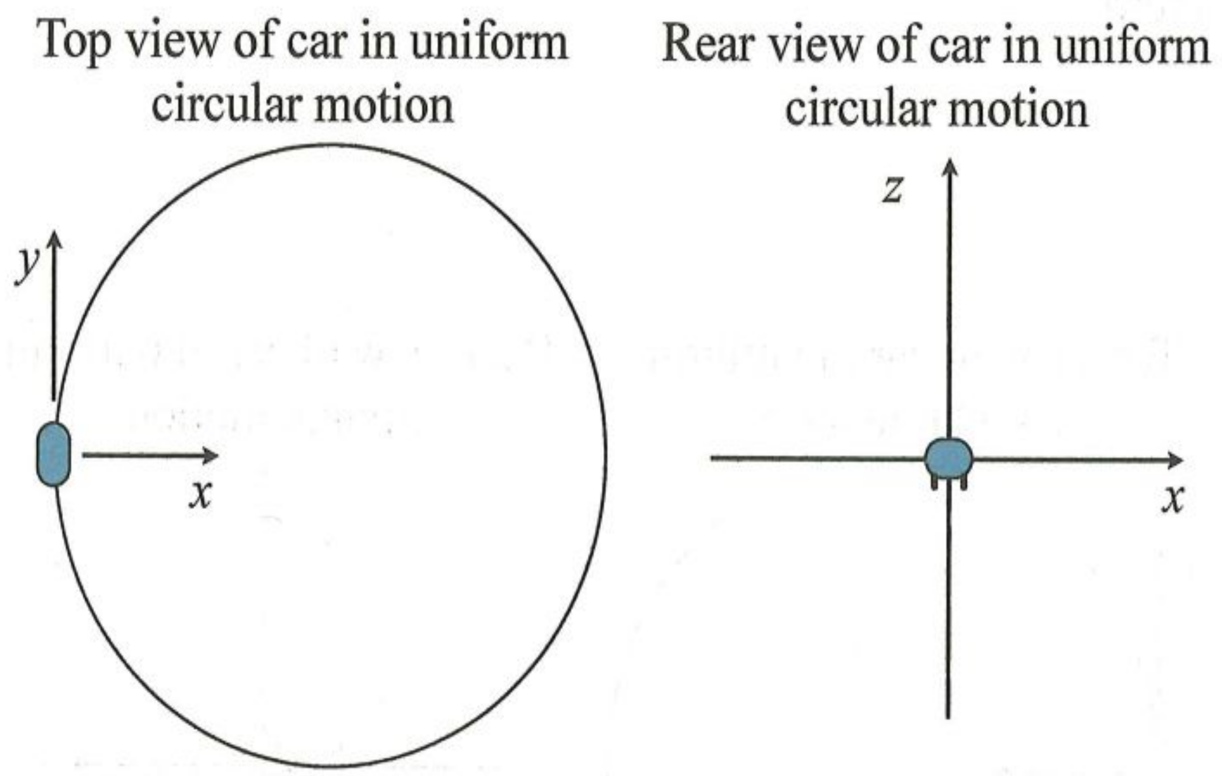


FIG. 1:

1. (a) A car of mass 2000 kg in uniform circular motion accelerates toward the centre of the circle due to the force of static friction between the car's tires and the road. (fill in the blanks) /2

Question 2

(b) If the car moves at 80 km/h around a circle of radius 100 m, find the acceleration of the car in SI units.

(b) If the car moves at 80 km/h around a circle of radius 100 m, find the acceleration of the car in SI units.

(c) Draw a free body diagram in the xz plane (the plane shown on the right of Fig. 1) to show the forces acting on the car in the directions perpendicular to the car's motion.

(d) Find the size of the frictional force that keeps the car in circular motion.

(e) Above what speed would the car's frictional force be overcome as the car tries to follow this curve?

(f) If the curve was banked toward the centre of the circle at an angle of 20° as shown on the right of Fig. 2, draw a free body diagram for the forces acting on the car in the directions perpendicular to the direction of motion as the car moves around the circle at 80 km/h.

(g) Resolving your vectors, find the equations you would need to solve and solve for the force of friction required to keep the car in circular motion at this speed with the banked curve.

1. Framing

2. Planning

3. Execution

4. Answer Checking

1. Framing

- Visual representation: Draw two FBDs to help you visualise the problem better.
- Assumptions and simplifications: Only consider this motion in only 2D. That is the car does not leave the surface of the track.
- Relevant concept: Friction, Centripetal acceleration, Newton’s second Law
- Information needed: Components of each force, acceleration, frictional force, max speed
- Similar problems: Any problems involving centripetal acceleration, Friction, and FBDs

2. Planning

- Rough estimate: Illustrate the problem with two Free Body Diagrams (top-down and from the back of the car) and write down the most forces you can from the get go.
- Solution plan: Find the components of each vector and write down each Newton's second law equations (Keep in mind that F = (mv^2)/r for centripetal acceleration)

3. Executi

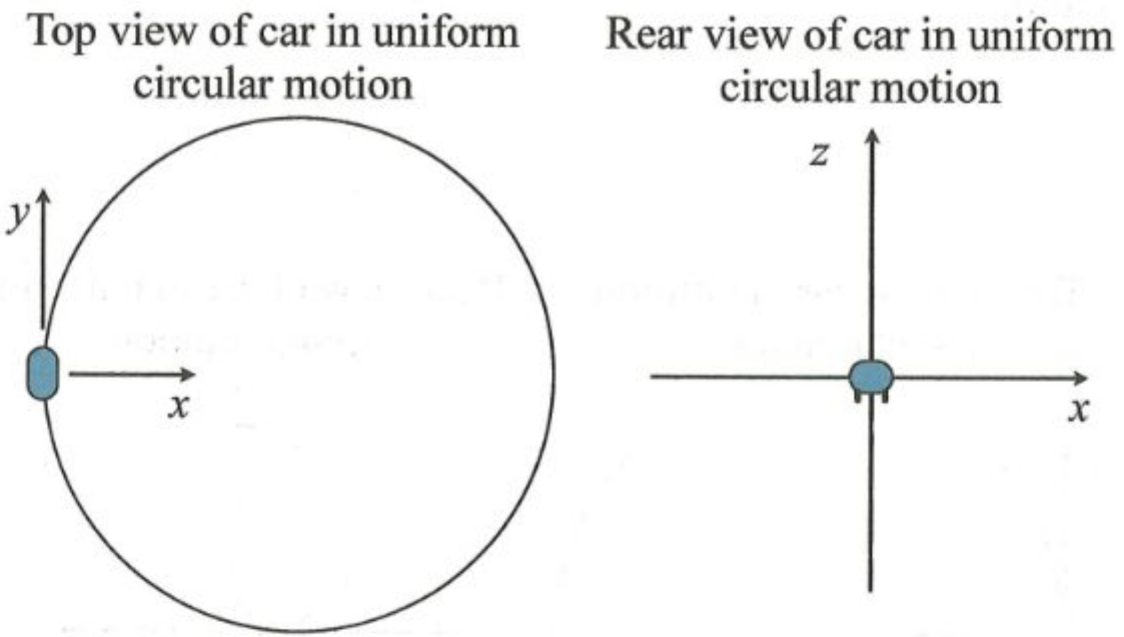


FIG. 1:

1. (a) A car of mass 2000 kg in uniform circular motion accelerates toward the __centre__ of the circle due to the force of __static__ friction between the car's tires and the road. (fill in the blanks) /2

(b) If the car moves at 80 km/h around a circle of radius 100 m, find the acceleration of the car in SI units.

/3

$$V = 80 \frac{km}{h} \times \frac{1\,h}{3600\,s} \times \frac{1000\,m}{1\,km}$$

$$= 22\ m/s$$

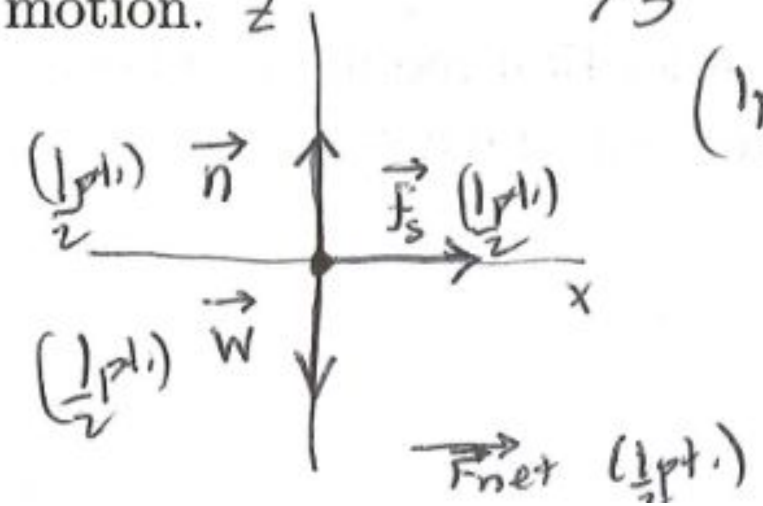
(1pt.)

$$a_c = \frac{V^2}{r} = \frac{(22)^2}{100} = 4.9\ m/s^2$$

(1pt.) (1pt.)

(c) Draw a free body diagram in the xz plane (the plane shown on the right of Fig. 1) to show the forces acting on the car in the directions perpendicular to the car's motion.

/3



(1pt. axes labelled)

(d) Find the size of the frictional force that keeps the car in circular motion. /2

$F_{net} = ma_c = f_s = (2000\,kg)(4.9\,m/s^2) = 9.9 \times 10^3\,N$

(1pt.) (1pt.)

(in km/h)

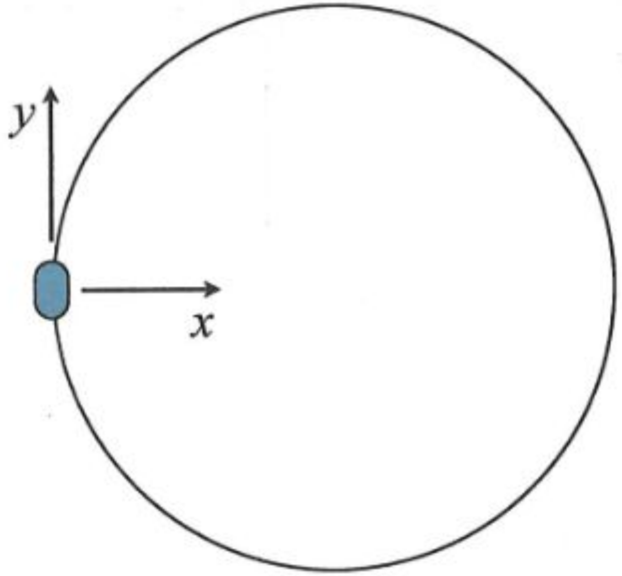
(e) Above what speed (in km/h) would the car's frictional force be overcome as the car tries to follow this curve? $(\mu_s = 0.6, \mu_k = 0.4, \mu_r = 0.02)$ 15

$f_{s\,max} = \mu_s mg = 0.6(2000\,kg)(9.8\,m/s^2) = 11760\,N = \frac{m v_{max}^2}{r}$ (1pt.) (1pt.)

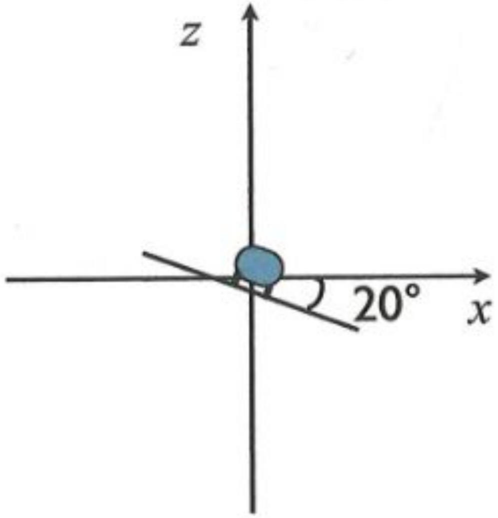
$v_{max} = \sqrt{\mu_s r g} = \sqrt{0.6(100\,m)(9.8\,m/s^2)} = 24.\ \frac{m}{s} \times 3.6 \frac{km/h}{m/s}$

(1pt.) (1pt.) $= 87.3\ km/h.$ (1pt.)

Top view of car in uniform circular motion



Rear view of car in uniform circular motion



4. Answer Checking

Compare to estimates: compare the calculation results to your rough estimates see whether the sign matches.

Units: Think about what unit we use for each force in this problem and add them in your final answer.

Limits: N/A

Getting (UnStuck)? If you get stuck during an exam, move on to another question and come back later to this one