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ENGS141 Engineering Statics - Homework 2

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Problem 3.2 (10 points).

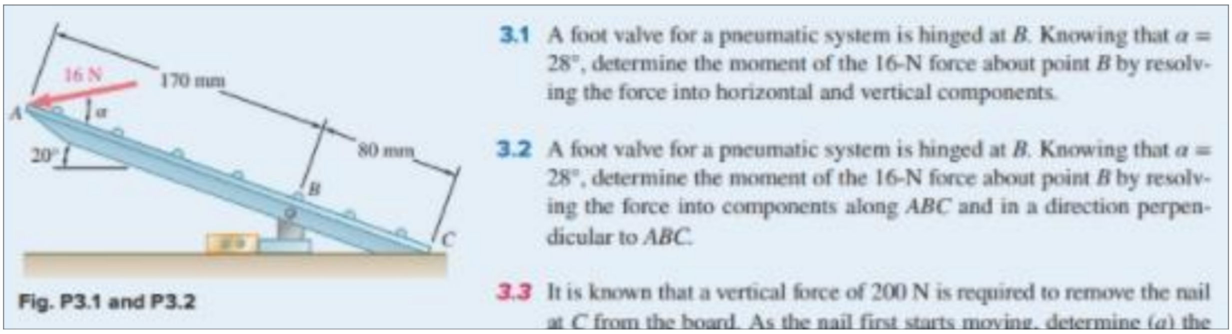
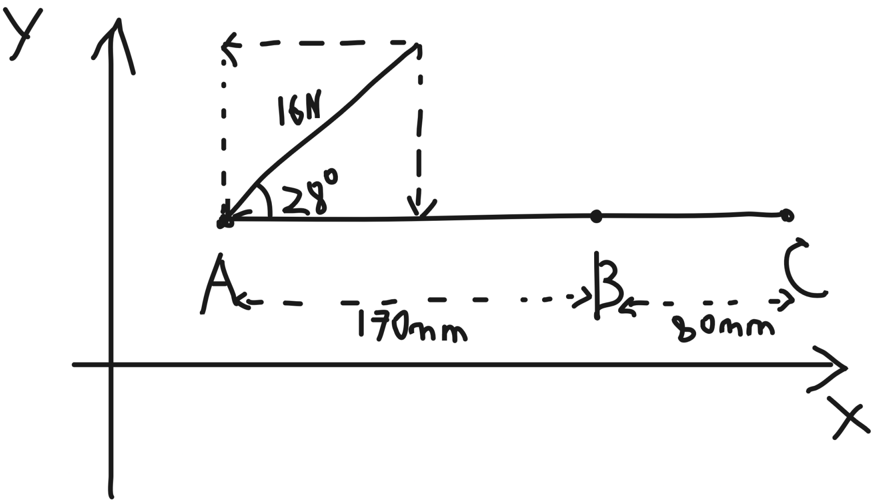


Fig. P3.1 and P3.2

3.1 A foot valve for a pneumatic system is hinged at B. Knowing that $\alpha = 28°$, determine the moment of the 16-N force about point B by resolving the force into horizontal and vertical components.

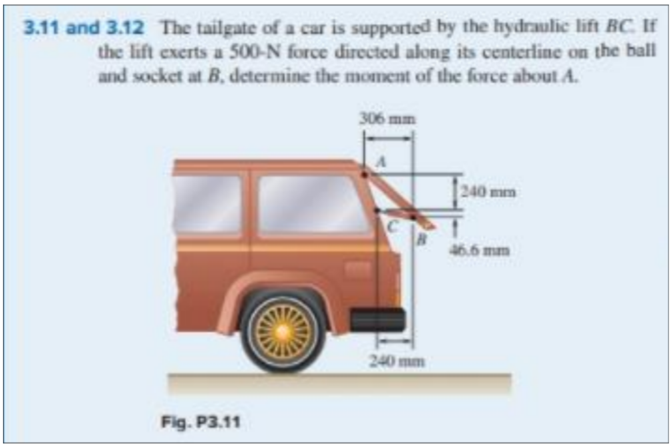
3.2 A foot valve for a pneumatic system is hinged at B. Knowing that $\alpha = 28°$, determine the moment of the 16-N force about point B by resolving the force into components along ABC and in a direction perpendicular to ABC.

3.3 It is known that a vertical force of 200 N is required to remove the nail at C from the board. As the nail first starts moving, determine (a) the



$\mathbf{F} = (-16\cos 28°\hat{\boldsymbol{\imath}} - 16\sin 28°\hat{\boldsymbol{\jmath}})N,\ \mathbf{M} = \mathbf{r}\times\mathbf{F} = (-0.170\hat{\boldsymbol{\imath}})\times(-16\cos 28°\hat{\boldsymbol{\imath}} - 16\sin 28°\hat{\boldsymbol{\jmath}})Nm \approx 1.28\hat{\boldsymbol{k}}Nm$

Problem 3.11 (10 points).



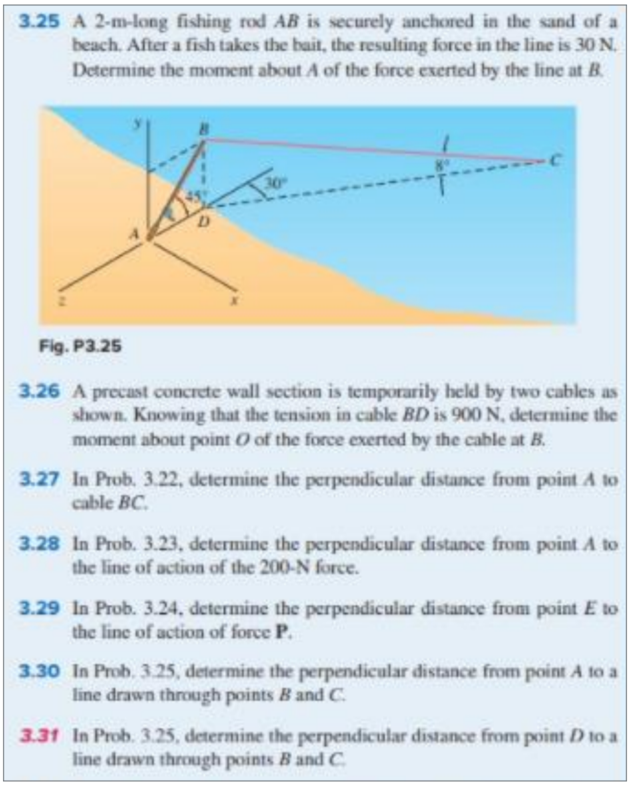
3.11 and 3.12 The tailgate of a car is supported by the hydraulic lift BC. If the lift exerts a 500-N force directed along its centerline on the ball and socket at B, determine the moment of the force about A.

Fig. P3.11

Denote the positive x axis to the right, and positive y axis up.

$$\mathbf{M} = \mathbf{r} \times \mathbf{F} = (0.306\hat{\imath} - 0.240\hat{\jmath}) \times \left(500\frac{0.240}{\sqrt{0.0466^2 + 0.240^2}}\hat{\boldsymbol{\imath}} - 500\frac{0.0466}{\sqrt{0.0466^2 + 0.240^2}}\hat{\boldsymbol{\jmath}}\right) Nm \approx 88.64\hat{\mathbf{k}} Nm$$

Problem 3.31 (10 points).



3.25 A 2-m-long fishing rod AB is securely anchored in the sand of a beach. After a fish takes the bait, the resulting force in the line is 30 N. Determine the moment about A of the force exerted by the line at B.

Fig. P3.25

3.26 A precast concrete wall section is temporarily held by two cables as shown. Knowing that the tension in cable BD is 900 N, determine the moment about point O of the force exerted by the cable at B.

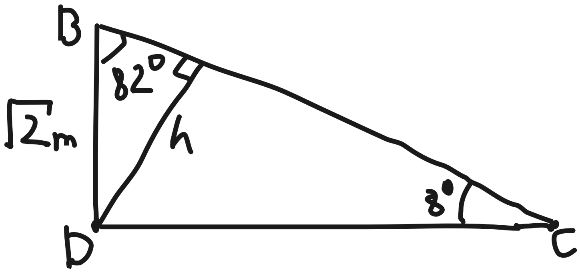
3.27 In Prob. 3.22, determine the perpendicular distance from point A to cable BC.

3.28 In Prob. 3.23, determine the perpendicular distance from point A to the line of action of the 200-N force.

3.29 In Prob. 3.24, determine the perpendicular distance from point E to the line of action of force **P**.

3.30 In Prob. 3.25, determine the perpendicular distance from point A to a line drawn through points B and C.

3.31 In Prob. 3.25, determine the perpendicular distance from point D to a line drawn through points B and C.



$$BD = AB\sin 45^\circ = \sqrt{2}m,\ \ h = \sqrt{2}\sin 82^\circ \approx 1.4m$$

Problem 3.35 (10 points).

3.35 Given the vectors $\mathbf{P} = 2\mathbf{i} + \mathbf{j} + 2\mathbf{k}$, $\mathbf{Q} = 3\mathbf{i} + 4\mathbf{j} - 5\mathbf{k}$, and $\mathbf{S} = -4\mathbf{i} + \mathbf{j} - 2\mathbf{k}$, compute the scalar products $\mathbf{P}\cdot\mathbf{Q}$, $\mathbf{P}\cdot\mathbf{S}$, and $\mathbf{Q}\cdot\mathbf{S}$.

$$\mathbf{P}\cdot\mathbf{Q} = 2\cdot 3 + 1\cdot 4 + 2\cdot(-5) = 0$$
$$\mathbf{P}\cdot\mathbf{S} = 2\cdot(-4) + 1\cdot 1 + 2\cdot(-2) = -11$$
$$\mathbf{Q}\cdot\mathbf{S} = 3\cdot(-4) + 4\cdot 1 + (-5)\cdot(-2) = 2$$

Problem 3.60 (10 points).

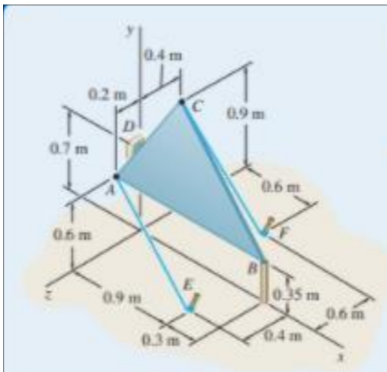


Fig. P3.59 and P3.60

3.59 The triangular plate ABC is supported by ball-and-socket joints at B and D and is held in the position shown by cables AE and CF. If the force exerted by cable AE at A is 55 N, determine the moment of that force about the line joining points D and B.

3.60 The triangular plate ABC is supported by ball-and-socket joints at B and D and is held in the position shown by cables AE and CF. If the force exerted by cable CF at C is 33 N, determine the moment of that force about the line joining points D and B.

3.61 A regular tetrahedron has six edges of length a. A force $\mathbf{P}$ is directed as shown along edge BC. Determine the moment of $\mathbf{P}$ about edge OA.

$$\mathbf{CF} = 0.6\hat{\imath} - 0.9\hat{\jmath} - 0.2\hat{\boldsymbol{k}} \implies \lambda_{CF} = \frac{0.6}{1.1}\hat{\boldsymbol{\imath}} - \frac{0.9}{1.1}\hat{\boldsymbol{\jmath}} - \frac{0.2}{1.1}\hat{\boldsymbol{k}}$$
$$\mathbf{DB} = 1.2\hat{\imath} - 0.35\hat{\jmath} \implies \lambda_{DB} = \frac{1.2}{1.25}\hat{\boldsymbol{\imath}} - \frac{0.35}{1.25}\hat{\boldsymbol{\jmath}}$$
$$\mathbf{DC} = 0.2\hat{\jmath} - 0.4\hat{\boldsymbol{k}}$$
$$M_{DB} = \lambda_{DB}\cdot(\mathbf{r}\times\lambda_{CF}F) = \left(\frac{1.2}{1.25}\hat{\boldsymbol{\imath}} - \frac{0.35}{1.25}\hat{\boldsymbol{\jmath}}\right)\cdot(-12\hat{\boldsymbol{\imath}} - 7.2\hat{\boldsymbol{\jmath}} - 3.6\hat{\boldsymbol{k}}) = -9.504Nm$$

Problem 3.69 (10 points).

*3.69 In Prob. 3.60, determine the perpendicular distance between cable CF and the line joining points D and B.

$$F_{\text{parallel}} = \mathbf{F} \cdot \lambda_{DB} = 24.84N \implies F_{perpendicular} = \sqrt{33^2 - 24.84^2} \approx 21.72N$$

$$|M_{DB}| = 9.504Nm = hF_{\text{perpendicular}} \implies h = \frac{9.504}{21.72} \approx 0.438m$$

Problem 3.7 (20 points).

3.6 A 90-N force is applied to the control rod AB as shown. Knowing that the length of the rod is 225 mm and that $\alpha = 25°$, determine the moment of the force about point B by resolving the force into horizontal and vertical components.

3.7 A 90-N force is applied to the control rod AB as shown. Knowing that the length of the rod is 225 mm and that $\alpha = 25°$, determine the moment of the force about point B by resolving the force into components along AB and in a direction perpendicular to AB.

3.8 A 90-N force is applied to the control rod AB as shown. Knowing that the length of the rod is 225 mm and that the moment of the force

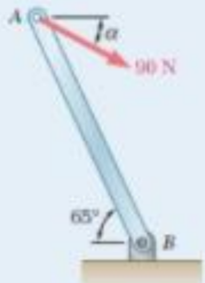
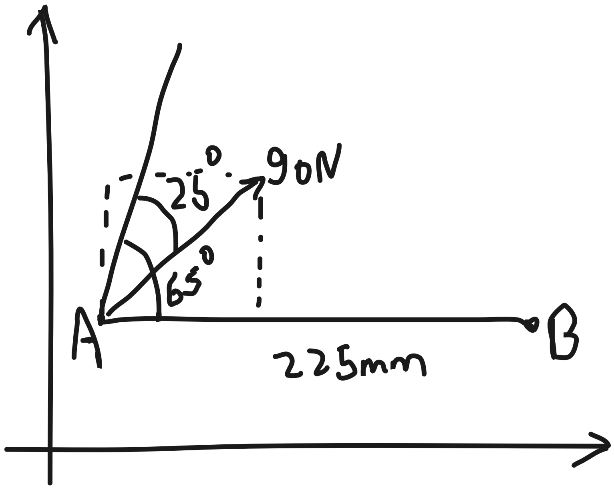


Fig. P3.6, P3.7 and P3.8



$$\mathbf{F} = (90\cos 40°\boldsymbol{\hat\imath} + 90\sin 40°\boldsymbol{\hat\jmath})N,\ \mathbf{M} = \mathbf{r} \times \mathbf{F} = (-0.225\hat{\imath}) \times (90\cos 40°\boldsymbol{\hat\imath} + 90\sin 40°\boldsymbol{\hat\jmath})Nm \approx -13.02\hat{\boldsymbol{k}}Nm$$

Problem 3.62 (20 points).

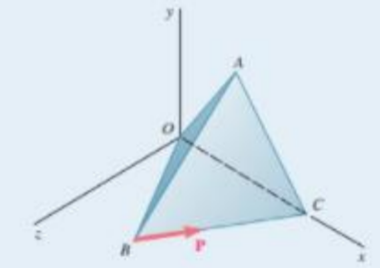


Fig. P3.61 and P3.62

3.62 A regular tetrahedron has six edges of length a. (a) Show that two opposite edges, such as OA and BC, are perpendicular to each other. (b) Use this property and the result obtained in Prob. 3.61 to determine the perpendicular distance between edges OA and BC.

$$O = (0,0,0)A = \left(\frac{a}{2}, \frac{a\sqrt{2}}{\sqrt{3}}, \frac{a}{2\sqrt{3}}\right), B = \left(\frac{a}{2}, 0, \frac{a\sqrt{3}}{2}\right), C = (a,0,0),$$

$$\vec{OA} \cdot \vec{BC} = \left(\frac{a}{2} \cdot \frac{a}{2}\right) + \left(\frac{a\sqrt{2}}{\sqrt{3}} \cdot 0\right) + \left(-\frac{a}{2\sqrt{3}} \cdot \frac{a\sqrt{3}}{2}\right) = 0 \implies OA \perp BC$$

The distance between those edges equals to the size of the perpendicular which is $d = \sqrt{\left(\frac{a\sqrt{3}}{2}\right)^2 - \left(\frac{a}{2}\right)^2} = \frac{a\sqrt{2}}{2}$, by basic geometry.

Python solutions

```
import numpy as np

def Problem3_2():
    # Values
    Force = 16
    Angle = 27
    Arm = 0.170

    vector_arm = [-Arm,0,0]
    vector_force = [-Force*np.cos(Angle* np.pi / 180),-Force*np.sin(Angle* np.pi / 180),0]
    return np.cross(vector_arm,vector_force)



def Problem3_11():
    # Values
    arm_delta_x = 0.306
    arm_delta_y = -0.240
    Force = 500
    force_delta_x = 0.240
    force_delta_y = -0.0466
    force_length = np.sqrt(force_delta_x**2 + force_delta_y**2)
```

```python
    vector_arm = [arm_delta_x,arm_delta_y,0]
    vector_force = [Force*force_delta_x/force_length,Force*force_delta_y/force_length,0]
    return np.cross(vector_arm,vector_force)


def Problem3_31():
    # Values
    Angle_DAB = 45
    Angle_DCB = 8
    AB = 2

    return (2*np.sin(Angle_DAB *  np.pi / 180)*np.cos(Angle_DCB *  np.pi / 180))

def Problem3_35():
    # Values
    vector_P = [2,1,2]
    vector_Q = [3,4,-5]
    vector_S = [-4,1,-2]

    return (np.dot(vector_P,vector_Q),np.dot(vector_P,vector_S),np.dot(vector_Q,vector_S))

def Problem3_60():
    # Values
    CF_x = 0.6
    CF_y = -0.9
    CF_z = -0.2

    DB_x = 1.2
    DB_y = -0.35
    DB_z = 0

    DC_x = 0
    DC_y = 0.2
    DC_z = -0.4

    Force = 33

    lenght_CF = np.sqrt(CF_x**2 + CF_y**2 + CF_z**2)
    CF_direction = np.array([CF_x/lenght_CF,CF_y/lenght_CF,CF_z/lenght_CF])
    lenght_DB = np.sqrt(DB_x**2 + DB_y**2 + DB_z**2)
    DB_direction = [DB_x/lenght_DB,DB_y/lenght_DB,DB_z/lenght_DB]
    DC = [DC_x,DC_y,DC_z]

    return np.dot(DB_direction,np.cross(DC,CF_direction*Force))

def Problem3_69():
    # Values
    Moment = np.absolute(Problem3_60())
    Force = 33

    CF_x = 0.6
    CF_y = -0.9
    CF_z = -0.2

    DB_x = 1.2
    DB_y = -0.35
    DB_z = 0

    lenght_CF = np.sqrt(CF_x**2 + CF_y**2 + CF_z**2)
```

```python
    CF_direction = np.array([CF_x/lenght_CF,CF_y/lenght_CF,CF_z/lenght_CF])

    lenght_DB = np.sqrt(DB_x**2 + DB_y**2 + DB_z**2)
    DB_direction = [DB_x/lenght_DB,DB_y/lenght_DB,DB_z/lenght_DB]

    force_parallel = np.dot(CF_direction*Force,DB_direction)
    force_perpendicular = np.sqrt(Force**2 - force_parallel**2)

    return Moment/force_perpendicular

def Problem3_7():
    # Values
    Force = 90
    rod_angle = 65
    force_angle = 25
    Arm = 0.225

    Angle = rod_angle-force_angle

    vector_arm = [-Arm,0,0]
    vector_force = [Force*np.cos(Angle* np.pi / 180),Force*np.sin(Angle* np.pi / 180),0]
    return np.cross(vector_arm,vector_force)

print("Problem 3.2: ", Problem3_2())
print("Problem 3.11: ", Problem3_11())
print("Problem 3.31: ", Problem3_31())
print("Problem 3.35: ", Problem3_35())
print("Problem 3.60: ", Problem3_60())
print("Problem 3.69: ", Problem3_69())
print("Problem 3.7: ", Problem3_7())
print("Problem 3.62 is basic geometry, no pyhton solution!")
```