APPENDIX E: Settings of the learning kit

Setting 1: Chapter of force vector (2D)

1. Equipments needed

The equipments needed are protractor, screw, nuts, pulleys, hooks, 2 weights of (100g) and rope.

2. Procedure

1. Fasten the protractor at the center of the wood plane (0.25, 0.25) m as shown in Figure a.

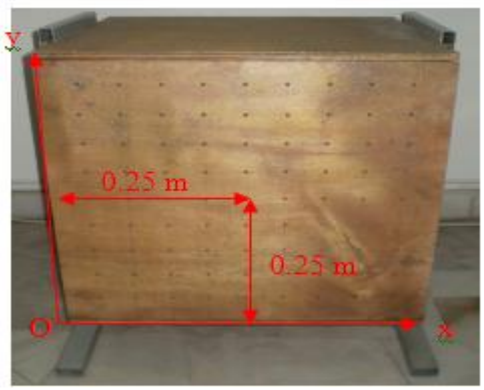


Figure a

2. Tighten the hook as shown in Figure b at the coordinate of *A* (0.30, 0.40) m and *B* (0.35, 0.30) m.
3. Attach the pulley on both hooks.
4. Attach the two weights of 100-g with rope and put on the pulleys as shown in Figure b.

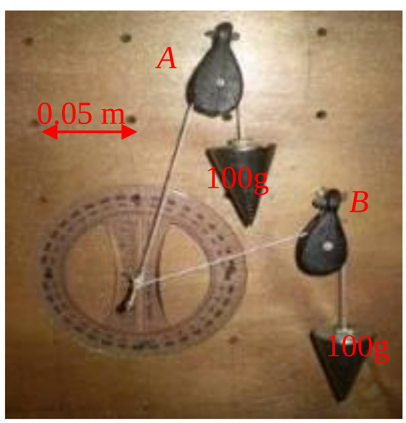


Figure b

5. Tighten the rope at the center of the screw.

3. Question and calculations

The screw in Figure 1 is subjected to two forces, F1 and F2. The angles of two forces are shown in Figure 2. Resolve the two forces into components in the x and y direction and determine the magnitude and direction of the resultant forces.

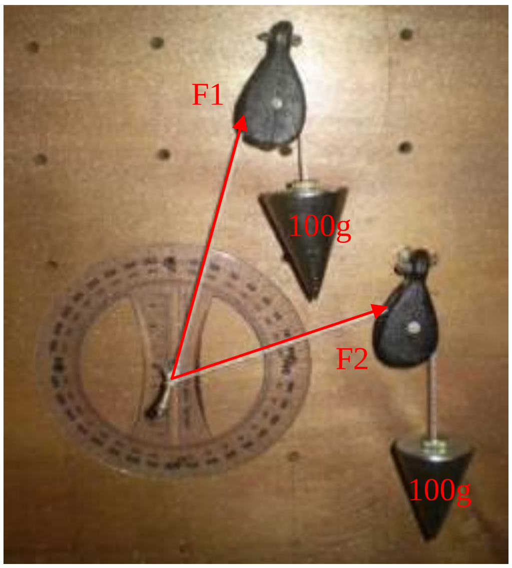


Figure 1: The screw is subjected to two forces

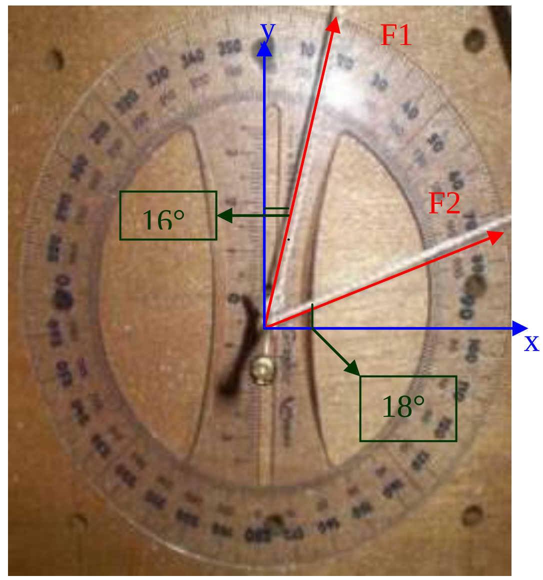


Figure 2: Angles of two forces

Solution:

F1 = F2 = 100g = 0.981N

Fx = 0.981 sin 16° + 0.981 cos 18° = 1.20 N

Fy = 0.981 cos 16° + 0.981 sin 18° = 1.25 N

The resultant force has a magnitude of

$F_R = (1.20^2 + 1.25^2)^{1/2} = 1.73$ N

The direction angle is

$\theta = \tan^{-1}(1.25/1.20) = 46.17°$

Setting 2: Chapter of force vector (3D)

1. Equipments needed

The equipments needed are 2 weights of (100g), rope, pulleys, hook and nuts.

2. Procedure

1. Tighten the hook at the coordinate of (0.25, 0.25) m as shown in Figure c.

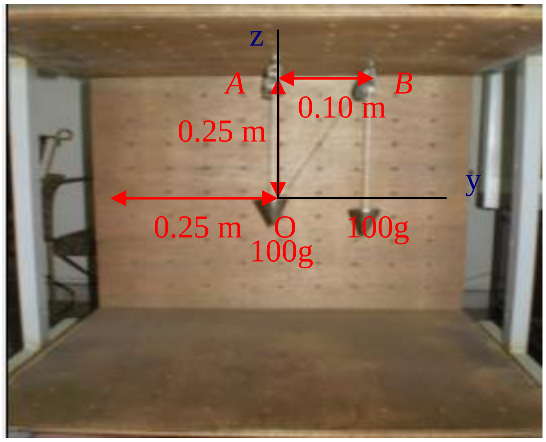


Figure c

2. Tighten the hook at the coordinate of *A* (0.25, 0, 0.25) m and *B* (0.20, 0.10, 0.25) from point O.
3. Attach the pulleys on the both hooks at point A and B respectively.
4. Attach the 2 weights of 100g with rope and put on the pulleys.
5. Tighten the rope at the hook at point O.

3. Question and calculations

If the ropes exert forces F1= 0.981N and F2 = 0.981N on the wood panel hook at *A* as shown in Figure 3. Determine the magnitude of the resultant force acting at *A*.

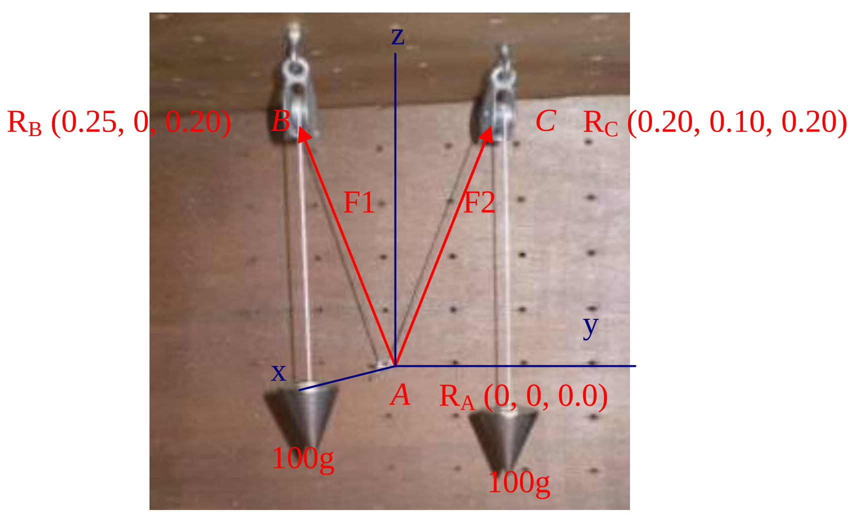


Figure 3: Setting of force vector (3D)

Solution:

For F_{AB},

R_{AB} = (0.25m – 0) i + (0 – 0) j + (0.20m – 0m) k

= (0.25i + 0.20k) m

$R_{AB} = (0.25^2 + 0.20^2)^{1/2} = 0.32$ m

F_{AB} = 0.981(0.25i + 0.20k)/0.32 = (0.766i + 0.61k) N

For F_{AC},

R_{AC} = (0.20m – 0) i + (0.10m – 0) j + (0.20 m – 0m) k

= (0.20i + 0.10j + 0.20k) m

$R_{AC} = (0.20^2 + 0.10^2 + 0.20^2)^{1/2} = 0.30$ m

F_{AC} = 0.981(0.20i + 0.10j + 0.20k)/0.3 = (0.65i + 0.327j + 0.65k) N

The resultant force is

$F_R = F_{AB} + F_{AC}$ = (0.766i + 0.61k) N + (0.65i + 0.327j + 0.65k) N

= (1.42i + 0.327j + 1.26k) N

The magnitude of F_R is

$F_R = (1.42^2 + 0.327^2 + 1.26^2)^{½} = 1.93$ N

Setting 3: Chapter of equilibrium of a Particle (2D)

1. Equipments needed

The equipments needed are weight (100g), hook, nut, protractor, spring and rope.

2. Procedure

1. Tighten the hook at the coordinate of *A* (0.10, 0.40) m and *B* (0.40, 0.40) m as shown in Figure d.

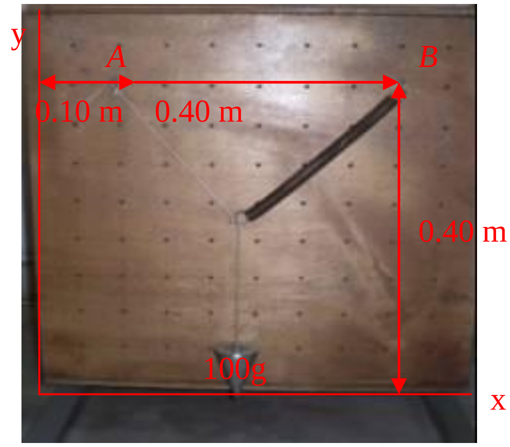
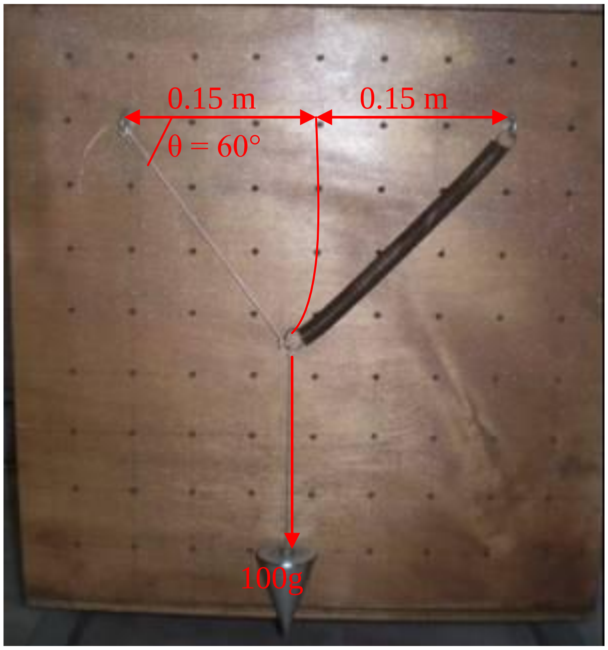


Figure d

2. Attach the spring at point A and B respectively.
3. Tighten the rope at the hook of point A and place a weight of 100g as shown in the figure d.

3. Question and calculations

Determine the unstretched length of spring AC in Figure 3 if a force F = 0.39 N (400g) causes the angle $\theta = 60°$ (Figure 4) for equilibrium in. Rope AB is 0.15m long and the stiffness of the spring is 40N/m.



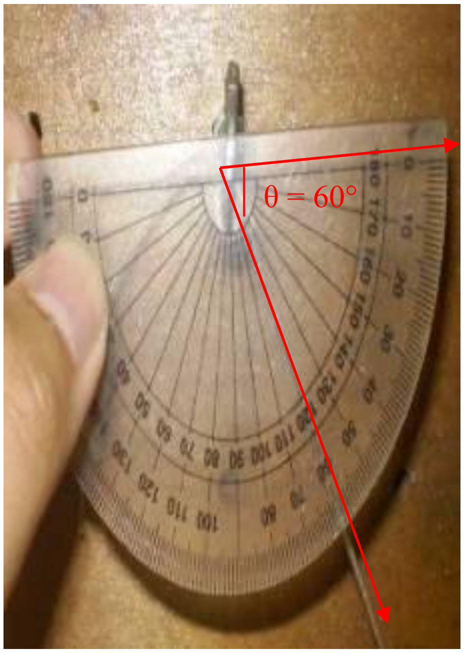
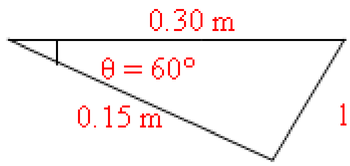


Figure 3: Setting of equilibrium of a particle (2D) Figure 4: Angle of the rope

Solution:

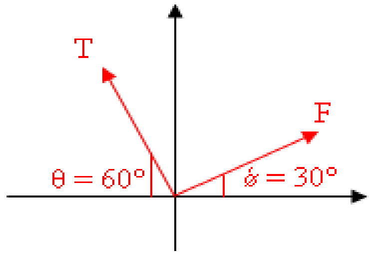


$l = \{0.30^2 + 0.15^2 - 2(0.3)*(0.15) \cos 60°\}^{1/2} = 0.26$ m

$$\frac{0.26}{\sin 60°} = \frac{0.15}{\sin ǿ}$$

0.3 sin ǿ = 0.15

ǿ = 30°



Fx = F cos 30° - T cos 60° = 0

Fy = T sin 60° + F sin 30° - 0.39 N = 0

Hence, 0.866F + 0.2885F = 0.225

F = 0.2N

F= kx

$0.2 = 40\,(0.15 - l')$

$l' = 0.155$ m

Setting 4: Chapter of equilibrium of a Particle (3D)

1. Equipments needed

The equipments needed are hook, nuts, pulleys, rope, measuring tape, spring, 3 weights of (100g, 100g and 400g) and ring.

2. Procedure

1. Tighten the 3 hook at the coordinate of *A* (0.15, 0.10), *B* (0.15, 0.15) and *C* (0.35, 0.30) as shown in the Figure e.

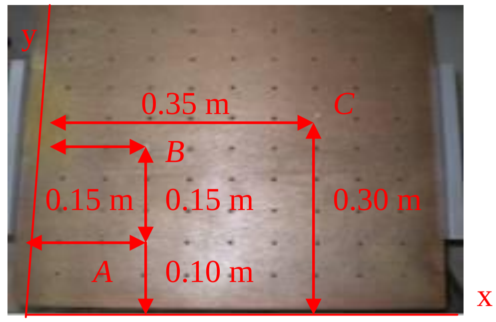


Figure e

2. Attach pulleys on 3 hooks at point *A*, *B* and *C* respectively as shown in Figure f.

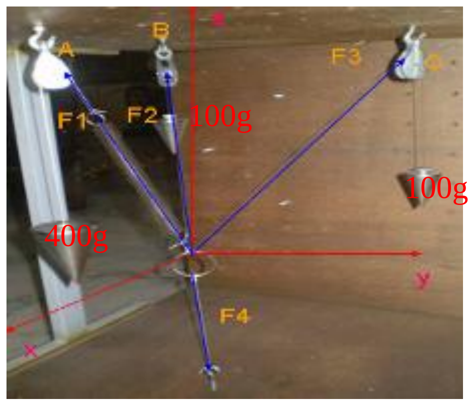


Figure f

3. Attach the weight of 400-g with rope and tighten it with spring as shown in Figure f. Then attach another 2 weights of 100g with rope.
4. Tighten all the four ropes at the center of the ring.

3. Question and calculations

Determine the stiffness of the spring, magnitude and coordinate direction of Force F in Figure 5 that is required for equilibrium of particle O.

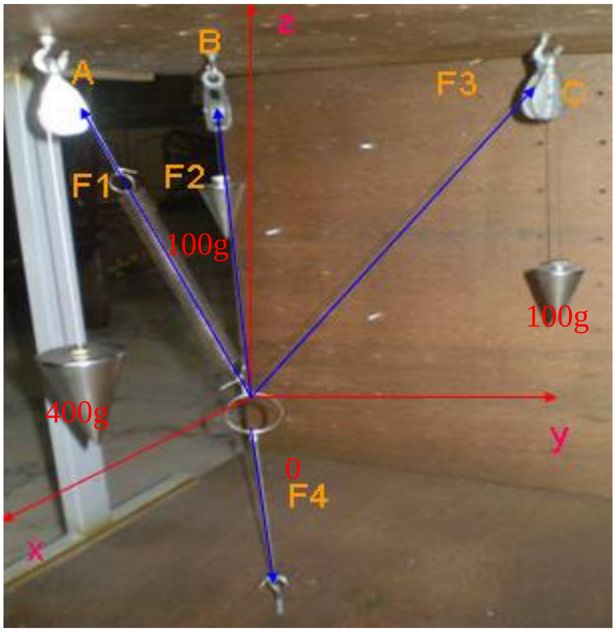


Figure 5: Setting of equilibrium of a particle (3D)

Solution:

F1= 4N

F2= 1N

F3= 1N

F4= 6N (assume) where g = 10 m/s²

The stiffness of the spring is

F1 = k (0.15m – 0.05m)

4 N = k (0.1m)

k = 40N/m

Each of the forces can be expressed in Cartesian vector form,

F1 = 4{(0.10i -0.05j + 0.20k)/ [(0.10² + 0.05² + 0.20²)½]}

= 1.74i -0.87j + 3.50k

F2 = 1{(-0.05i -0.05j + 0.20k)/ [(0.05² + 0.05² + 0.20²)½]}

= -0.24i -0.24j + 0.94k

F3 = 1{(-0.10i +0.15j + 0.20k)/ [(0.10² + 0.15² + 0.20²)½]}

= -0.37i + 0.56j + 0.74k

For equilibrium,

F1+F2+F3+F4 = 0

Fx = 1.13N

Fy = -0.55N

Fz = -0.82N

F = 1.13i - 0.55j - 0.82k

F = 1.50N

For direction of a Cartesian Vector,

Uf = 1.13/1.50i - 0.55/1.50j - 0.82/1.50k

Alpha = 41.12º

Beta = 111.51º

Gamma = 123.14º

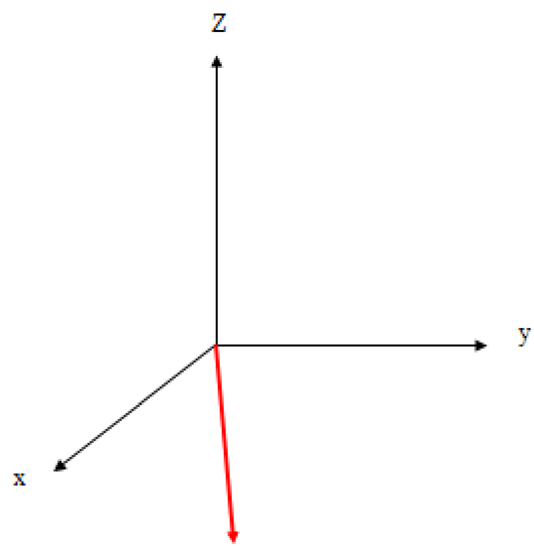


Figure 6: The magnitude and correct direction of F

Setting 5: Chapter of force system resultant

1. Equipments needed

The equipments needed are “L” bracket, screw, nuts, rope, weight (100g), pulley, measuring tape, hook and protractor.

2. Procedure

1. Tighten the hook 0.35 m away from point O as shown in figure g.

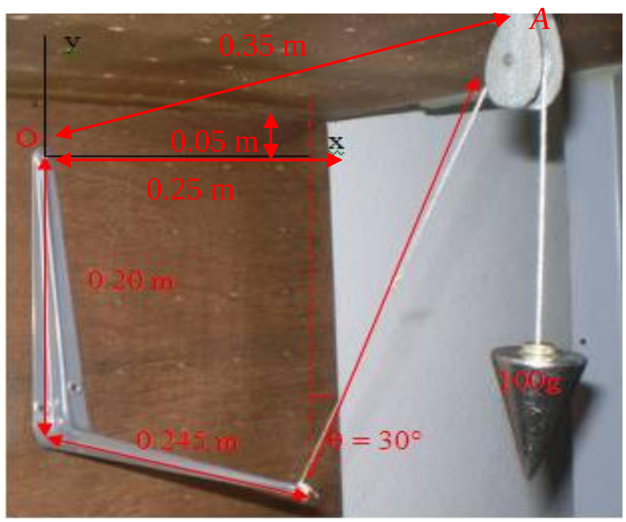


Figure g

2. Place the "L" bracket at point O as shown in Figure g.
3. Put the pulley at point *A*.
4. Attach the weight of 100g with a rope and tighten it at end of the "L" bracket.

3. Question and calculations

The force F acts at the end of the "L" bracket shown in Figure 6 and 7. Determine the moment of the force about point O.

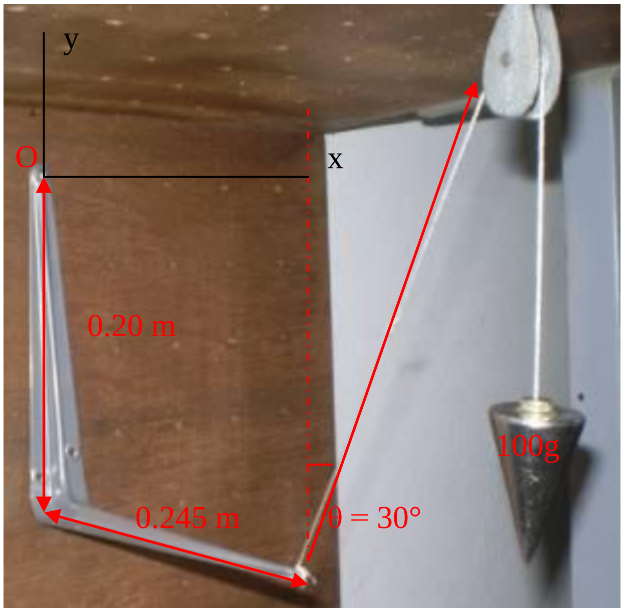


Figure 6: Setting of force system resultant

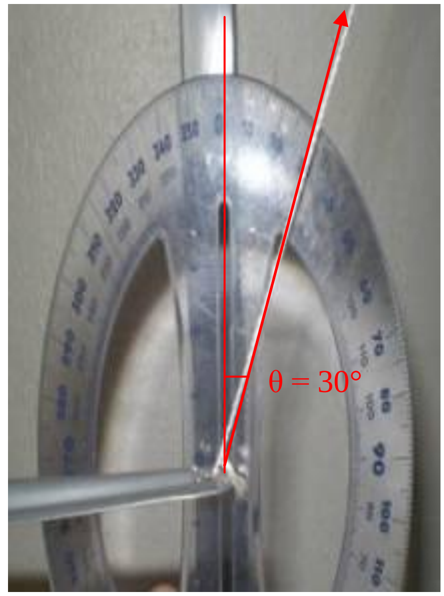


Figure 7: Angle of the force

Solution:

Scalar Analysis

$\curvearrowleft + M_o = 0.98 \cos 30° (0.245) + 0.98 \sin 30° (0.20) = 0.31$ Nm

or Vector analysis

$r = \{0.245i – 0.20j\}$m

$F = \{0.98 \sin 30°i + 0.98 \cos 30°j\} = \{0.50i + 0.85j\}$ N

The moment is

$$M_o = r \times F = \begin{vmatrix} i & j & k \\ 0.245 & -0.20 & 0 \\ 0.50 & 0.85 & 0 \end{vmatrix}$$

$$= \{(0.245)*(0.85) – (-0.20)*(0.50)\} = 0.31 \text{ Nm}$$

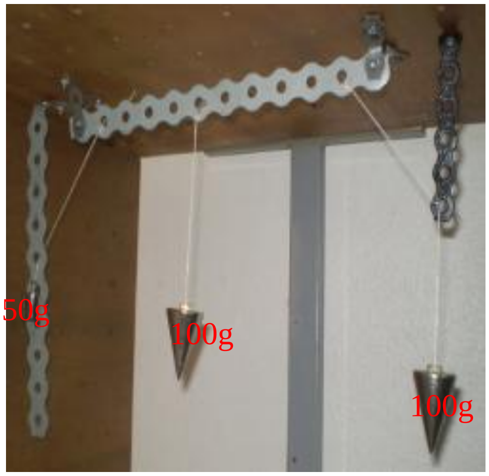
Setting 6: Chapter of further reduction of a force

1. Equipments needed

The equipments needed are 3 weights of (50g, 100g & 100g), rope, beam, measuring tape, screws, nuts and protractor.

2. Procedure

1. Tighten the “L” steel beam at point *A* (0.30, 0.45) and “L” black steel beam at point *B* (0.30, 0.05).



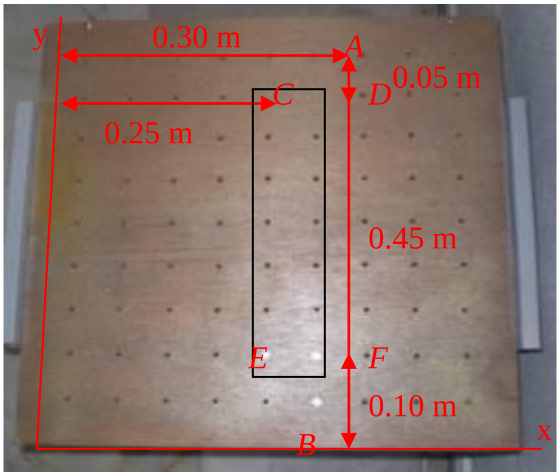


Figure h

Figure i

2. Place and tighten the beam as shown in the black frame at coordinate of *C* (0.25, 0.40) m, *D* (0.30, 0.40) m, *E* (0.25, 0.10) m and *F* (0.30, 0.10) respectively in figure i.
3. Attach the 3 weights of 50g, 100g and 100g as shown in the figure h.

3. Question and calculations

Replace the three forces acting on the shaft by a single resultant force in Figure 8 and 9. Specify where the force acts, measured from end *B*.

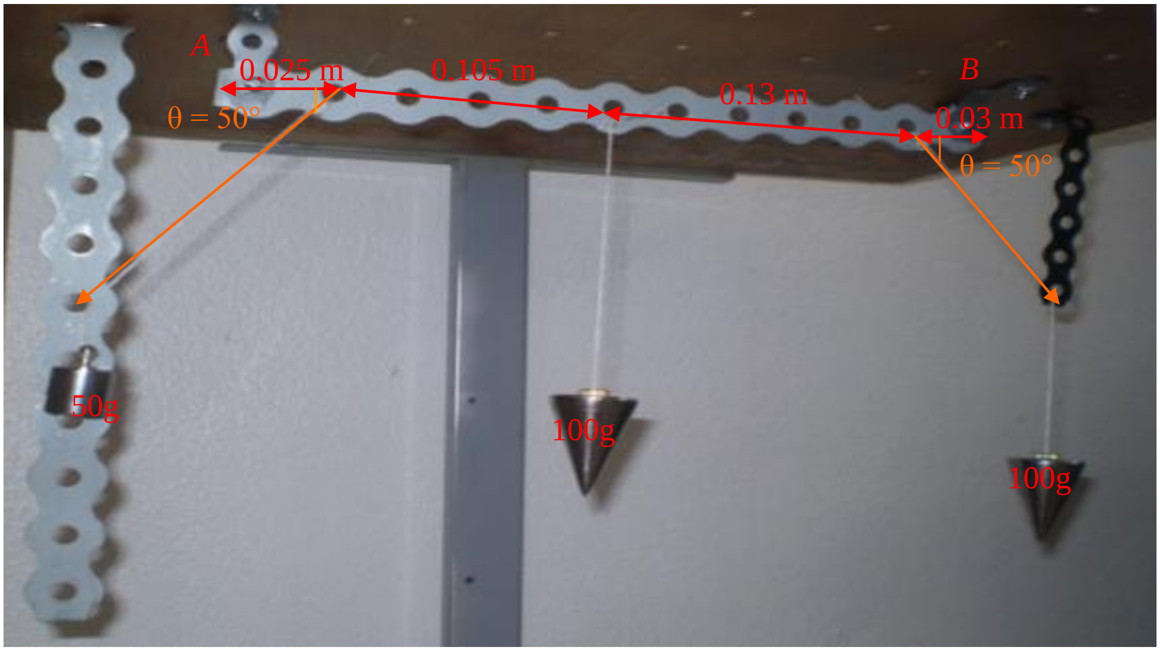


Figure 8: Setting of further reduction of a force

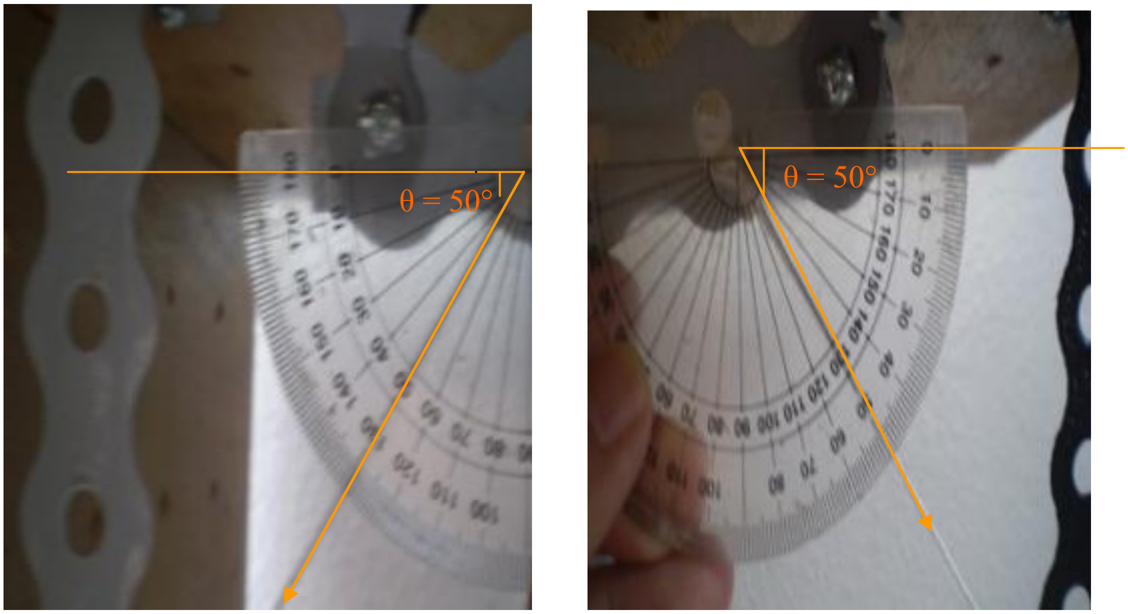


Figure 9: Angle of the force

Solution:

$\mathbf{F_{Rx} = \sum Fx;}$ $\overset{+}{\rightarrow}$ $F_{Rx} = -0.49 \cos 50° + 0.98 \cos 50° = 0.315$ N

$\mathbf{F_{Ry} = \sum Fy;}$ $+\uparrow$ $F_{Ry} = -0.49 \sin 50° - 0.98 – 0.98 \sin 50° = -2.10$ N

$F = (0.315^2 + 2.10^2)^{1/2} = 2.12$ N

$\theta = \tan^{-1} (2.10/0.315) = 81.5°$

$+ \mathbf{M_{RB} = \sum M_B;}$ $2.10x = (0.98 \sin 50°)*(0.03) + 0.98(0.16) + (0.49 \sin 50°)*(0.265)$

$x = 0.13$ m

Setting7 & 8: Chapters of equilibrium of a rigid body (2D)

1. Equipments needed

The equipments needed are hook, rope, beam, screws, nuts, protractor and measuring tape.

2.1 Procedure

1. Tighten the hook at the coordinate of *A* (0.25, 0.35) as shown in Figure j.

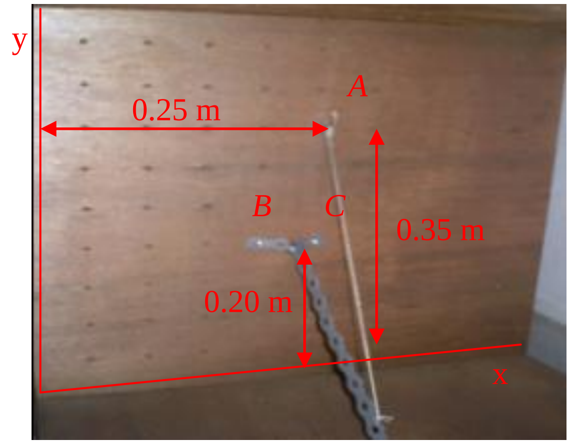


Figure j

2. Tighten the beam at the coordinate of *B*(0.20, 0.20) and *C* (0.25, 0.20)
3. Tighten the rope at the hook at point *A* to the end of the beam.

2.2 Procedure

1. Tighten the hook 0.20 m away from point *D* as shown in Figure k. Then attach a pulley on it.

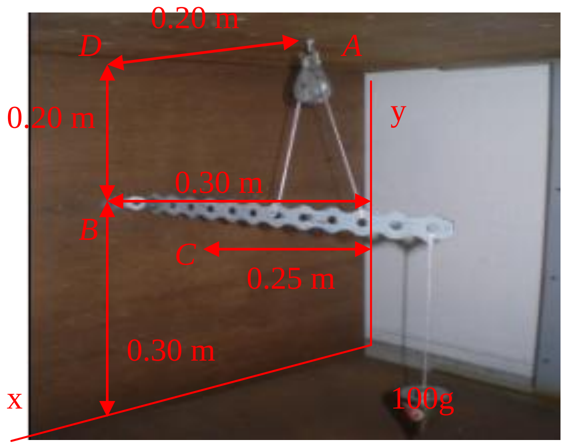


Figure k

2. Place and tighten the beam at the coordinate of *B* (0.30, 0.30) m and *C* (0.25, 0.30).
3. Attach the weight of 100g with a rope and tighten it at the end of the beam.
4. Tighten the rope in hole 7 and hole 10 from the hinge at point *B*.

3. Question and calculations

3.1 The beam has a weight of 0.50 N (50g) and a center of gravity at *G* as shown in Figure 10, 11 and 12. Determine the rope force in *CD* needed to just start lifting the beam (i.e. so the reaction at *B* becomes zero). Also, determine the horizontal and vertical components of force at the hinge at *A*.

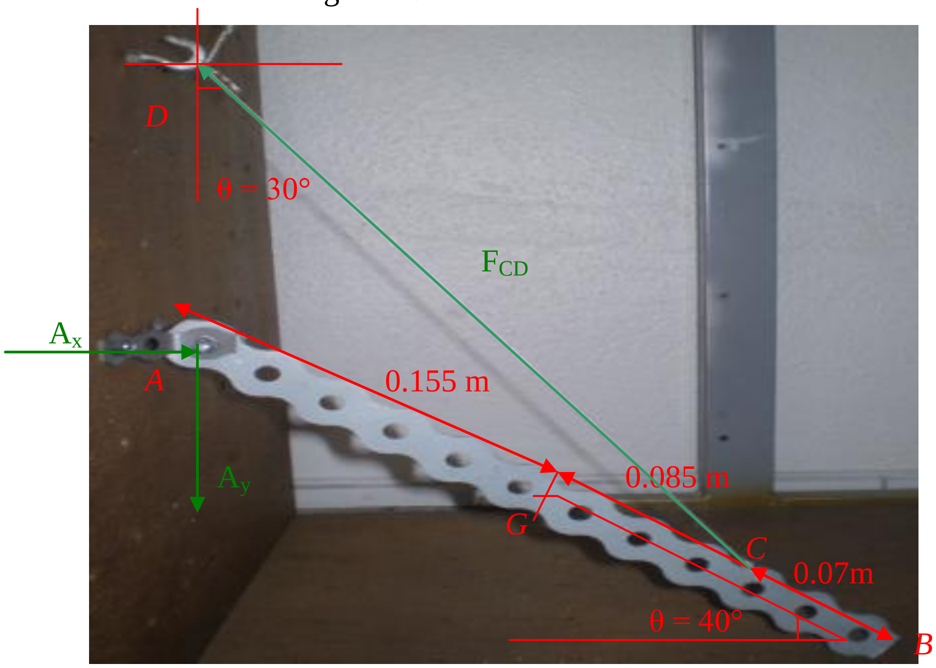


Figure 10: Setting of hinge subjected to two dimensional force system

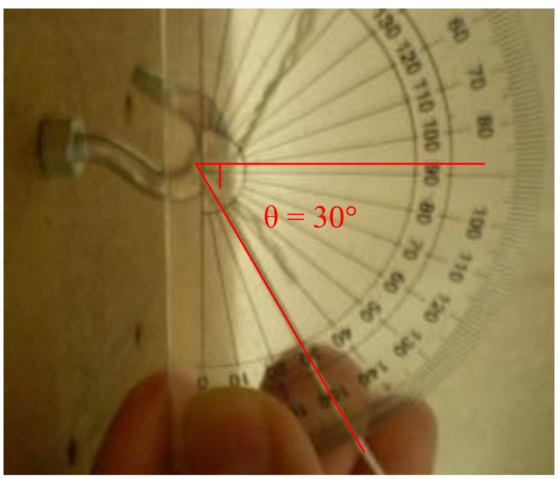


Figure 11: Angle of the rope

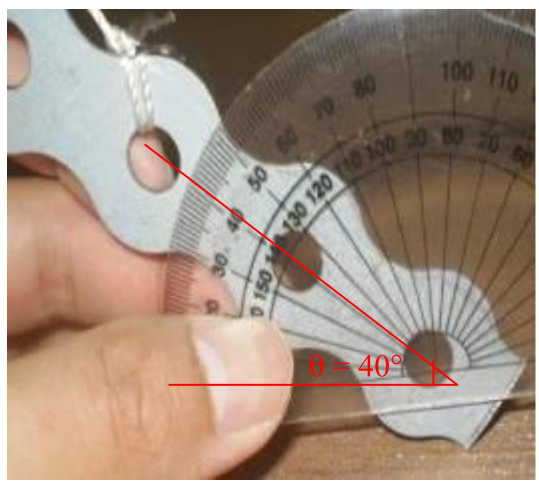


Figure 12: Angle of the beam

Solution:

↺ + $\mathbf{M_A = 0;}$

$F_{CD} \cos 30° (0.24 \cos 40°) - F_{CD} \sin 30° (0.24 \sin 40°) – 0.155(0.5 \cos 40°)= 0$

$0.08\ F_{CD} = 0.06$

$F_{CD} = 0.75$ N

$\overset{+}{\rightarrow}$ $\mathbf{F_{Rx} = 0;}$ = 0.75 sin 30° = 0.375N

+↑ $\mathbf{F_{Ry} = 0;}$ $-A_y + 0.75 \cos 30° = 0.5$

$A_y = 0.15$ N

3.2 Determine the tension in the cable and the horizontal and vertical components of reaction of the pin *A* as shown in Figure 13 and 14. The pulley at *D* is frictionless ant the weighs 0.981 N (50g).

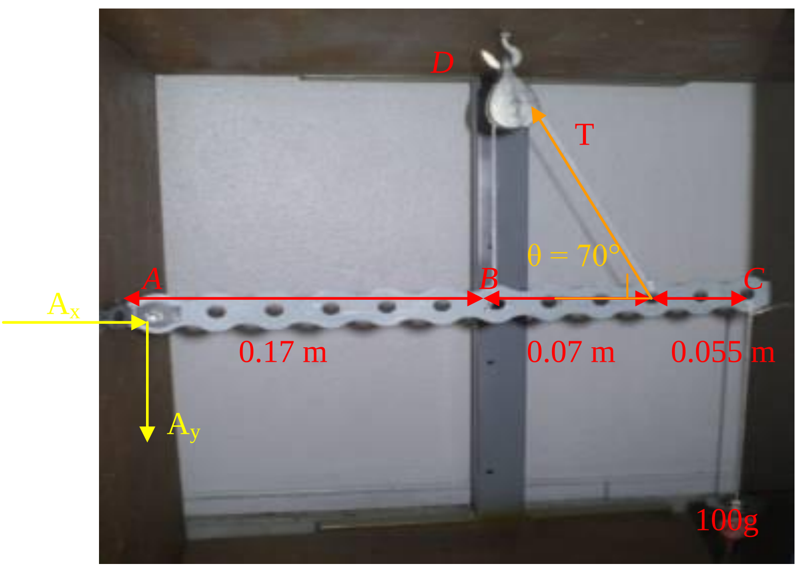


Figure 13: Setting of rigid body

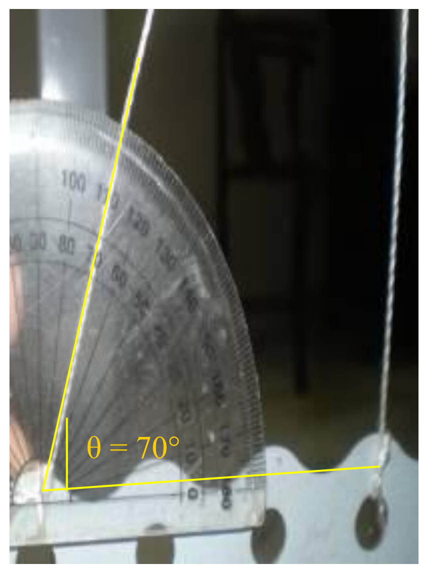


Figure 14: Angle of the rope

Solution:

↺ + $\mathbf{M_A = 0;}$ 0.17 T + 0.245 T – 0.3*0.981 = 0

T = 0.76 N

$\overset{+}{\rightarrow}$ $\mathbf{F_{Rx} = 0;}$ $A_x = 0.76 \cos 70° = 0.26$N

+↑ $\mathbf{F_{Ry} = 0;}$ $0.76 + 0.76 \sin 70° - 0.981 - A_y = 0$

$A_y = 0.50$ N

Setting 9: Chapters of equilibrium of a rigid body (3D)

1. Equipments needed

The equipments needed are hook, screw (27cm long), nuts, 2 weights of (50g & 100g) and rope.

2. Procedure

1. Tighten the screw at the coordinate of *A* (0.25, 0.25) m as shown in figure l.

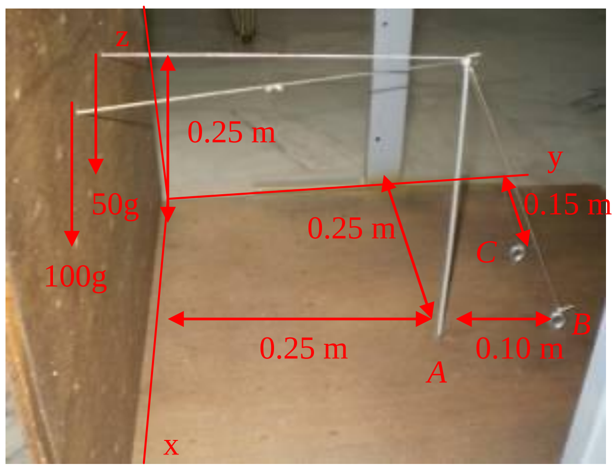


Figure l

2. Tighten the hooks at the coordinate of (0.35, 0.25) and (0.35, 0.15) respectively.
3. Then, tighten the rope on top of the screw with the hooks at point *B* and *C* respectively.
4. Attach the weights of 50g and 100g with a rope and tighten it on top of the screw.

3. Question and calculations

The ropes exert the forces shown on the screw as shown in Figure 15 and 16. Assuming the screw is supported by a **ball and socket joint** at its base, determine the components of reaction at *A*. the forces of 0.49 N and 0.98 N lie in a horizontal plane.

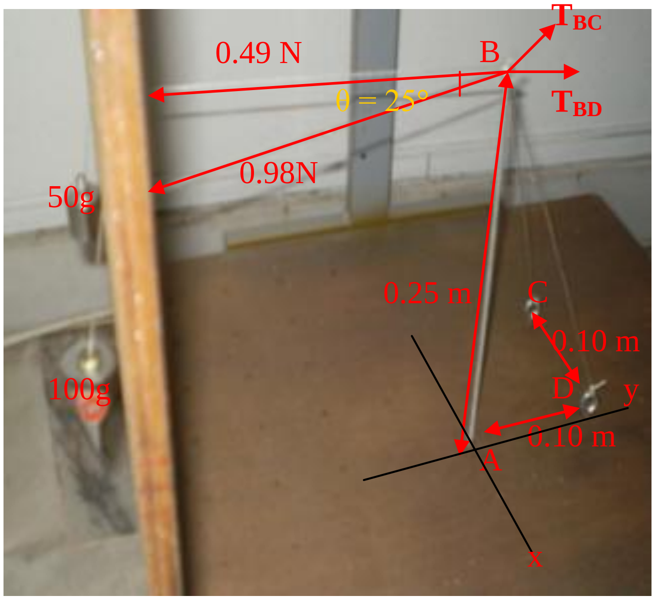


Figure 15: Setting of rigid body

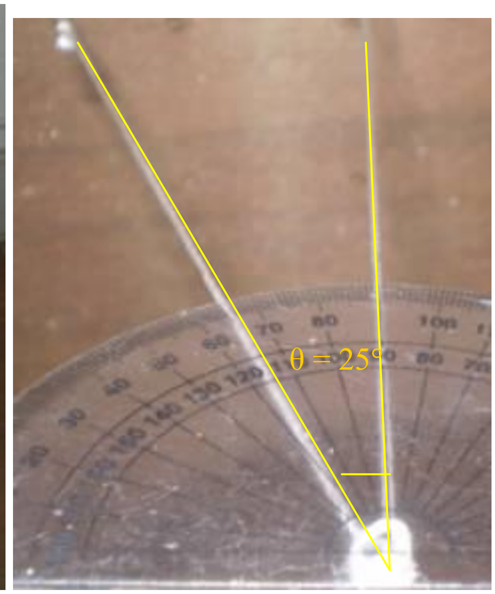
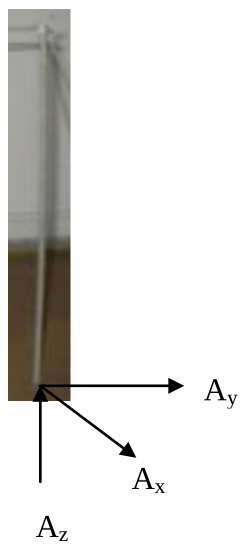


Figure 16: Angle of the rope

Solution:



$T_{BD} = \{0.1\ T_{BD} / (0.0725)^{½}\}\ j - \{0.25\ T_{BD} / (0.0725)^{½}\}\ k$

$T_{BC} = \{-0.1\ T_{BC} / (0.0825)^{½}\}\ i + \{0.1\ T_{BC} / (0.0825)^{½}\}\ j - \{0.25\ T_{BC} / (0.0825)^{½}\}\ k$

$\sum M_x = 0$;

$(0.981 \cos 25° + 4.90)*(0.25) - \{0.1\ T_{BC} / (0.0825)^{½}\}*(0.25)$

$- \{0.1\ T_{BD} / (0.0725)^{½}\}*(0.25) = 0$

$\sum M_y = 0$;

$0.981 \sin 25° - \{0.1\ T_{BC} / (0.0825)^{½}\}*(0.25) = 0$

$\mathbf{T_{BC} = 1.20\ N}$

$\mathbf{\sum Fx = 0;}$

$A_x + 0.981 \sin 25° - \{0.1\ T_{BC} / (0.0825)½\} = 0$

$\mathbf{\sum Fy = 0;}$

$A_y - 0.981 \cos 25° - 0.49 + \{0.1\ T_{BD} / (0.0725)½\} + \{0.1\ T_{BC} / (0.0825)½\} = 0$

$\mathbf{\sum Fz = 0;}$

$A_Z - \{0.25\ T_{BD} / (0.0725)½\} - \{0.25\ T_{BC} / (0.0825)½\} = 0$

$\mathbf{T_{BD} = 2.70\ N}$

$\mathbf{A_x = A_y = 0}$ (BA is two-force member so that $A_x = A_y = 0$)

$\mathbf{A_Z = 3.55\ N}$

Setting 10: Force Table

1. Equipments needed

The equipments needed are 3 weights of (100g), pulleys, rope, protractor, screw and nuts.

2. Procedure

1. Tighten the screw at the coordinate of *A* (0.25, 0.25) m as shown in figure m.

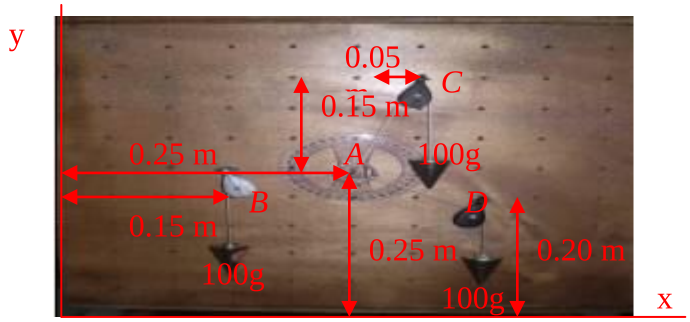


Figure m

2. Tighten the 3 hooks at coordinate of *B* (0.15, 0.25) m, *C* (0.30, 0.40) m and *D* (0.35, 0.20) m respectively.
3. Attach pulleys on the 3 hooks at point *B*, *C* and *D* respectively.
4. Attach the 3 weights of 100g with rope.
5. Then, tighten all the 3 ropes at the ring. Make sure that the ring does not touch the screw.

3. Question and solution

What is the net force of force vectors $A + B + C$ as shown in Figure 17.

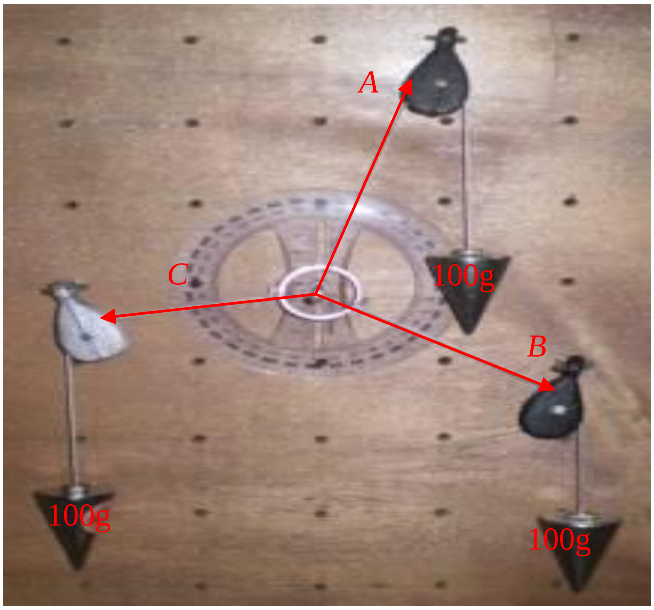


Figure 17: Setting of force table

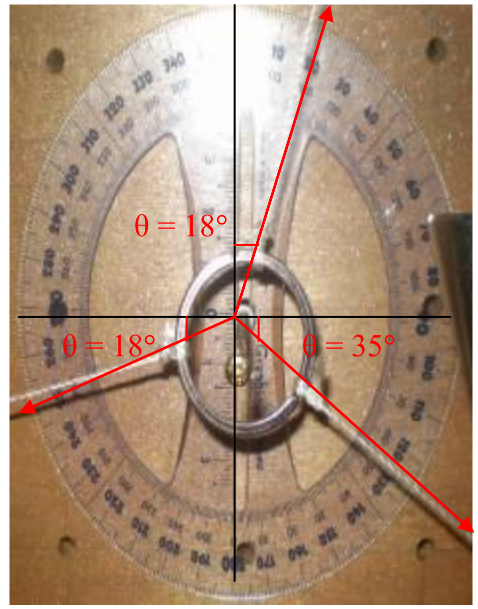


Figure 18: Angle of force vectors

Note that if the ring is not in center or touch the screw. This means that the forces on the ring are not balanced (not in static equilibrium).

Solution:

One method of determining the vector sum of these three forces (i.e. the net force) is to employ the method of head-to-tail addition. In this method, an accurately drawn scaled diagram is used and each individual vector is drawn to scale. Where the head of one vector ends, the tail of the next vector begins. Once all vectors are added, the resultant (i.e. the vector sum) can be determined by drawing a vector from the tail of the first vector to the head of the last vector. This procedure is shown below:

Firstly, rearrange the force vectors as shown in Figure 19.

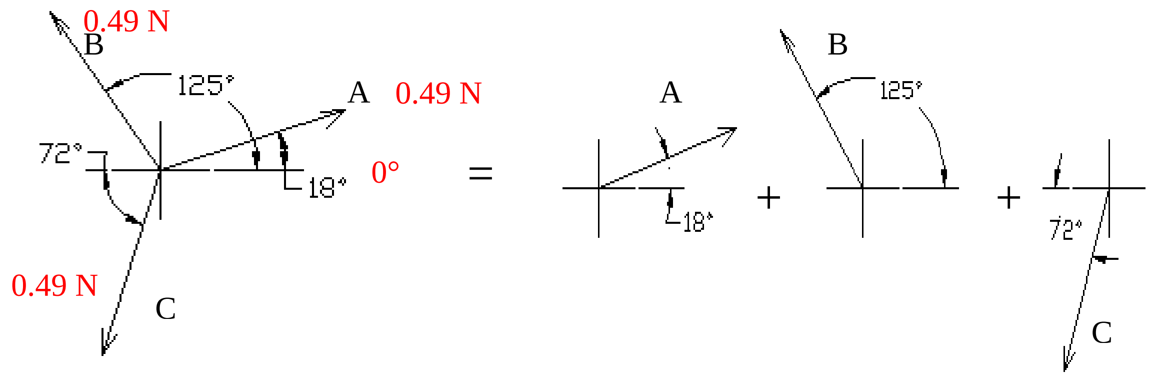


Figure 19: Rearrange the force vectors

Then employ the method of head-to-tail addition as shown in Figure 20.

Scale: 1cm = 0.49 N

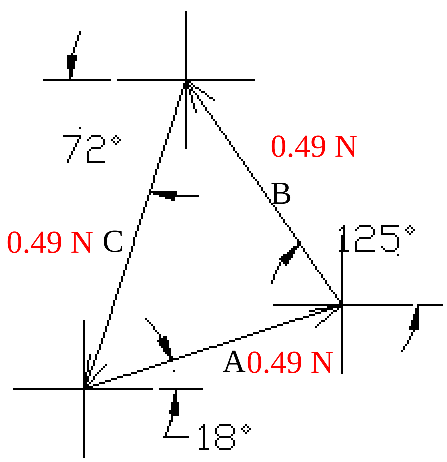


Figure 20: Method of head-to-tail addition

Hence, force vectors A + B + C = 0 (Proved) that is the vector sum of the three vectors is 0 Newton and the three vectors add up to 0 Newton. The last vector ends where the first vector began such that there is no resultant vector.

Setting 11: Torque in different direction

1. Equipments needed

The equipments needed are beam, measuring tape, 5 weights of (50g, 100g, 100g, 100g and a unknown mass), rope, screw and nut.

2. Procedure

1. Tighten the steel beam at the coordinate of *A* (0.25, 0.10) as shown in figure n.

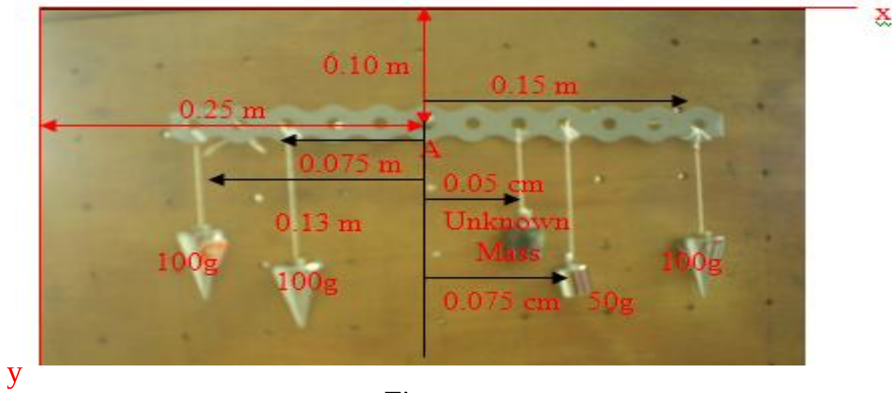


Figure n

2. Attach the 5 weights of 100g, 100g, unknown mass, 50g and 100g with the rope at tighten it on the steel beam as shown in figure n.

3. Question and calculations

Calculate the unknown mass as shown in Figure 21.

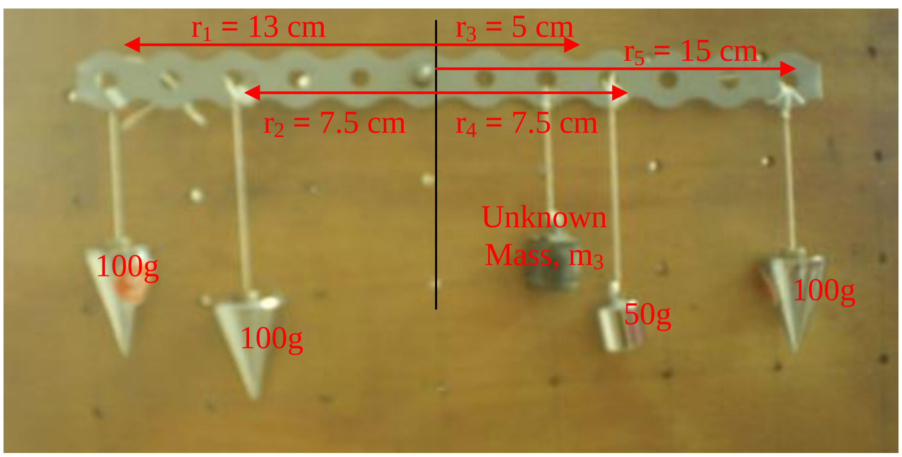


Figure 21: Setting of torque

Solution:

$\sum\tau cc = \sum\tau cw$;

$F_1\, r_1 + F_2\, r_2 = F_3\, r_3 + F_4\, r_4 + F_5\, r_5$; $F_i = m_i g$

$m_1\, g\, r_1 + m_2\, g\, r_2 = m_3\, g\, r_3 + m_4\, g\, r_4 + m_5\, g\, r_5$

(100g)*(13) + (100g)*(7.5) = m_3 (5) + (50g)*(7.5) + (100g)*(15)

m_3 = 35g