THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF PHYSICS

INTRODUCTORY PHYSICS
PHY1010

TUTORIAL SHEETS 2019/20

PART 1

PHY1010: Introductory Physics

Syllabus Part I

1. Vectors: Vectors and scalars; Vector addition and subtraction; Vector components; Addition of vectors by components.

2. Description of motion: Speed and velocity; Instantaneous velocity; Displacement; Acceleration; Uniformly accelerated motion; Time and acceleration; Acceleration of gravity; Projectile motion.

3. Newton's laws of motion: First law; Inertia and mass; Force; Second law; Action and reaction; Third law; Mass and weight; Frictional forces; Coefficients of friction; Weightlessness.

4. Work and Energy: Work; Power; Energy; Work/energy theorem; Kinetic and potential energy; Conservation of energy; Conservative and non-conservative forces.

5. Linear momentum: Linear momentum; Conservation of linear momentum; Elastic and inelastic collisions; Impulse; Rocket propulsion.

6. Rotational motion: Angular measure; Angular speed and acceleration; Centripetal acceleration and force; Equations of motion; Law of gravitation; Gravitation and weight; Weightlessness; Orbital motion.

7. Rotational work, energy, and momentum: Rotational work and kinetic energy; Moment of inertia; Torque; Angular momentum; Combined rotation and translation.

8. Equilibrium: Translational equilibrium; Rotational equilibrium; Centre of gravity; Toppling over of objects; Mechanical advantage.

9. Mechanical properties of matter: Density; Hooke's law; Young's modulus; Shear, and Bulk modulus; Pressure and depth; Archimedes' principle; Buoyancy.

10. Pressure and temperature of a gas: Atmospheric pressure; Barometers, Thermometers; Temperature scales; Ideal gas law.

11. Thermal properties of matter: Heat and heat units; Thermal energy; Specific heat capacities; Heat of fusion and melting; Calorimetry; Thermal expansion; Heat conduction, convection, and radiation.

12. Thermodynamics I and II: Kelvin scale; State variables; First law of thermodynamics; Work done by and on a gas; Specific heat of an ideal gas; isothermal, adiabatic, and isobaric processes; Second law; Entropy; Carnot engine; refrigerators and heat pumps.

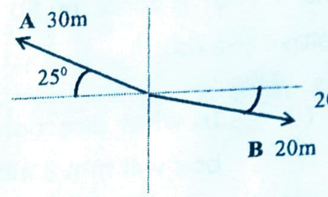
13. Harmonic motion: Periodic motion; Hooke's law spring; Harmonic motion; Sinusoidal motion; Simple pendulum; Forced vibrations.

14. Waves and Oscillations: Description of a wave; Reflection of a wave; Standing waves; Wave resonance; Transverse and longitudinal waves; Compression waves.

PHY1010 Introductory Physics 2019/20
Tutorial Sheet 01
Vectors

01*. A displacement **D** of 100m from the origin at an angle of 37^0 above the x-axis is the result of three successive displacements: $\mathbf{d_1}$ of 100m along the negative x-axis, $\mathbf{d_2}$ of 200m at an angle of 150^0 above the x-axis, and a displacement $\mathbf{d_3}$. Find $\mathbf{d_3}$.
[355m, 353.5^0]

02*. Find the direction and magnitude of:



(i) the vector sum **A + B** [10.22m, 145.16^0]

(ii) the vector difference **A – B**, [49.56, 157^0] and

(iii) the vector difference **B – A**. [49.56m, 337^0]

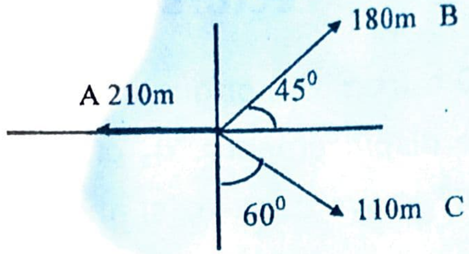
03*. A particle undergoes three *successive* displacements in a plane as follows: 4.0m southwest, 5.0m east, 6.0 m in a direction $60°$ north of east. Choose the y-axis pointing north and the x-axis pointing east and find

i) The components of each displacement,
ii) The components of the resultant displacement, $[5.17m, 2.37m]$
iii) The magnitude and direction of the resultant displacement, $[5.69m, 24.63^0]$ and
iv) Graphically show the approximate displacement of the particle.

04*. The resultant of two force vectors **A** and **B** has a magnitude of 150 N along the y-axis. If the force vector **B** makes an angle of 60^0 with the positive x-axis, find the magnitude of **B** and the direction of **A**, given that the x-component of **A** is equal to -60 N.
[120N, 142.48^0]

05*. When displacement **B** is added to displacement **A** the result is a displacement **C** that has components C_x = -3.0cm, C_y = +6.0cm, and C_z = +4.0cm. Displacements **A** and **B** are in the same direction, but the magnitude of **A** is only half that of **B**. Find the components of **A**. [-1, 2, 4/3]

06. The three vectors **A**, **B**, and **C** are as shown. Find the magnitude and direction of a vector **D** which when added to these three vectors will give a zero resultant.



[73.36 m, 260.16^0]

07**. A man pulls a box with a force of 70 N along the positive *y*-axis, while a boy pulls it with a force of 50 N, making an angle of 80° counter clock-wise with the positive *y*-axis.

(i) In what direction should a *second boy* apply a force of 60 N so that the box will move along the positive *y*-axis? *Hint*: two values are possible.

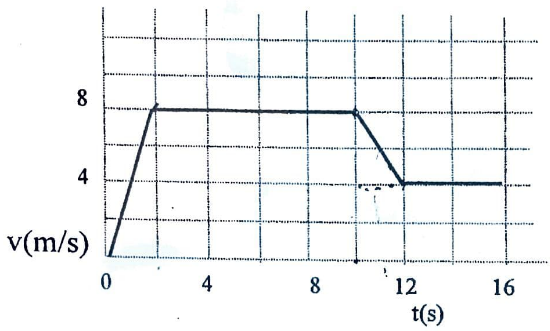
(ii) Find the magnitude and direction of the force that a *second man* should apply so that the box does not move at all?

(i) [34.85^0, 325.15^0], (ii) [-112.97 N, -44.39 N]

8** While exploring a cave, a person starts at the entrance and moves the following successive distances. She goes 75.0 m north, 250 m east, 125 m at an angle 30.0^0 north of west, and 150 m south. Find the resultant displacement from the cave entrance. Draw a rough diagram. [$R = \sqrt{141.75^2 + (-12.5)^2} = 142.3m$]

PHY1010 Tutorial Sheet 2 2019/20
Uniformly Accelerated Motion & Projectiles.

01. The velocity-time graph of a runner is shown in the figure.
(i) How far does the runner go in 16 s? (ii) What is the acceleration of the runner at t = 2 s? And at t = 11 s? [$100\,\text{m}$] [$4\,\text{m/s}^2, -2\,\text{m/s}^2$]



02*. A truck travelling at 22.5 m/s decelerates at 2.27 m/s².

(a) How much time does it take for the truck to stop? [$9.91s$]

(b) How far does it travel while stopping? [$112\,\text{m}$]

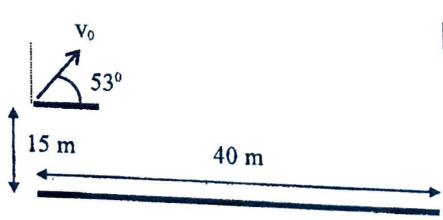
(c) How far does it travel during the third second after the brakes are applied? [$16.8\,\text{m}$]

03**A ball is dropped off a high cliff, and 2 s later another ball is thrown vertically downward with an initial speed of 30 ms^{-1}. How long will it take the second ball to overtake the first? [$t = 3.88s$]

04*. You fire a projectile 35^0 above horizontal with an initial velocity of 200 m/s. It lands in a valley 300 m below the launch point. What is the time of flight of the projectile, and what is the range of projectile? [$25.8\,\text{s}, 4.23\times10^3\,m$].

05. A coin is projected at an angle of 53^0 above the horizontal from a point 15 m above the ground level. It reaches the ground at a horizontal distance of 40 m from the launch point.

Calculate (i) the time it was in air (ii) the velocity with which the coin was projected. [$3.728s, 17.8m/s$]



06**. A train approaching a station does two successive half-kilometres in 16 and 20 seconds respectively. Assuming the retardation to be uniform, find the further distance the train runs before stopping. [667.4 m]

07**. Suppose you have a car with a maximum acceleration of $a = 6.0\ m/s^2$ and a maximum deceleration from braking of $a = -8.0\ m/s^2$. We want to find the minimum time it would take you to start from rest, cover 500 m, and come to a stop at the 500 m mark. You do this by accelerating as much as possible for a part of the 500 m, followed by a period of maximum deceleration to the final stop.

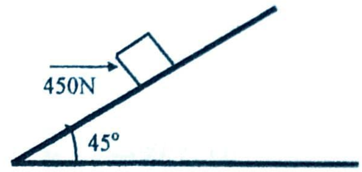
Find the minimum time. [17.1s]

PHY1010 Tutorial Sheet 3 2019/20

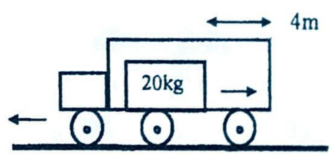
Newton's Laws of Motion

01*. A 45 kg woman stands on a spring scale inside an elevator. (The scale reads the force with which it pushes upward on the woman). What does the scale read when the elevator is accelerating (a) upward at 3.65 m/s², (b) downward at 3.65 m/s² ? $[605.25N, 276.75N]$

02*. When a force of 450 N pushes on a 20 kg box as shown, the acceleration of the box up the incline is 0.70 m/s². Find the coefficient of sliding friction between the box and the incline. [0.363]



03*. The rear side of a truck is open and a box of mass 20 kg is placed on the truck, 4 m away from the open end. If the truck starts from rest with an acceleration of 2 m/s² on a straight road, find the distance the truck will travel when the box will fall off from the rear. Given μ=0.15. [15.2 m]



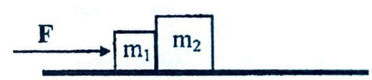
04. Two blocks with masses m_1 = 3.2 kg and m_2 = 4.1 kg are touching each other on a frictionless table. If the force **F** is equal to 6.8 N,

(a) what is the acceleration of the two blocks, and

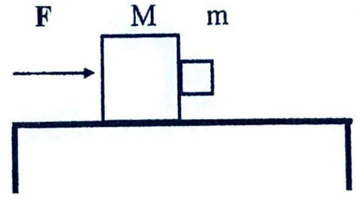
(b) with what force does m_1 push against m_2 ?

(c) Repeat (a) and (b) if **F** is in the reverse direction and pushes on m_2 rather than on m_1.

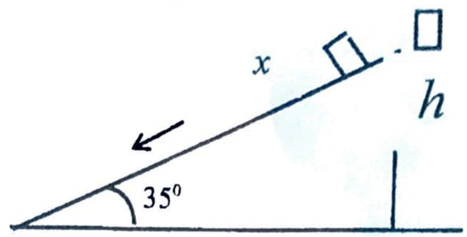
$[0.932\,\mathrm{m/s^2}]\ [3.82N]\ [-0.932\,\mathrm{m/s^2}]\ [2.98N]$



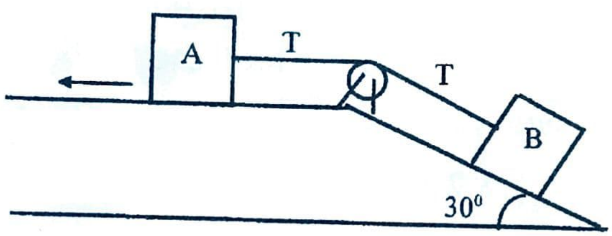
05*. The force **F** in the figure pushes a block of mass M, which in turn pushes a block of mass m. There is no friction between M and the supporting surface. If the coefficient of friction between the two blocks is μ, how large must **F** be if the block of mass m is not to slip? $F = (M+m).\frac{g}{\mu}$



06.** A block takes twice as long to slide down an inclined plane that makes an angle of 35° with the horizontal as it does to fall freely through the same vertical distance h. What is the coefficient of kinetic friction? [$\mu = 0.16$]



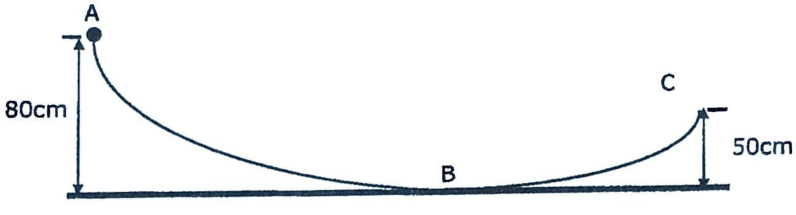
07. The two boxes have identical masses of 45kg. Both experience a sliding friction force with μ=0.15. Find the tension in the tie cord and the acceleration of the boxes. [T = 114.68N. a = 1.078m/s^2]



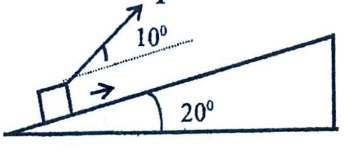
PHY1010 Introductory Physics 2019/20
Tutorial Sheet 4 Work and Energy.

01. A pump is needed to lift water from a well though a height of 3.0 m at a rate of 0.6kg/min. What must be the minimum power of the pump in watts, and in horsepower? [Power $= 0.294$ watt or $= 3.94 \times 10^{-4}\ hp$]

02. A bead of mass 15g is sliding on a wire. It has a speed of 2.0m/s at *A*, and it stops as it reaches the point *C*. The length of the wire from *A* to *C* is 250cm.
How large an average friction force opposed the motion of the bead? [$f = 0.0296$N]



03. A steel block weighing 12N is pulled up an inclined plane 20^0 above the horizontal by a constant force of 7.35 N which makes an angle of 10^0 above the inclined plane.
The block starts from rest and is pulled 2.0 m along the inclined plane.
The coefficient of friction between the block and the inclined plane is 0.20.
Determine: (a) the work done on the block by the force, [$W = 14.48J$]
(b) increase in potential energy of the block [$\Delta PE = 8.21J$]
(c) increase in kinetic energy of the block, and [$KE_{final} = 2.27J$]
(d) amount of work required to overcome the frictional force. [$W_f = W - E = 4J$]

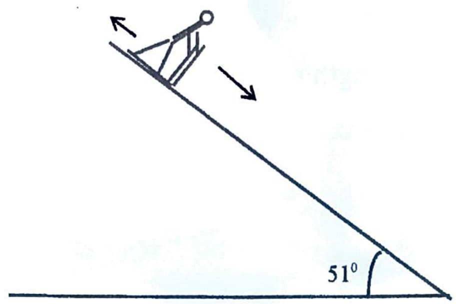


04**. A record skiing speed of 203.1km/h was achieved on a mountain slope inclined downward at 51^0. At this speed, the force of friction on the skier (air and sliding friction) balances the pull of gravity along the slope, so that the motion proceeds at a constant velocity.

(a) What is the rate at which gravity does work on the skier? Assume that the mass of the skier is 75kg. [32227 J/s]

(b) What is the rate at which sliding friction does work? Assume that the coefficient of sliding friction $\mu_k = 0.03$ [783 J/s]

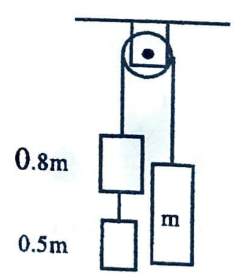
(c) What is the rate at which air friction does work? [31444 J/s]



05. A running man has one-half the kinetic energy that a running boy of half his mass has. The man speeds up by 1.0 m/s and then has the same kinetic energy as the boy. What were the original speeds of the man and the boy?

$[v_{man-orig} = 2.42m/s,\ v_{boy-orig} = 4.83m/s]$

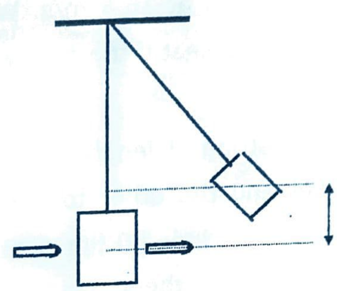
06*. The frictionless system shown is released from rest. After the right-hand mass has risen 75 cm, the object of mass 0.50 m falls loose from the system. What is the speed of the right-hand mass when it returns to its original position? $[v_{down} = 1.88\,m/s]$



Tutorial Sheet 5(2019/20)
Linear Momentum & Collisions

01. Car 1 was sitting at rest when it was hit from the rear by car 2 of identical mass. Both cars had their breaks on and they skidded together 6 m in the original direction of motion. If the stopping force is ~ 0.7 × (combined weight of the cars) , i.e., $\mu = 0.7$, find the approximate speed of car 2 just before the collision took place. [18.14 m/s]

02**. A bullet of mass 10 g and travelling at a speed of 500 m/s strikes a block of mass 2 kg which is suspended by a string of length 5 m. The bullet goes through the block in a very short time and the centre of gravity of the block is found to rise a vertical distance of 10 cm. What is the speed of the bullet just after it emerges from the block? [220 m/s]



03. A billiard ball at rest is struck by another billiard ball of the same mass whose speed is 6.0 m/s. After an elastic collision the striking ball goes off at an angle of 25^0 with respect to its original direction of motion. Find the angle the struck ball makes with this direction and the final speeds of both balls. [65.4^0, 5.44 m/s, 2.53 m/s]

04**. A vessel at rest explodes, breaking into three pieces. Two of the pieces, with masses m_1 and m_2 ($m_1 = 2m_2$), fly off perpendicular to one another with the same speed of 30 m/s. The third piece has mass $m_3 = 3m_2$. Find the magnitude and direction of its velocity just after the explosion. [22.4 m/s, 206.6^0]

05**. A particle of mass m, moving with a velocity u makes a head-on elastic collision with a particle of mass $2m$ initially at rest. Show that the particle of mass m loses $(8/9)^{th}$ of its initial kinetic energy in the collision. [fractional loss of KE = 8/9]

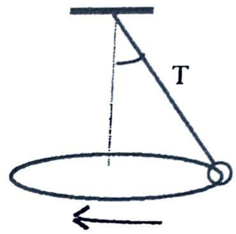
Tutorial Sheet 6 2019/20

Motion in a Circle

01*. A belt runs on a wheel of radius 44 cm. During the time the wheel takes to coast uniformly to rest from an initial speed of 1.6 rev/s, 29.5 m of belt length passes over the wheel. Find the deceleration of the wheel and the number of revolutions it turns while stopping. [$\alpha = -0.12 rev/s^2$ $\theta = 67 rad = 10.7 rev$]

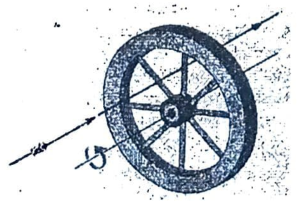
02. A carton of eggs sits on the horizontal seat of a car as the car rounds a 26 m radius bend at 16.5 m/s. What minimum coefficient of friction must exist between carton and seat if the eggs are not to slip? [$\mu = 1.07$]

03. A string of length 30 cm has one end attached to a fixed point and the other to a mass of 100 g which revolves in a horizontal circle 80 times per minute. Calculate (i) the angle of inclination of the string to the vertical, and (ii) the tension T in the string. [$\theta = 62.18^0$ $T = 2.10\text{N}$]



04*. A 450 g ball at the end of a cord is whirled in an almost horizontal circle of radius 1.25 m. Its tangential speed in the circle is 8.5 m/s. *Do not* neglect the weight of the ball; the string cannot be perfectly horizontal. (a) What must the tension in the cord be? (b) What angle does the cord make with the horizontal? [$T = 26.4\text{N}$ $\theta = 9.62^0$]

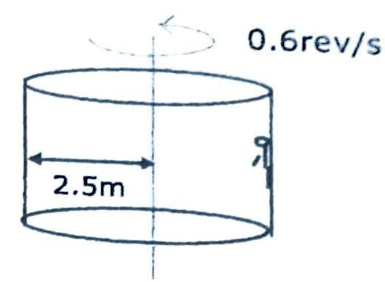
05*. A wheel of radius 25cm has eight spokes. It is mounted on a fixed axle and is rotating at a constant angular speed ω. You shoot a 20cm long arrow parallel to the axle through the wheel at a speed of 6m/s. The arrow and the spokes are supposed to be thin. Calculate the maximum value of ω (in rad/second and in rev/second) so that the arrow just goes through without hitting any of the spokes. Does it matter where between the axle and the rim of the wheel you aim? If so, what is the best location? [$\omega = 23.79 rad/\sec = 3.79 rev/\sec$]



06*. A train is travelling at 50 km/h on a curve, the radius of which is 500 m. If the distance between the rails is 1.5 m, find how much the outer rail must be raised above the inner, so that there may be no lateral thrust on the rails. [6 cm]

07*. A satellite orbits the earth in about 87 minutes if its orbital radius is 6500 km. Use these data to find the mass of the earth. Given $G = 6.67\times10^{-11}$ [$5.97\times10^{24}\,kg$]

08. A person is held stationary in a rotating drum against the wall by the static friction force exerted on him by the wall as shown. Find the required coefficient of static friction between the man and the surface of the drum to keep him from slipping downward. The radius of the drum is 2.5m, and it is rotating at 0.6rev/s. [$\mu = 0.28$]



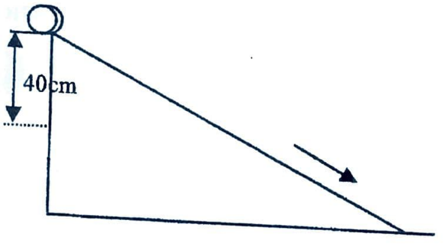
09*. A particle is to slide along the horizontal circular path on the inside of the funnel. The surface of the funnel is frictionless. How fast must the particle be moving, in terms of r and θ, if it is to execute this motion? [$v = \sqrt{\dfrac{rg}{\tan\theta}}$]

PHY1010 (2019/20)
Tutorial Sheet 7
Rotational Work, Energy, and Momentum

01*. A force of 2.2 N acts tangentially to the rim of a solid 52 kg disk that has a radius of 32 cm. (a) How long does it take to accelerate the disk (rotating about its usual axis) from rest to 210 rev/min? (b) Through how many revolutions does it rotate during this time? [83.1 s; 145 rev]

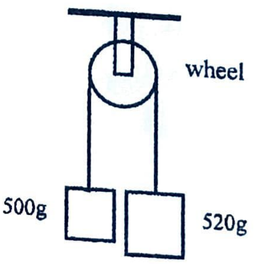
02*. A cylinder of radius 24 cm is mounted on a horizontal axis coincident with the cylinder's axis. A cord is wound on the cylinder, and a 100 g mass is hung from it. After being released, the mass drops 180 cm in 1.50 s. Find the moment of inertia of the cylinder and the tension in the cord while the mass is falling. [0.0295 kg.m^2; 0.820 N]

03*. A wheel of radius 6 cm and a radius of gyration of 5.0 cm starts from rest and rolls down a slope. (a) What is the linear speed when it reaches a point 40 cm vertically lower than its starting point? (b) How fast is it rotating (in rev/s) at that time? [2.15 m/s; 5.71 rev/s]

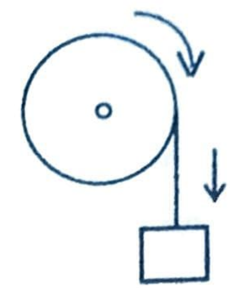


04*. A children's marry-go-round consisting of an essentially uniform 150 kg solid disk, is rotating at 15 rev/min about a vertical axis. The radius of the disk is 6 m. If an 80 kg person quickly sits down on the edge, what is its new angular speed? [7.26 rev/min]

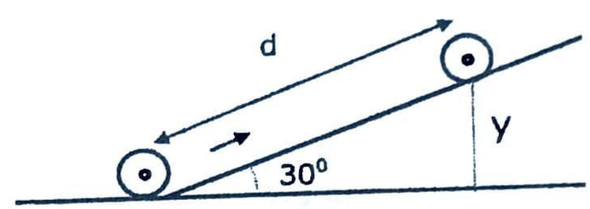
05*. The system is released from rest. (a) How fast is the frictionless wheel (I =0.0050 kg.m^2, r = 7.0 cm) turning after the 520 g mass has fallen 2.0 m?
(b) How long does it take the mass to drop this far?
[8.05 rad/s; 7.46 s]



06*. A wheel of radius 6cm is mounted so as to rotate about a horizontal axis through its centre. A string of negligible mass wrapped round its circumference carries a mass of 200 g attached to its free end. When allowed to fall, the mass descends through 100cm in 5 seconds. Calculate the angular acceleration of the wheel, its moment of inertia, and the tension in the cord. [1.33 rad/s^2, 0.0875 kg.m^2, 1.944 N]

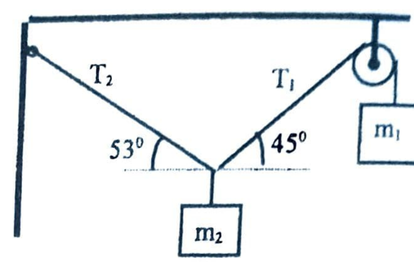


07. A disk is made to roll without slipping up an incline making 30^0 with the horizontal. If the speed at the bottom of the incline was 2 m/s, how high up the incline will the disk travel before rolling back down again. Neglect rolling friction. Use the method of conservation of energy. [0.612 m]

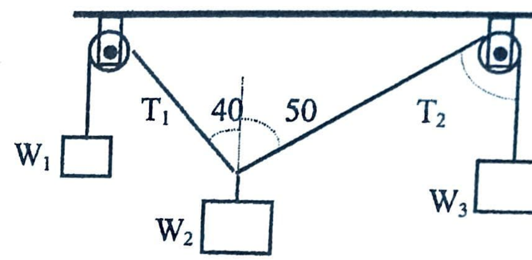


PHY1010 (2019/20)
Tutorial Sheet 8
Static Equilibrium

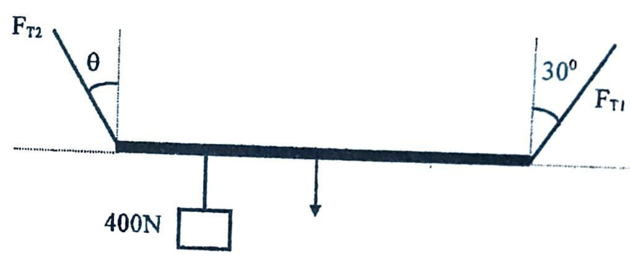
01. The system in the figure is at equilibrium when m_1 = 10 kg. Find the values of T_1, T_2, and m_2. Assume the pulley to be massless and frictionless so that it does not change the tension in the cord. [98 N, 115.5 N, 16.5 kg,]



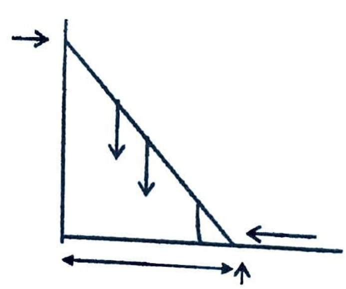
02*. For the equilibrium situation shown in the figure, find W_3 and W_2. Assume that W_1=800 N and that the pulleys are frictionless, so that they do not change the tensions in the cords. [665 N, 1044 N]



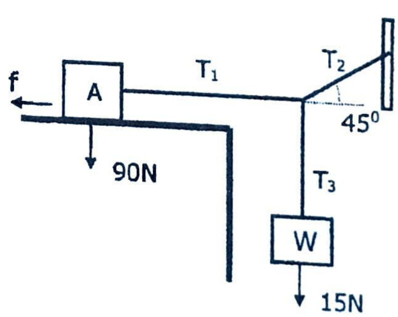
03**. The uniform 120 N board is supported by two ropes as shown. A 400 N weight is suspended one-quarter of the way from the left end. Find the angle θ made by the left rope and F_{T1}, F_{T2}. [14.4°, 184.8 N, 360 N]



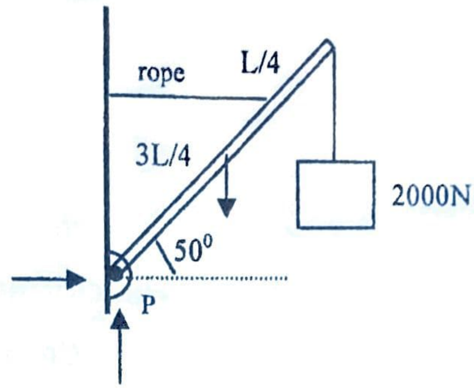
04*. A uniform ladder 5 m long weighing 200 N is leaning against a frictionless vertical wall with its base 3m from the wall. The coefficient of static friction between the bottom of the ladder and the ground is 0.45. How far, measured along the ladder, can a 600 N man climb before the ladder starts to slip? [3.16 m along the ladder]



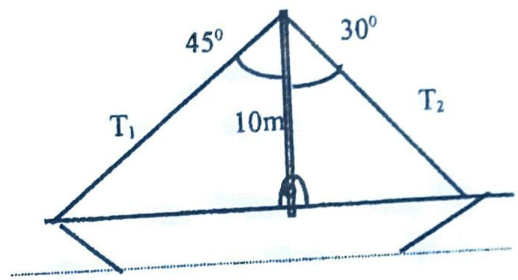
05*. Show that the static friction force between the block A and the surface can hold the system in equilibrium for the weight of block A given. Take $\mu_s = 0.30$ [T_1= 15 N, f =27 N]



06*. A uniform, 400N boom is supported as shown. Find the tension in the tie rope and the forces exerted on the boom by the pin at *P*. [2460 N, 2400 N,



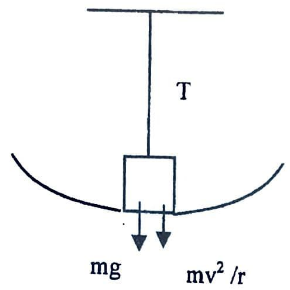
07. The mast of a sailboat is held by two steel cables attached as shown. The front cable has a tension of 5000N. What is the tension in the rear cable? What force does the foot of the mast exert on the sailboat? Neglect the weight of the mast. The foot of the mast is hinged (hence exerts no torque). [3536 N, 6830 N]



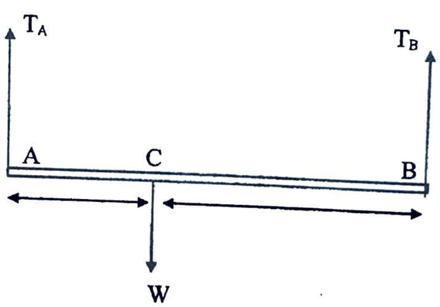
Tutorial Sheet 9. 2019/20
Mechanical Properties of Matter

1. A force of 20N is applied to the ends of a wire 4m long, and produces an extension of 0.24mm. If the diameter of the wire is 2mm, calculate the stress on the wire, its strain, and the value of the Young modulus. [6.37×10^6 N/m^2, 6×10^{-5}, $1.06\times10^{11}\ N/m^2$]

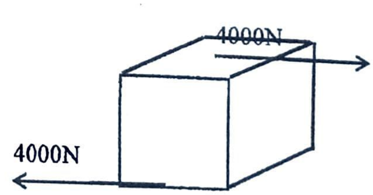
2. A 15 kg mass fastened to the end of a steel wire of un-stretched length 0.5 m is whirled in a vertical circle with an angular velocity of 2 rev/s at the bottom of the circle. The cross section of the wire is 0.02 cm^2. Calculate the elongation of the wire when the weight is at the lowest point of the path. Steel has Y.M.= 2.0×10^{11} Pa. [1.66mm]



3. A rod 1.05 m long is hanging from 2 wires *A* & *B*. A weight *W* is hanging from the rod by a wire. The cross-sectional area of wire *A* = 1mm^2, and that of wire *B* = 4mm^2.
Where, measured from *A*, should the wire holding *W* be hung so that there is: (a) equal stress in the two wires, (b) equal strain in the two wires? Given $Y_A = 2.4\times10^{11}$ Pa and $Y_B = 1.2\times10^{11}$ Pa.
[(a) $0.84m$ *from A* (b) $0.7m$ *from A*]



4. Two parallel and opposite forces, each of 4000 N, are applied tangentially to the upper and lower faces of a cubical metal block 25 cm on each side. Find the angle of shear, and the displacement of the upper surface relative to the lower surface. Shear modulus for the metal is 0.80×10^{11} Pa [$\phi\approx8\times10^{-7}$, 2.0×10^{-7} m]



5. A glass tube is bent into a U-shape and water is poured into the tube until it stands 15 cm high in each side. A 3 cm column of alcohol is slowly poured into one side; the two liquids do not mix. How far will the water column in the other side rise? Given, density of alcohol = 720 kg/m^3, and that of water = 1000 kg/m^3. [1.32 cm]

6. A copper wire *LM* is fused at one end, M, to an iron wire MN. The copper wire has length 0.900 m and cross-section 0.90×10^{-6} m^2. The iron wire has length 1.400 m and cross-section 1.30×10^{-6} m^2. The compound wire is stretched; its total length increases by 0.0100 m.

Calculate:

(a) the tension applied to the compound wire (b) the extension of each wire
(c) the ratio of the extensions of the two wires

[Y.M. of copper = 1.30×10^{11} Pa. Y.M. of iron = 2.10×10^{11} Pa.]

[F = 780N, $\Delta L_c = 6$mm, $\Delta L_i = 10 - 6 = 4$mm, Ratio $c : i = 1.5 : 1$]

7. A solid weighs 237.5 g in air and 12.5 g in a liquid in which it is wholly submerged. The density of the liquid is 900 kg/m^3.
Calculate (i) the density of the solid (ii) the density of another liquid in which the same solid would float with one-fifth of its volume exposed above the liquid surface.

[(i) $950 kg/m^3$ (ii) $1187.5 kg/m^3$]

8. Figure shows the essential parts of a hydraulic brake system. The area of the piston in the master cylinder is 6.4 cm^2, and that of the piston in the brake cylinder is 1.8 cm^2. The coefficient of friction between shoe and wheel drum is 0.5. If the wheel has a radius of 34 cm, determine the frictional torque about the axle when a force of 44 N is exerted on the brake pedal. [2.18 N-m]