THE COPPERBELT UNIVERSITY

PHYSICS DEPARTMENT

TEST 1 – AUGUST 2020

PH 110 – *INTRODUCTORY PHYSICS*

TIME: **2** HOURS MAX MARKS: **100**

ATTEMPT **ALL** QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS.

CLEARLY INDICATED YOUR STUDENT IDENTIFICATION NUMBER AND LECTURE GROUP ON THE FRONT COVER OF THE ANSWER BOOKLET

You may use the following information:

Acceleration due to gravity, $g = 9.8\ m/s^2$

Q1. (a) A car travels 1 km between two stops. It starts from rest and accelerates at 2.5 m/s^2 until it attains a velocity of 12.5 m/s. The car continues at this velocity for some time and decelerates at 3 m/s^2 until it stops. Calculate the total time for the journey. [**10 marks**]

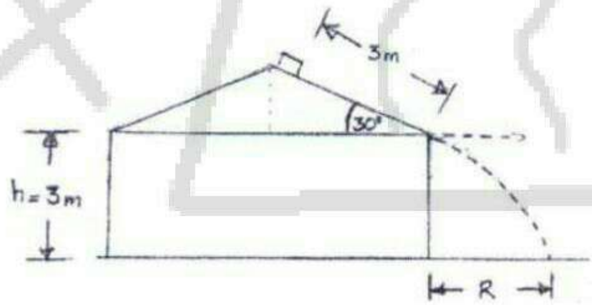
(b) A crate slides from rest and accelerates uniformly at 4.9 m/s^2 along a frictionless roof 3 m long which is inclined at an angle of 30^o to the horizontal as indicated in the Figure below. Determine:

(i) the velocity of the crate just after losing contact with the roof,

(ii) the velocity (magnitude and direction) of the crate just before it hits the ground,

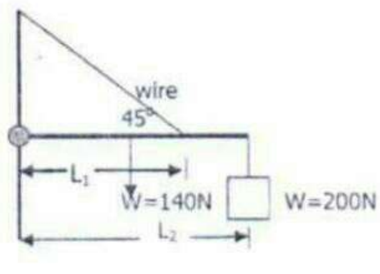
(iii) the time the crate takes to hit the ground after losing contact with the roof, and

(iv) the horizontal distance between the point directly below the roof and the landing Point (i.e. the range). [**15 marks**]



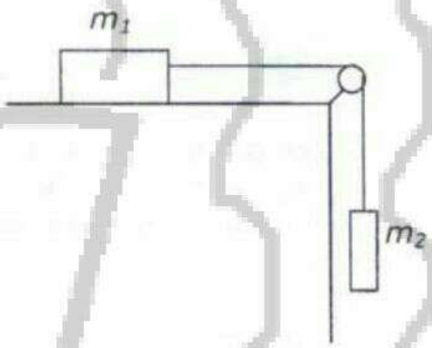
Q2. (a) A block of weight $W = 200$ N is supported by a uniform beam of weight 140 N as shown in the Figure below. If L_1 = 1.1 m and L_2 = 1.4 m, find the tension in the wire and the vertical and horizontal components of the force exerted by the hinge on the beam.

[**10 marks**]

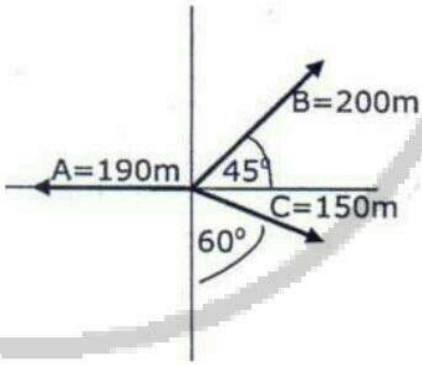


(b) (i) Give two conditions required for an object to be static equilibrium. **[4 marks]**

(ii) Two objects with masses $m_1 = 10$ kg and $m_2 = 5$ kg are connected by a light string that passes over a frictionless pulley as shown in the Figure below. If, when the system starts from rest, m_2 falls 1 m in 1.2 seconds, determine the coefficient of kinetic friction between m_1 and the table. **[11 marks]**



Q3. (a) The magnitude and directions of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ are as shown in the Figure below. Find the magnitude and direction of a fourth vector $\vec{D}$ which when added to these three vectors will give a resultant of zero. **[12 marks]**



(b) Two people pull as hard as they can on ropes attached to a 200 kg object. If they pull in the same direction the object accelerates at 1.52 m/s^2 to the right. If they pull in opposite directions the object accelerates at 0.518 m/s^2 to the left. Ignoring any other forces, what is the force exerted by each person on the object? **[9 marks]**

(c) If $\vec{A}$ and $\vec{B}$ are nonzero vectors, is it possible for $\vec{A} \cdot \vec{B}$ and $\vec{A} \times \vec{B}$ both to be zero? Explain.

[4 marks]

Q4. (a) An acre-foot is the volume of water that would cover 1 acre of flat land to a depth of 1 foot. How many gallons are in 1 acre-foot? **[5 marks]**

(b) You are using water to dilute small amounts of chemicals in the laboratory, drop by drop. How many drops of water are in a 1.0-L bottle? **[9 marks]**

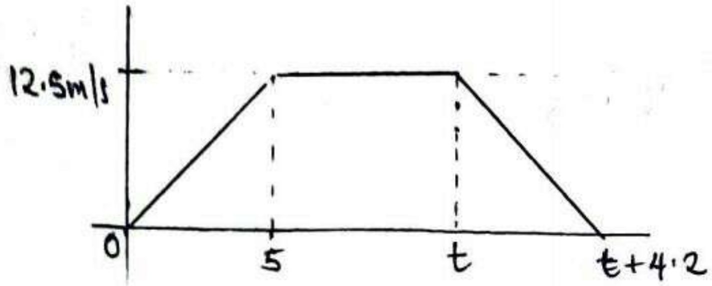
(c) (i) State the principle of homogeneity. **[2 marks]**

(ii) The wavelength λ associated with a moving particle depends on its mass m, velocity v and Planck's constant h which is measured in kgm^2s^{-1}. Show dimensionally, that

$$\lambda \propto \frac{h}{mv}$$

[9 marks]

QUESTION 1 a.



$D_t = 1\,km$

$V_0 = 0\,m/s$

$V = 12.5\,m/s$

$a_1 = 2.5\,m/s^2$

$a_2 = 3\,m/s^2$

$V = V_0 + at$

$12.5 = 0 + 2.5t$

$\frac{2.5t}{2.5} = \frac{12.5}{2.5}$

$t = 5\ sec$

$V = V_0 + at$

$0 = 12.5 + (-3t)$

$\frac{3t}{3} = \frac{12.5}{3}$

$t = 4.2$ seconds

to find the total distance we just find the are of the trapezium

$A = \frac{1}{2}(a+b)h$ where $a = t - 5$

$b = t + 4.2$

$h = 12.5$

$D = \frac{1}{2}(a+b)h$

$D = 1\,Km$ or $1000\,m$

$1000 = \frac{1}{2}\left[(t-5)+(t+4.2)\right]12.5$

$1000 = 0.5(2t - 0.8)12.5$

$1000 = (2t - 0.8)6.25$

$1000 = 12.5t - 5$

$\frac{1000 + 5}{12.5} = \frac{12.5t}{12.5}$

$t = 80.4$ seconds

$\therefore$ total time taken is $t + 4.2 = 80.4 + 4.2$

$= \underline{\underline{84.6 \text{ seconds}}}$

QUESTION 1 b

i) $a = 4.9\ m/s^2$

$s = 3m$

$v = ?$

$v_0 = 0\ m/s$

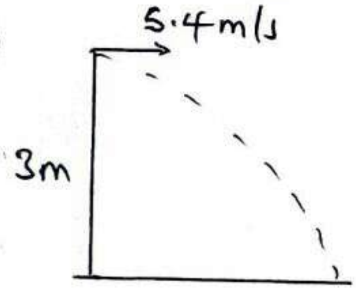
$$v^2 = v_0^2 + 2as$$

$$v^2 = 0^2 + 2(4.9)(3)$$

$$\sqrt{v^2} = \sqrt{29.4}$$

$$v = \underline{\underline{5.4\ m/s}}$$

ii)



The velocity is the x is the Same throughout the motion.

to find the ~~dis~~ velocity in the y we use equation

$v_{y_1} = 0$

$$v^2 = v_0^2 + 2as$$

$$v^2 = v_0^2 + 2gH$$

$$v^2 = (0)^2 + 2(9.8)(3)$$

$$\sqrt{v^2} = \sqrt{58.8}$$

$$v = 7.7\ m/s$$

$$\therefore \text{magnitude} = \sqrt{(v_x)^2 + (v_y)^2}$$

$$= \sqrt{5.4^2 + 7.7^2}$$

$$= \underline{\underline{9.4\ m/s}}$$

$$\tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{7.7}{5.4}\right) = 54.95° = 55°$$

$\therefore$ the velocity is 9.4m/s and an angle of 55° below the positive x-axis.

Question 1 b

iii) $y = V_o t + \frac{1}{2} a t^2$

$y = V_o t + \frac{1}{2} g t^2$, we consider the vertical motion

$3 = 0(t) + \frac{1}{2} g t^2$

$3 = \frac{1}{2} \times 9.8 \times t^2$

$\frac{3}{4.9} = \frac{4.9 t^2}{4.9}$

$\sqrt{t^2} = \sqrt{0.6122}$

$t = \underline{0.78 \text{ seconds}}$

iv) we conside the motion in the horizontal

$x = V_o t + \frac{1}{2} a t^2$ $\quad a = 0 \text{ m/s}$

$x = V_o t + \frac{1}{2}(0) t^2$

$x = 5.4 \times 0.78$

$x = \underline{4.212 \text{ m}}$

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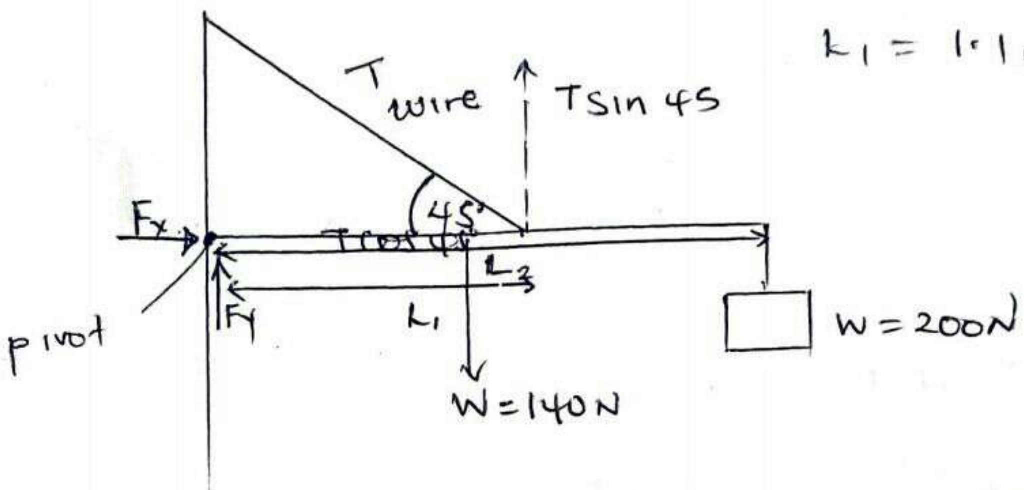
Question 2 a.

$L_2 = 1.4m$

$L_1 = 1.1m$



We resolve the T into its components

$\Sigma F_y = 0$

$T\sin 45 + F_y - W_{beam} - W_{block} = 0$

$T\sin 45° + F_y - 140 - 200 = 0$

$T\sin 45° + F_y - 340 = 0$

$T\sin 45° + F_y = 340$ ---- (i)

$\Sigma F_x = 0$

$F_x - T\cos 45 = 0$

$F_x = T\cos 45$ ---- (ii)

We find the torque $\Sigma \tau = 0$

$-(200 \times 1.4) - (140 \times 0.7) + (1.1 \times T\sin 45) = 0$

$-280 - 98 + 1.1T\sin 45 = 0$

$$\frac{1.1\,T\sin 45}{1.1\sin 45} = \frac{378}{1.1\sin 45}$$

$T = 485.98$

$T = 486N$

Tension = 486N

QUESTION 29.

$F_x = T\cos 45$

$F_x = 486\cos 45$

$F_x = \underline{\underline{343.6N}}$

$T\sin 45 + F_y = 340$

$F_y = 340 - T\sin 45$

$F_y = 340 - 486\sin 45$

$F_y = 340 - 343.65$

$F_y = -3.65$

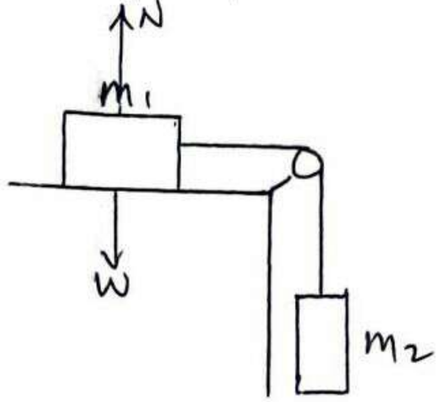
$\therefore F_y = \underline{\underline{3.65N}}$ and it should point downwards

QUESTION 2b

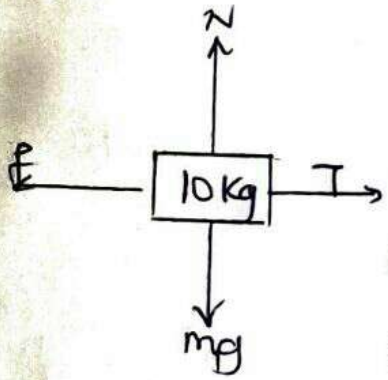
i) - The sum of clockwise and anticlockwise torque must be equal to zero

- The sum of the forces in the x-component ~~and~~ and in the y-component must be equal to zero.

(ii)



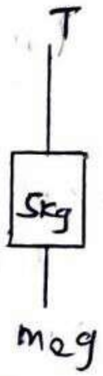
, we draw the free body diagrams for each mass



$N = mg$

$f = \mu N$

$f = \mu mg$



$\Sigma F_x = m_1 a$

$T - f = m_1 a$

$T - \mu mg = m_1 a$

$T - 10\mu g = 10a$ ---(i)

$\Sigma F_y = m_2 a$

$m_2 g - T = m_2 a$

$5g - T = 5a$ --- ii

Solving the two equations simultaneously

$$\begin{cases} T - 10\mu g = 10a \\ -T + 5g = 5a \end{cases} +$$

$$5g - 10\mu g = 15a$$

$$\frac{15a - 5g}{-10g} = \frac{-10\mu g}{-10g}$$

$$\mu = \frac{-15a + 5g}{+10g}, \quad \text{or } \mu = \frac{-15a + 5g}{10g}$$

QUESTION 26

ii) $S = 1m$

$t = 1.2$ seconds

$V_0 = 0$ m/s

$x = V_0 t + \frac{1}{2}at^2$

$1 = 0(t) + \frac{1}{2}(a)(1.2)^2$

$\frac{1}{0.72} = \frac{0.\cancel{72}a}{0.\cancel{72}}$

$a = 1.4$ m/s

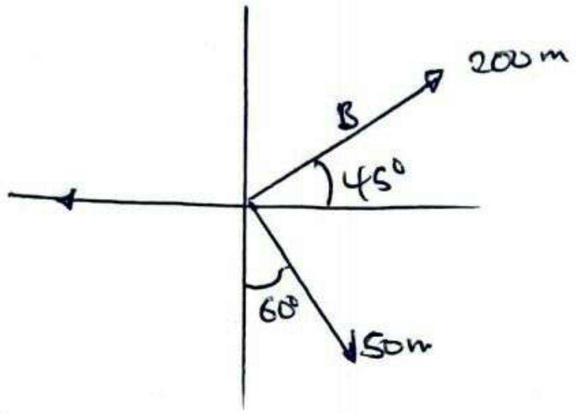
$\therefore \mu_k = \frac{-15a + 5g}{10g}$

$\mu_k = \frac{-15(1.4) + 5(9.8)}{10(9.8)}$

$\mu_k = \frac{-21 + 49}{98} = 0.286$

$\mu_k = \underline{\underline{0.3}}$

(c) QUESTION 3a



Resolving the vectors and angles measured from the positive x-axis.

Vector	x-component	y-component
A = 190m	190cos180 = 190m	190 sin180 = 0m
B = 200 m	200cos45 = 141.4m	200 sin45 = 141.4m
C = 150m	150 cos330 = 129.9m	150m sin 330 = -75m
D	$\Sigma F_x = 81.3m$	$\Sigma F_y = 66.4$

vector D = (x component) + (y component)

$D = X_D + Y_D$

$D = -(81.3i + 66_j)$

$D = -81.3i - 66.4j$

magnitude of D $= \sqrt{(81.3)^2 + (66.4)^2}$

$= \underline{104.97m}$

Direction $\tan^{-1}\left(\frac{66.4}{81.3}\right) = 39.24° = \alpha$

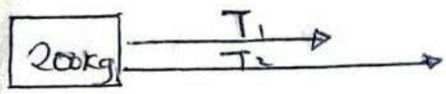
the angle is 180 + 39.24

$\theta = \underline{219.24°}$

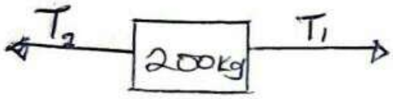
∴ the magnitude is 104.97m at an angle of 219.24 from the positive x-axis

QUESTION 8b

$a = 1.52 m/s^2$



$a = 0.518 m/s^2$



$\Sigma F_x = ma$

$T_1 + T_2 = 200 \times 1.52$

$T_1 + T_2 = 304$ --- (i)

$\Sigma F_x = ma$

$T_2 - T_1 = ma$

$T_2 - T_1 = 200 \times 0.518$

$T_2 - T_1 = 103.6$ --- (ii)

Solving simultaneously

$$+\begin{cases} T_1 + T_2 = 304 \\ -T_1 + T_2 = 103.6 \end{cases} +$$

$$\frac{2T_2}{2} = \frac{407.6}{2}$$

$$T_2 = \underline{\underline{203.8}}\ N$$

$T_1 + T_2 = 304$

$T_1 + 203.8 = 304$

$T_1 = 304 - 203.8$

$$T_1 = \underline{\underline{100.2\ N}}$$

QUESTION 3c.

It is possible because, dot product of any two orthogonal vectors is zero and the cross product of any two linear product is zero.

QUESTION 4 a:

1 acre = 43560 ft^2

1 ft^3 = 7.48 gallons.

Using dimensional analysis

$$\frac{7.48 \text{ gallon}}{1 \text{ ft}^2} \times \frac{43560 \text{ ft}^2}{1}$$

$$= \underline{\underline{325,828.8 \text{ gallons}}}$$

QUESTION 4 b.

1 L $\rightarrow$ 1000 cm^3

1 drop $\rightarrow$ 50 mm^3

Converting 50 mm^3 to cm^3

$(1 \text{ cm})^3 \rightarrow (10 \text{ mm})^3$

1 cm^3 $\rightarrow$ 1000 mm^3

$x \rightarrow 50 \text{ mm}^3$

$$\frac{\cancel{1000}x}{\cancel{1000}} = \frac{50 \text{ cm}^3}{1000}$$

$x = 0.05 \text{ cm}^3$

1 drop $\rightarrow$ 0.05 cm^3

$x \rightarrow 1000 \text{ cm}^3$

$$\frac{0.\cancel{05}x}{0.\cancel{05}} = \frac{1000}{0.05}$$

$$x = \underline{\underline{20\,000 \text{ drops}}}$$

QUESTION 4 C

i) The dimensions of all terms on the two sides of the equation are the same.

(ii) $\lambda \propto m \propto v \propto h$

$\lambda = k m^x v^y h^z$

$L = M^x \cdot [LT^{-1}]^y [ML^2T^{-1}]^z$

$L = M^x \cdot L^y \cdot T^{-y} \cdot M^z L^{2z} T^{-z}$

$L = M^x \cdot M^z \cdot L^y \cdot L^{2z} \cdot T^{-y} \cdot T^{-z}$

$L = M^{x+z} \cdot L^{y+2z} \cdot T^{-y-z}$

$M^0 L^1 T^0 = M^{x+z} \cdot L^{y+2z} \cdot T^{-y-z}$

$x + z = 0$ - (i) $\quad 1 = y + 2z$ - (ii) $\quad 0 = -y - z$ -- (iii)

Solving (ii) and (iii) simultaneously $\quad y + z = 0$

$-\begin{Bmatrix} y + 2z = 1 \\ y + z = 0 \end{Bmatrix} \quad - \quad y + z = 0$

$z = 1 \qquad y + 1 = 0$

$y = -1$

$x + z = 0$

$x + 1 = 0$

$x = -1$

$\lambda = k m^x v^y h^z$

$\lambda = k m^{-1} v^{-1} h^1$

$\lambda = \frac{k h}{mv}$

$\lambda \propto \frac{h}{mv}$ hence shown.