Roll No.

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 1

Sem AY: Odd Sem 2019-20
Course Code: MEC 325
Course Name: ENGINEERING DYNAMICS
Program & Sem: B.Tech. & V DE

Date: 27.09.2019
Time: 2:30PM to 3:30PM
Max Marks: 40
Weightage: 20%

Instructions:

(i) Use of non-programmable scientific calculators is allowed.

Part A [Memory Recall Questions]

Answer all the Question. Each Question carries two marks. **(6Qx2M=12M)**

1. A body of negligible mass is called as ___________

   (a) Rigid body (b) Particle (c) System of particles (d) Resistant body

2. If **P** is the resultant force acting on the body, **m** is the mass of the body and **a** is the acceleration of the body, then according to Newton's second law of motion,

   (a) P + m.a = 0 (b) P x m.a = 0 (c) P/m.a = 0 (d) P = m.a

3. The equation of motion $v^2 = u^2 + 2.a.s$ is valid in case of

   (a) Variable acceleration (b) Constant acceleration

   (b) Zero acceleration (d) None of these.

4. The velocity vector of a missile travelling through air is ____________ to its trajectory at all points. (Tangential/Normal)

5. The tangential component of acceleration for a particle having curvilinear motion is _____________ $(\rho\beta^{\circ\circ} / \rho\beta^{\circ 2})$ (where ρ is the radius of curvature of the curvilinear path of motion and β is the angular displacement of the particle along the curvilinear path

6. The correct relation among the relations given below is

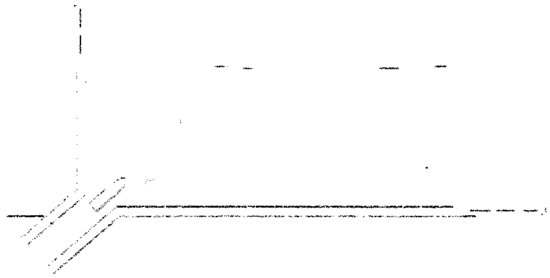
   (a) a.ds = v.dv (b) a.dv = s.ds (c) v.ds = a.dv (d) v.da = s.dv

(Q.NO. 1 to 6) (C.O.NO.1) [Knowledge]

Part B [Thought Provoking Questions]

Answer both the Questions. Each Question carries six marks. **(2Qx6M=12M)**

7. A projectile is ejected into an experimental fluid at time The initial speed is v_o and the angle to the horizontal is θ. The drag on the projectile results in an acceleration term a_D= -kv, where *k* is a constant and **v** is the velocity of the projectile. Determine the *x*- and *y* components of the velocity. Include the effects of gravitational acceler



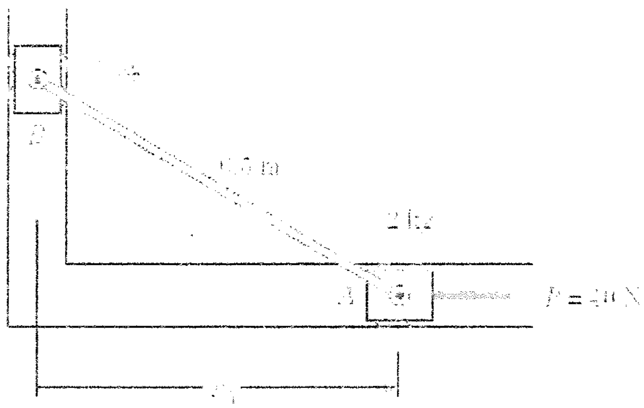
8. Work is the dot (scalar) product of Force and Displacement of the body. With the help of this information, derive the expression for work associated with the weight of the body and the gravitational potential energy under constant gravitational acceleration.

(C.O.NO.1)[Comprehension]

Part C [Problem Solving Questions]

Answer the Question. The Question carries sixteen marks. **(1Qx16M=16M)**

9. The sliders *A* and *B* are connected by a light rigid bar of length l=0.5m and move with negligible friction in the slots, both of which lie in a horizontal plane. For the position where x_a=0.4m, the velocity of *A* is v_a=0.9m/s to the right. Determine the acceleration of each slider and the force in the bar at this instant.



(C.O.NO.2)[Application]

SCHOOL OF ENGINEERING

Semester: 5th Sem.

Course Code: MEC 325

Course Name: EngineeringDynamics

Date: 27/09/2019

Time: 2:30 pm – 3:30 pm

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	A	
1.	CO1	Module-1 Kinematics of particles and Module-2 Kinetics of particles	12			12
2.	CO1	Module-1 Kinetics of Particles		6		6
3.	CO2	Module-2 Kinetics of Particles		6		6
4.	CO3	Module-2 Kinetics of Particles			16	16
	Total Marks		12	12	16	40

K =Knowledge Level   C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60% Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

[I hereby certify that All the questions are set as per the above guide lines. Mr. Pramod Pandey]

Reviewers' Comments

SCHOOL OF ENGINEERING

SOLUTION

Date: 27/09/2019

Semester: 5th Sem.

Time: 2:30 pm – 3:30 pm

Course Code: MEC 325

Max Marks: 40

Course Name: EngineeringDynamics

Weightage: 20%

Part A (1Q x 12M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1.	(1) (b) Particle (2) (d) P = m.a (3) (c) Constant acceleration (4) Tangential (5) $\rho\ddot{\beta}$ (6) (a) a.ds = v.dv	2 marks for each correct answer 12 marks	12 minutes

Part B (2Q x 6M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
2.		2 marks for diagram + 2 marks for	12 minutes

SOLUTION Let's sketch the "acceleration diagram" of the projectile as shown

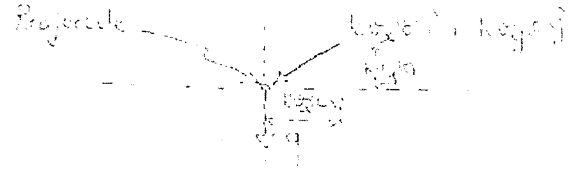


Figure: Acceleration diagram of the projectile

From the acceleration diagram we know that the acceleration $\vec{a}$ of the projectile is $\vec{a}(t) = (-k v_x(t))\hat{i} + (-g - k v_y(t))\hat{j}$

$$a_x = \frac{dv_x}{dt} \qquad a_y = \frac{dv_y}{dt}$$

We want to find v_x and v_y so we can integrate $\frac{dv_x}{dt} = -k v_x$ and $\frac{dv_y}{dt} = -g - k v_y$.

Let's do this one after another

We have $\frac{dv_x}{dt} = -k v_x$,

$$\frac{dv_x}{v_x} = -k\,dt, \quad v_x(0) = v_0\cos\theta$$

$$\int_{v_0\cos\theta}^{v_x} \frac{dv_x}{v_x} = -k \int_0^t dt,$$

$$(\ln v_x)\Big|_{v_0\cos\theta}^{v_x} = -k(t)\Big|_0^t,$$

$$\ln v_x - \ln v_0\cos\theta = -k(t-0),$$

$$\ln\left(\frac{v_x}{v_0\cos\theta}\right) = -kt,$$

$$\frac{v_x}{v_0\cos\theta} = e^{-kt},$$

$$\boxed{v_x = v_0\cos\theta\, e^{-kt}}$$

Let's now find $v_y(t)$.

formulae or equations + 2 marks for correct answers

3.

We have $\frac{dv_y}{dt} = -g - kv_y$.

$$\frac{dv_y}{g + kv_y} = -dt$$

$$\int_{v_0 \sin\theta}^{v_y} \frac{dv_y}{g + kv_y} = -\int_0^t dt$$

$$\frac{1}{k}\left[\ln(g + kv_y)\right]_{v_0 \sin\theta}^{v_y} = -t$$

$$\frac{1}{k}\left[\ln(g + kv_y) - \ln(g + kv_0 \sin\theta)\right] = -t$$

$$\ln\left(\frac{g + kv_y}{g + kv_0 \sin\theta}\right) = -kt$$

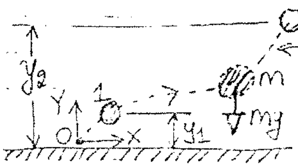
$$\frac{g + kv_y}{g + kv_0 \sin\theta} = e^{-kt}$$

$$g + kv_y = (g + kv_0 \sin\theta)e^{-kt}$$

$$\boxed{v_y = \frac{1}{k}(g + kv_0 \sin\theta)e^{-kt} - \frac{g}{k}} \quad (v_y(t))$$

WORK ASSOCIATED WITH WEIGHT WHEN g = CONSTANT

This case makes sense when the variation in altitude is "small."



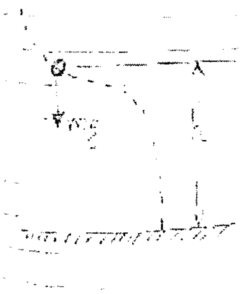
— path of the particle of mass m. (Curvilinear path, to be general)

The work done by the force due to gravity mg on the particle is:

$$U_{1-2} = \int_1^2 \vec{F} \cdot d\vec{r} = \int_{y_1}^{y_2} (-mg\hat{j}) \cdot (dx\hat{i} + dy\hat{j}) = \int_{y_1}^{y_2} -mg\,dy$$

$$= -mg\int_{y_1}^{y_2} dy = -mg\,(y)\Big|_{y_1}^{y_2} = -mg\,(y_2 - y_1). \quad \square$$

GRAVITATIONAL POTENTIAL ENERGY WHEN g = CONSTANT



The work done by the force of gravitational attraction in moving the particle from h to the ground is [illegible]. Gravitational potential energy is defined as the work done in elevating the particle from the ground to h. Therefore,

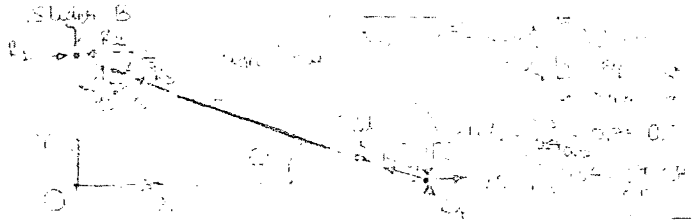
$V_g = mgh.$

In general, $V_g = mg(h_2 - h_1)$.

1 mark each for diagrams + 3 marks for derivation + 1 Mark each for correct expressions = 6M

12 minutes

Part C (Q x M = Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
4.	Solution to the problem [illegible] [illegible] Let's [illegible] we have the following: [illegible] [illegible] means that forces due to gravity [illegible] [illegible] Solution: [illegible] body diagrams and write out [illegible] of motion [illegible] Slider B  We must write the equations of motion for the two sliders and the rod [illegible] Since the rod [illegible] [illegible] These can be [illegible] as [illegible] — (1) [illegible] — (2) [illegible] along the [illegible] [illegible] — (3) [illegible] — (4) [illegible] Let's examine equations [illegible] and [illegible] contain [illegible] unknowns [illegible] [illegible] problem. So let us try the two equations [illegible] and (4) to solve the problem.	4 marks for F.B.D. + 4 Marks for correct equations used + 4 marks for calculations + 4 marks for correct answers	24 minutes

[illegible]
[illegible] T, $\ddot{x}_A$ and $\ddot{x}_B$.
WE MUST [illegible] ANOTHER EQUATION [illegible]
[illegible] CONSTRAINT [illegible] for the [illegible].

The configuration of the system is always [illegible] [illegible]

[illegible]

[illegible]
[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] (5)

Equation (5) is that "another" equation that should be solved simultaneously with equations (1) and (4) for T, $\ddot{x}_A$ and $\ddot{x}_B$.

Equations (1), (4) and (5) [illegible]

[illegible]

From (5): $\ddot{x}_A = \frac{1}{0.4}$ [illegible]

From (1), (4) and (5):

[illegible]

[illegible]

[illegible]

Hence (1) and (5) [illegible]
from (5) and (1):
$\ddot{x}_A =$ [illegible]
Therefore, the [illegible]

a) the force in the [illegible]

b) the acceleration of block A is [illegible] and,

c) the acceleration of block B is [illegible] m/s^2.

[illegible]
[illegible] acceleration [illegible]

Roll No.													

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 2

Sem & AY: Odd Sem 2019-20 | **Date**: 16.11.2019

Course Code: MEC 325 | **Time**: 2:30 PM to 3:30 PM

Course Name: ENGINEERING DYNAMICS | **Max Marks**: 40

Program & Sem: B.Tech. (MEC) & V (DE) | **Weightage**: 20%

Instructions:

(i) ***Use of non-programmable scientific calculators is allowed.***

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries four marks. (3Qx4M=12M)

1. For a rigid body motion, prove that the relative velocity $v_{A/B} = r\theta° e_\theta$, where r is the distance between points A and B on the rigid body, e_θ is the unit vector in θ direction and $\theta°$ is the angular velocity of the rigid body.

(C.O.NO.2) [Knowledge]

2. The radial component of acceleration vector of a rigid body is given by $a_r = \omega \times v$, where ω is the angular velocity and **v** is the velocity vector. If $\omega = 8$ ***rad/s*** in counterclockwise direction and $v = -0.54\, I - 0.355\, j$, determine a_r.

(C.O.NO.2) [Knowledge]

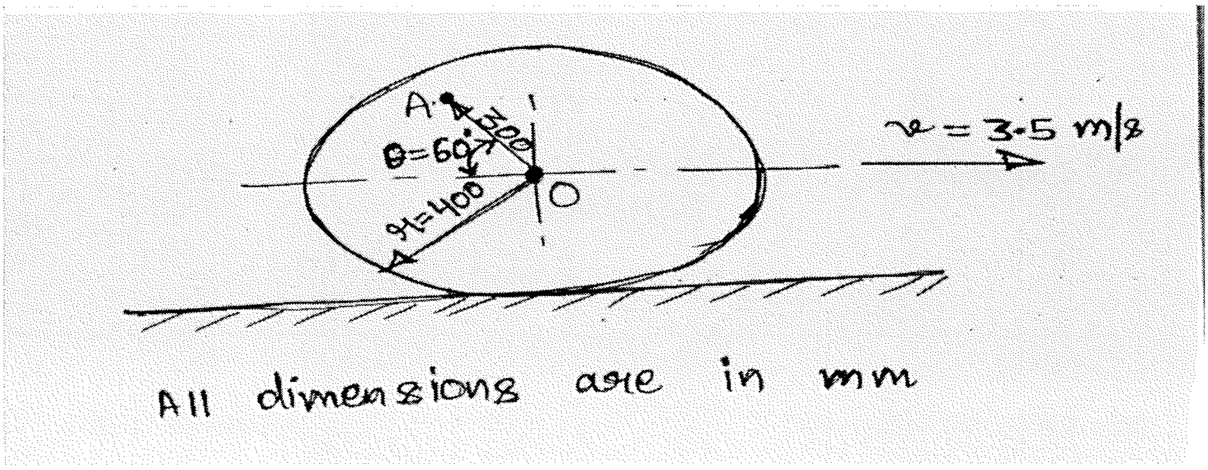
3. "All the lines in a rigid body have same angular velocities and angular accelerations." Prove this statement.

(C.O.NO.2) [Knowledge]

Part B [Thought Provoking Questions]

Answer both the Questions. Each Question carries six marks. (2Qx6M=12M)

4. The wheel of radius $r = 400$ ***mm*** rolls to the right without slipping and has a velocity $v_0 = 3.5$ ***m/s*** of its center O. Calculate the velocity of point A on the wheel for the instant represented.



(C.O.NO.2) [Comprehension]

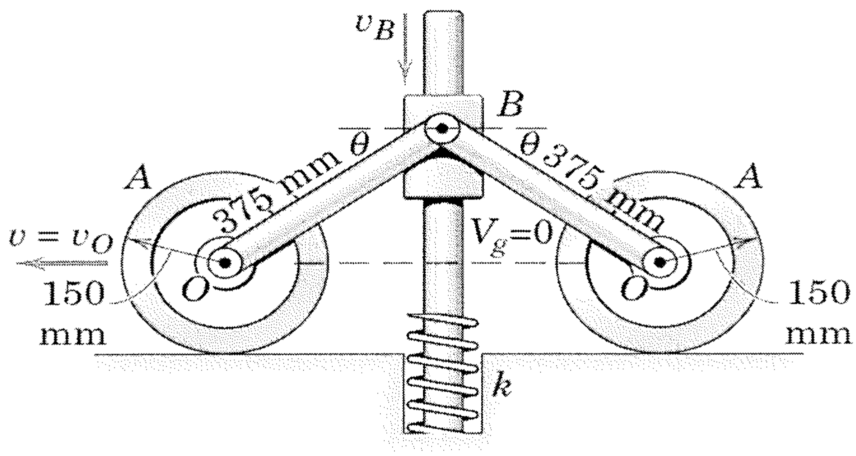
5. Prove that the relative acceleration for a rigid body motion is given by $\mathbf{a}_{A/B} = -\mathbf{r}\boldsymbol{\theta}^{\circ 2}\, \mathbf{e}_r + \mathbf{r}\ddot{\boldsymbol{\theta}}\, \mathbf{e}_\theta$, where r is the distance between points A and B, $\boldsymbol{\theta}^{\circ}$ is the angular velocity, $\ddot{\boldsymbol{\theta}}$ is the angular acceleration, $\boldsymbol{e}_r$ is the unit vector in radial direction and $\boldsymbol{e}_\theta$ is the unit vector in $\dot{\boldsymbol{\theta}}$ direction.

(C.O.NO.2) [Comprehension]

Part C [Problem Solving Questions]

Answer the Question. The Question carries sixteen marks. (1Qx16M=16M)

6. In the mechanism shown, each of the two wheels has a mass of ***30 kg*** and a centroidal radius of gyration of ***100 mm***. Each link *OB* has a mass of ***10 kg*** and may be treated as a slender bar. The ***7-kg*** collar at ***B*** slides on the fixed vertical shaft with negligible friction. The spring has a stiffness ***k = 30 kN/m*** and is contacted by the bottom of the collar when the links reach the horizontal position. If the collar is released from rest at the position ***θ = 45°*** and if friction is sufficient to prevent the wheels from slipping, determine the velocity $\boldsymbol{v_B}$ of the collar as it first strikes the spring.



(C.O.N.O.3) [Application]

SCHOOL OF ENGINEERING

Semester: 5^{th} Sem.

Course Code: MEC 325

Course Name: EngineeringDynamics

Date: 16/11/2019

Time: 2:30 pm – 3:30 pm

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
				K			C			A		
1.	CO1	Module-1 Kinematics of particles and Module-2 Kinetics of particles		12								12
2.	CO1	Module-1 Kinetics of Particles					6					6
3.	CO2	Module-2 Kinetics of Particles					6					6
4.	CO3	Module-2 Kinetics of Particles								16		16
	Total Marks			12			12			16		40

K =Knowledge Level   C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60% Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

SCHOOL OF ENGINEERING

SOLUTION

Semester: 5th Sem.

Course Code: MEC 325

Course Name: EngineeringDynamics

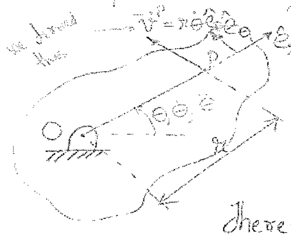
Date: 16/11/2019

Time: 2:30 pm – 3:30 pm

Max Marks: 40

Weightage: 20%

Part A (3Q x 4M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1.	Let's obtain vector relations for the velocity and acceleration of a point in a rigid body rotating about a fixed point in itself.  We want a vector relation for $\vec{v}^P$. We observe that $\vec{\omega} \times \vec{r}^P = \begin{vmatrix} \hat{e}_r & \hat{e}_\theta & \hat{k} \\ 0 & 0 & \dot{\theta} \\ r & 0 & 0 \end{vmatrix}$ $= 0\,\hat{e}_r - \hat{e}_\theta(-r\dot{\theta}) + \hat{k}(0)$ $= r\dot{\theta}\hat{e}_\theta$. Therefore, $\vec{v}^P = \vec{\omega} \times \vec{r}^P$. ▨ Next class: Vector relation for $\vec{a}^P$.	Calculations = 2M Correct answer = 2M	5 min.
2.	The acceleration of A along $\hat{e}_\theta$ is given by $\bar{a}_\theta = \bar{\alpha} \times \bar{r} =$ [illegible] -0.54 -0.355 $= \hat{i}(0-(8)(-0.355)) - \hat{j}(0-(8)(0.54))$ $+ 0\hat{k}$ $= 2.84\hat{i} - 4.32\hat{j}$	Procedure = 2M Correct relation = 2M	5 min.

3.	The rotation of a rigid body is described by its angular motion. Figure 5/2 shows a rigid body which is rotating as it undergoes plane motion in the plane of the figure. The angular positions of any two lines 1 and 2 attached to the body are specified by θ_1 and θ_2 measured from any convenient fixed reference direction. Because the angle β is invariant, the relation $\theta_2 = \theta_1 + \beta$ upon differentiation with respect to time gives $\dot{\theta}_2 = \dot{\theta}_1$ and $\ddot{\theta}_2 = \ddot{\theta}_1$ or, during a finite interval, $\Delta\theta_2 = \Delta\theta_1$. Thus, *all lines on a rigid body in its plane of motion have the same angular displacement, the same angular velocity, and the same angular acceleration.*  Figure 5/2	Diagram = 2M Procedure = 2M	5 min.

Part B (2Q x 6M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
4.	*Solution II (Vector).* We will now use Eq. 5/6 and write $\mathbf{v}_A = \mathbf{v}_O + \mathbf{v}_{A/O} = \mathbf{v}_O + \boldsymbol{\omega} \times \mathbf{r}_0$ where $\boldsymbol{\omega} = -10\mathbf{k}$ rad/s $\mathbf{r}_0 = 0.2(-\mathbf{i}\cos 30^\circ + \mathbf{j}\sin 30^\circ) = -0.1732\mathbf{i} + 0.1\mathbf{j}$ m $\mathbf{v}_O = 3\mathbf{i}$ m/s We now solve the vector equation $\mathbf{v}_A = 3\mathbf{i} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & -10 \\ -0.1732 & 0.1 & 0 \end{vmatrix} = 3\mathbf{i} + 1.732\mathbf{j} + \mathbf{i}$ $= 4\mathbf{i} + 1.732\mathbf{j}$ m/s *Ans.* The magnitude $v_A = \sqrt{4^2 + (1.732)^2} = \sqrt{19} = 4.36$ m/s and direction agree with the previous solution.	Calculations = 4M Correct answer = 2M	10 min.
5.	We found the vector relation for velocity $\vec{v} = \vec{\omega} \times \vec{r}$. Let's give a vect. relation for $\vec{\alpha}$. Then use these relations to solve a pr[illegible] RECAP. $\vec{r}^{P} = r\hat{e}_r$, $\vec{v} = \vec{\omega} \times \vec{r} = r\dot{\theta}\hat{e}_\theta$ We know. $\vec{a} = -r\dot{\theta}^2\hat{e}_r + r\ddot{\theta}\hat{e}_\theta$. CHECK THIS OUT, $\vec{\alpha} \times \vec{r} = \begin{vmatrix} \hat{e}_r & \hat{e}_\theta & \hat{k} \\ 0 & 0 & \ddot{\theta} \\ r & 0 & 0 \end{vmatrix}$ $= 0\hat{e}_r - \hat{e}_\theta(0 - r\ddot{\theta}) + 0\hat{k}$ $= r\ddot{\theta}\hat{e}_\theta$ 	Diagram = 2M Procedure = 4M	10 min.

Part C (1Q x 16M = 16 Marks)

<table>
<tr><th>Q No</th><th>Solution</th><th>Scheme of Marking</th><th>Max. Time required for each Question</th></tr>
<tr><td>6.</td><td>WORK AND ENERGY
Plane Kinetics of Rigid Bodies –
We will use the work-energy relation
$T_1 + V_1 + U'_{1-2} = T_2 + V_2$
derived before Test 1 for particles and systems of particles. The determination of kinetic energy for rigid bodies is performed using the relation:
$T = \frac{1}{2} m v_G^2 + \frac{1}{2} I_G \omega^2$.
SOLUTION: (a) Let's consider the motion from $\theta = 45^\circ$ to $\theta = 0^\circ$. Since the mechanism starts at rest we have:
$T_1 = 0$.
When $\theta = 0^\circ$ we have:
$T_2 = (T_{wheels})_2 + (T_{links})_2 + (T_{collar})_2$.
Also $(T_{wheels})_2 = 0$ because the wheels have reached their furthest locations and will "return" as θ increases in ~~the opposite~~ any direction. Let the velocity of the collar at $\theta = 0^\circ$ be v_B. Then
$(T_{collar})_2 = \frac{1}{2}(7) v_B^2$.
We now determine $(T_{links})_2$. It is given by:
$(T_{links})_2 = 2\left[\frac{1}{2} m v_G^2 + \frac{1}{2} I_G \omega^2\right]$
This means $v_D = 0$. Next, $v_B = v_D + \omega(0.375)$
$\Rightarrow v_B/0.375 = \omega$. Furthermore, $v_G = v_D + \omega\left(\frac{0.375}{2}\right)$
$= \left(\frac{v_B}{0.375}\right)\left(\frac{0.375}{2}\right) = \frac{v_B}{2}$. Therefore,
$(T_{links})_2 = 2\left[\frac{1}{2} m\left(\frac{v_B}{2}\right)^2 + \frac{1}{2} \frac{m(0.375)^2}{12} \frac{v_B^2}{(0.375)^2}\right]$
$(T_{links})_2 = \frac{m v_B^2}{4} + \frac{m v_B^2}{12} = m v_B^2\left(\frac{1}{4} + \frac{1}{12}\right) = m v_B^2\left(\frac{3+1}{12}\right)$
$= \frac{m v_B^2}{3}$. (m = 10)
Therefore, $T_2 = 0 + \frac{m v_B^2}{3} + \frac{1}{2}(7) v_B^2 = 6.833 v_B^2$.
Next, we find V_1. We have:
$V_1 = (7)(9.81)(0.375 \sin 45^\circ) + 2(10)(9.81)\left(\frac{0.375 \sin 45^\circ}{2}\right)$
$\Rightarrow V_1 = 44.22$ J.
Furthermore, $V_2 = 0$ and $U'_{1-2} = 0$. From the work-energy relation:
$\Rightarrow 0 + 44.22 + 0 = 6.833 v_B^2 + 0$
$\Rightarrow v_B = 2.5439$ m/s.</td><td>F.B.D. = 2 M
Calculations = 10 M
Correct answers = 4 M</td><td>25 min.</td></tr>
</table>

Roll No												

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Semester: 2019 - 20
Course Code: MEC 325
Course Name: ENGINEERING DYNAMICS
Program & Sem: B.Tech. (MEC) & V (DE-II)

Date: 23 December 2019
Time: 9:30 AM to 12:30 PM
Max Marks: 80
Weightage: 40%

Instructions:
(i) Read all the questions carefully and answer accordingly.
(ii) All questions are compulsory.
(iii) Use of Non-Programmable Calculators is allowed.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 5 marks. **(4Qx5M=20M)**

1. Fill in the blanks [5Qx1M=5M] (C.O.No.2) [Knowledge]

(a) The product of mass and velocity is termed as_________

(b) When a large force acts over a small finite period of time, the force is called as _________ force.

(c) In terms of mass **m** and radius **r**, Mass moment of inertia of a ring is __________

(d) The energy possessed by a particle by virtue of its motion is called as ___________

(e) Work done by weight will be ___________ if the particle is moved from lower to upper position.

2. In the Equation of Motion for a Spring-Mass-Damper system $3x'' + x' + 4x = 5 \cos 2t$

(a) Coefficient of damping for the system is _________ [1M] (C.O.No.4) [Knowledge]

(b) Natural frequency of the system is _________ [2M] (C.O.No.4) [Knowledge]

(c) Amplitude of forced vibration is ________ [2M] (C.O.No.4) [Knowledge]

3. A truck travels 164 m in 8 seconds while being decelerated at a constant rate of 0.5 m/s^2.

Determine

(a) Its initial velocity. [2M] (C.O.No.1) [Knowledge]

(b) Its final velocity. [2M] (C.O.No.1) [Knowledge]

(c) The distance travelled in initial 3 seconds. [1M] (C.O.No.1) [Knowledge]

4. A block of mass **m** is pulled along a horizontal surface (whose free body diagram is as shown in Fig.1) by applying a force **F** at an angle **θ** with the horizontal. The coefficient of dynamic friction between the block and the ground is **μ**.

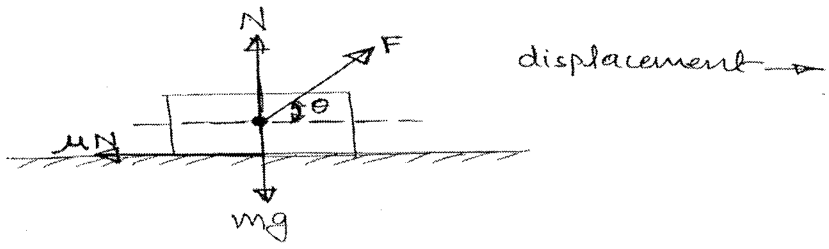


Fig.1

If the block travels at a uniform velocity, then determine

(a) The applied force (in terms of **μ**, **m**, **θ**). [3M] (C.O.No.3) [Knowledge]

(b) The work done by the applied force (in terms of **μ**, **m**, **θ**) [2M] (C.O.No.3) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 8 marks. **(4Qx8M=32M)**

5. The pickup truck weighs 1500 kg and reaches a speed of 14 m/s from rest in a distance of 100 m up the 10-percent incline (as shown in Fig.2) with constant acceleration. Calculate the normal force under each pair of wheels and the friction force under the rear driving wheels. The effective coefficient of friction between the tires and the road is known to be at least 0.8.

[8M] (C.O.No.3) [Comprehension]

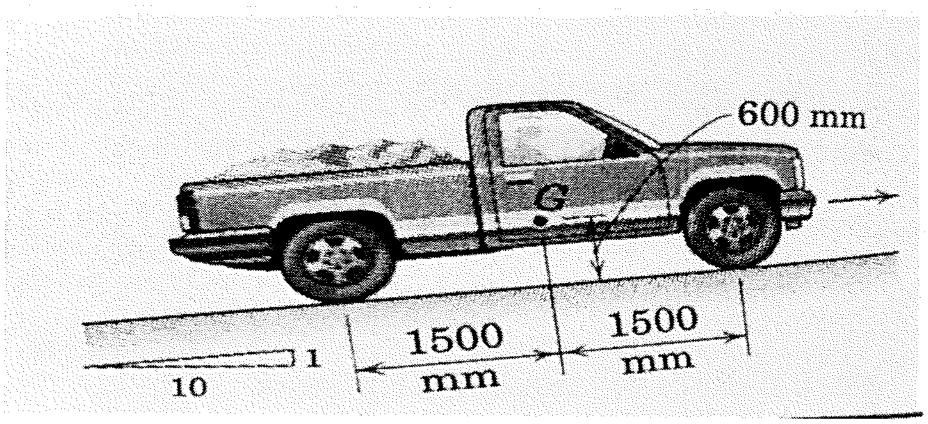


Fig.2

6. Derive Equations of Motion (from Newton's 2nd Law of Motion) for

(a) Spring-Mass-Damper system. [4M] (C.O.No.4) [Comprehension]

(b) Simple pendulum. [4M] (C.O.No.4) [Comprehension]

7. The 8 kg block is moved 0.2 m to the right of the equilibrium position and released from rest at time t=0 (as shown in Fig.3). Determine its displacement at time t=2 s. The viscous damping coefficient c is 20 N.s/m and the spring stiffness k is 32 N/m.

[8M] (C.O.No.4) [Comprehension]

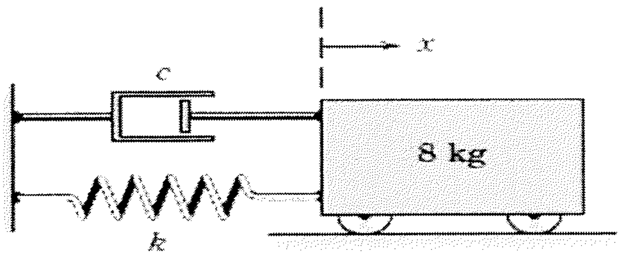


Fig.3

8. Derive the expression for solution of Equation of Motion (particular integral part only) for forced vibration of a spring-mass-damper system. [8M] (C.O.No.4) [Comprehension]

Part C [Problem Solving Questions]

Answer both the Questions. Each Question carries 14 marks. (2Qx14M=28M)

9. Solve the Equation of Motion for a critically damped Spring-Mass-Damper system and draw the Amplitude v/s Time graph for the same system. [14M] (C.O.No.4) [Application]

10. Derive the equation of motion for the homogeneous circular cylinder, which rolls without slipping (as shown in Fig.4). If the cylinder mass is 50 kg, the cylinder radius 1 m, the spring constant 75 N/m, and the damping coefficient 20 N.s/m, determine

(*a*) The undamped natural frequency [2M] (C.O.No.4) [Application]
(*b*) The damping ratio [2M] (C.O.No.4) [Application]
(*c*) The damped natural frequency [3M] (C.O.No.4) [Application]
(*d*) The period of the damped system. [3M] (C.O.No.4) [Application]
(e) Amplitude as a function of time if the cylinder is released from rest at the position x=0.2 m when t= 0. [4M] (C.O.No.4) [Application]

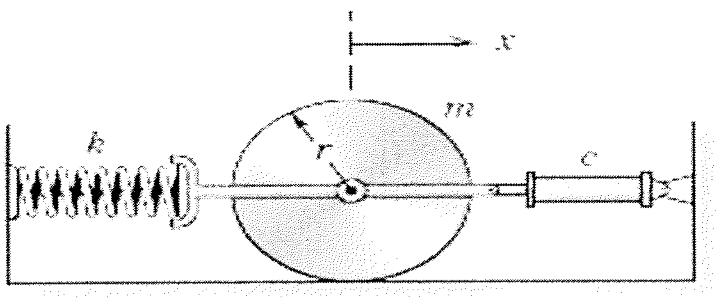


Fig.4

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO (% age of CO)	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	A	
1	CO2	Module-2	5			5
2	CO4	Module-4	5			5
3	CO1	Module-1	5			5
4	CO3	Module-3	5			5
5	CO3	Module-3		8		8
6	CO4	Module-4		8		8
7	CO4	Module-4		8		8
8	CO4	Module-4		8		8
9	CO4	Module-4			14	14
10	CO4	Module-4			14	14
	Total Marks		20	32	28	80

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

Faculty Signature:

Reviewer Commend:

Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

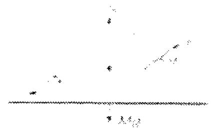
SOLUTION

Semester : 5th Semester : 2019 - 20
Course Code: MEC 325
Course Name: Engineering Dynamics (DE-II)
Program & Sem: B.Tech. & 5th Sem.

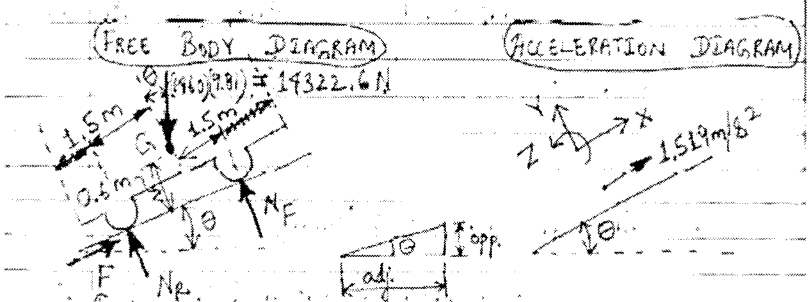
Date: 23rd Dec 2019
Time: 9:30 am to 10:30 am
Max Marks: 80
Weightage: 40 %

Part A (4Q x 5M = 20Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1.	(a) Linear momentum. (b) Impulsive force. (c) mr^2 (d) Kinetic energy. (e) Negative.	Each correct answer for 1 M	5 min.
2.	(a) 1 N.s/m (b) 1.154 rad/s (c) 0.605 m	(a) 1 M (b) 2 M (c) 2 M	5 min.
3.	(a) 22.5 m/s (b) 18.5 m/s (c) 65.25 m	(a) 1.5 M (b) 1.5 M (c) 2 M	5 min.

<table>
<tr><td>4.</td><td>
... As the block moves ... horizontal and vertical components:
$$F\cos\theta = \mu N$$
$$F\sin\theta + N = Mg$$
Eliminating N from these equations,
$$F\cos\theta = \mu(Mg - F\sin\theta)$$
or $$F = \frac{\mu Mg}{\cos\theta + \mu\sin\theta}$$
The work done by this force during a displacement d is
$$W = Fd\cos\theta = \frac{\mu Mgd\cos\theta}{\cos\theta + \mu\sin\theta}$$</td><td>(a) 2.5 M
(b) 2.5 M</td><td>7 min.</td></tr>
</table>

Part B (4Q x 8M = 32 Marks)

<table>
<tr><th>Q No</th><th>Solution</th><th>Scheme of Marking</th><th>Max. Time required for each Question</th></tr>
<tr><td>5.</td><td>$v(s=0)$ too.
<u>SOLUTION</u>: $m = 1460$ kg, $v(t=0) = 0$, $v(s=60\text{ m}) = 13.5$ m/s, the acceleration is constant, $\mu = 0.8$ at the minimum.
The acceleration of the truck is given by: (from $v^2 = u^2 + 2as$)
$$a = \frac{(13.5)^2 - 0^2}{2(60)} \Rightarrow a = 1.519\ m/s^2.$$


$$\tan\theta = \frac{\text{opp.}}{\text{adj.}} = 10\% = \frac{10}{100} \Rightarrow \theta = \tan^{-1}(0.1)$$
$$\Rightarrow \theta = 5.71°$$
$$\Sigma F_X = F - (1460)(9.81)\sin(5.71°) = F - 1417.9$$
$$ma_X = ma = (1460)(1.519)$$
$$\Sigma F_X = ma_X : F - 1417.9 = (1460)(1.519) \Rightarrow F = \sout{83,833.4}\ 3635.64\ N.$$
$$\Sigma F_Y = -14322.6\cos 5.71° + N_R + N_F,\ ma_Y = m(0) = 0,$$
(14250.9 ≈ −14251)
$$\Sigma F_Y = ma_Y : -14,251 + N_R + N_F = 0,$$
$$\Rightarrow N_R + N_F = 14251. \quad \text{—(1)}$$</td><td>F.B.D. = 2 M
Calculations = 4 M
Correct answers = 2 M</td><td>25 min.</td></tr>
</table>

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Since the truck is not rotating, we have $\alpha = 0$. Therefore, $\Sigma M_G = I\alpha = 0 \Rightarrow \Sigma M_G = 0$. Then

$\Sigma M_G = 0: 1.5 N_F - 1.5 N_R + 0.6 F = 0$ (3635.64; 23,833.4 N)
$\Rightarrow -1.5 N_R + 1.5 N_F = -2,181.4$ — ②

From ① and ②: $N_R = \dfrac{\begin{vmatrix} 14251 & 1 \\ -2181.4 & 1.5 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ -1.5 & 1.5 \end{vmatrix}} = 7,852.63\ N$, normal force on the pair of rear wheels

$N_F = \dfrac{\begin{vmatrix} 1 & 14251 \\ -1.5 & -2181.4 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ -1.5 & 1.5 \end{vmatrix}} = 6398.37\ N$, normal force on the front wheels

IS THE FRICTION FORCE "OKAY?"

$\mu_{required} = \dfrac{3635.64}{7852.63} = 0.4629 < 0.8$ okay!
</td>
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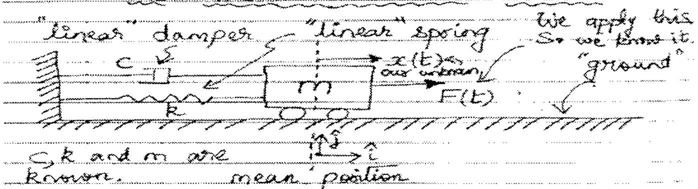
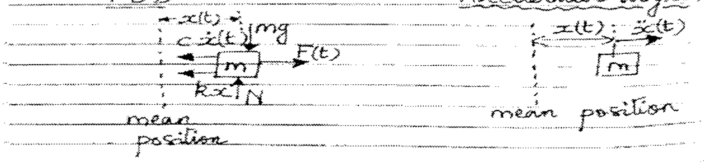
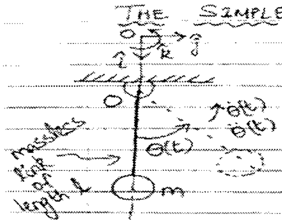
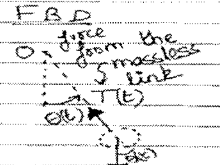
<tr>
<td>6.</td>
<td>
THE SPRING-MASS-DAMPER SYSTEM


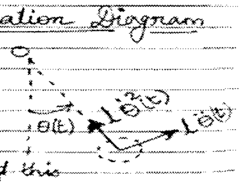
FBD   Acceleration Diagram


$\Sigma \vec{F} = m\vec{a}: F(t) - c\dot{x}(t) - k\,x(t) = m\ddot{x}(t)$, — ① (along $\hat{i}$)
$N - mg = 0$. — ② (along $\hat{j}$)

THE SIMPLE PENDULUM


Here the motion of the pendulum is described by θ(t). So our "equation of motion for the simple pendulum" must have θ(t) as the unknown.

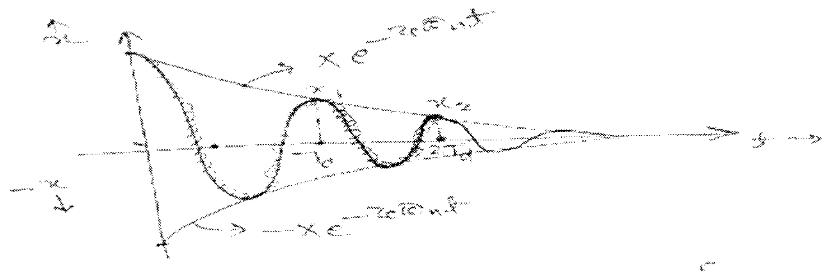
FBD   Acceleration Diagram




Let's be "clever" now. Let's write $\Sigma \vec{F} = m\vec{a}$ along the two components of acceleration of the mass instead of doing so along $\hat{i}$ and $\hat{j}$. We have:
$T(t) - mg\cos\theta(t) = m\,l\,\dot{\theta}^2(t)$, — ③
$-mg\sin\theta(t) = m\,l\,\ddot{\theta}(t)$. — ④
</td>
<td>F.B.D. = 2 M
Calculations = 4 M
Correct answers = 2 M</td>
<td>25 min</td>
</tr>
</table>

7.	[illegible] damped … [illegible] The velocity is then [illegible] Evaluating the displacement and velocity at time t = 0 gives [illegible] Solving the two equations for C and φ yields C = [illegible] m and φ = [illegible] rad. Therefore, the displacement in meters is [illegible] Evaluation for time t = 2 s gives x = 0.01616 m Ans.	F.B.D. = 2 M Calculations = 4 M Correct answers = 2 M	25 min.
8.	P.I. $P.I. = \frac{\frac{F_0}{m}\sin\omega t}{D^2 + (2\zeta\omega_n)D + \omega_n^2}$ [D → operator, $D^2 \to -\omega^2$] $\Rightarrow P.I. = \frac{\frac{F_0}{m}\sin\omega t \; \{(\omega_n^2-\omega^2) - (2\zeta\omega_n)D\}}{(\omega_n^2-\omega^2) + (2\zeta\omega_n)D\;\{(\omega_n^2-\omega^2) - (2\zeta\omega_n)D\}}$ $= \frac{F_0}{m}\frac{\{(\omega_n^2-\omega^2)\sin\omega t - (2\zeta\omega\omega_n)\cos\omega t\}}{(\omega_n^2-\omega^2)^2 + (2\zeta\omega\omega_n)^2}$ $= \frac{F_0}{m}\cdot\frac{R\sin(\omega t-\phi)}{R^2}$ $= \frac{\frac{F_0}{m}}{\sqrt{(\omega_n^2-\omega^2)^2+(2\zeta\omega\omega_n)^2}}\sin(\omega t-\phi)$ $P.I. = \frac{(F_0/s)}{\sqrt{\left\{1-\left(\frac{\omega}{\omega_n}\right)^2\right\}^2+\left(\frac{2\zeta\omega}{\omega_n}\right)^2}}\sin(\omega t-\phi)$ Amplitude of Vib^n → Independent of time Vib^n with freq. [illegible] $\tan\phi = \left[\frac{2\zeta(\omega/\omega_n)}{1-\left(\frac{\omega}{\omega_n}\right)^2}\right]$ Scanned by CamScanner	Procedure = 6M Correct expression = 2M	25 min.

Part C (0Q x 0M = 0Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
9.	Case-(c) When $\left(\frac{c}{2m}\right)^2 < \frac{k}{m}$ → Under Damped System $n_1, n_2 = \left(-\frac{c}{2m}\right) \pm \sqrt{\left(\frac{c}{2m}\right)^2 - \frac{k}{m}}$ (is negative) $n_1, n_2 = \left(-\frac{c}{2m}\right) \pm \sqrt{-\left[\frac{k}{m} - \left(\frac{c}{2m}\right)^2\right]}$ $= \left(-\frac{c}{2m}\right) \pm \sqrt{-1}\sqrt{\frac{k}{m} - \left(\frac{c}{2m}\right)^2}$ $n_1, n_2 = \left(-\frac{c}{2m}\right) \pm i\sqrt{\frac{k}{m} - \left(\frac{c}{2m}\right)^2}$ → Introducing two terms (i) Damping factor (or) Damping Ratio ⇒ $\zeta_c = \sqrt{\frac{\left(\frac{c}{2m}\right)^2}{\frac{k}{m}}}$ $\zeta_c = \sqrt{\frac{\left(\frac{c}{2m}\right)^2}{\omega_n^2}} = \frac{c}{2m\omega_n}$ $\boxed{\zeta_c = \frac{c}{2m\omega_n} = \frac{c}{c_c}}$ where c_c = critical damping coefficient $\boxed{c_c = 2m\omega_n}$ (ii) Damped frequency $(\omega_d) = \left(\sqrt{1-\zeta_c^2}\right)\omega_n$ → Now, $n_1, n_2 = (-\zeta_c\omega_n) \pm i\sqrt{\omega_n^2 - (\zeta_c\omega_n)^2}$ $= -\zeta_c\omega_n \pm i\left(\sqrt{1-\zeta_c^2}\right)\omega_n$ $= -\zeta_c\omega_n \pm i\,\omega_d$ Here, n_1 and n_2 values are complex conjugate and distinct. 	Procedure = 8M Correct expression = 2M Graph = 4M	29 min.

→ In this case $x = C_1 \exp\{(-\zeta\omega_n - i\omega_d)t\}$
$+ C_2 \exp\{(-\zeta\omega_n - i\omega_d)t\}$

$x = C_1 e^{(-\zeta\omega_n)t} e^{i\omega_d t} + C_2 e^{(-\zeta\omega_n)t} e^{-i\omega_d t}$

$= e^{-\zeta\omega_n t}\left[C_1 e^{i\omega_d t} + C_2 e^{-i\omega_d t}\right]$

$= e^{-\zeta\omega_n t}\left[C_1(\cos\omega_d t + i\sin\omega_d t) + C_2(\cos\omega_d t - i\sin\omega_d t)\right]$

$= e^{-\zeta\omega_n t}\left[(C_1 + C_2)\cos\omega_d t + (C_1 - C_2)\, i \sin\omega_d t\right]$

Let us assume $C_1 + C_2 = R\sin\phi$
$i(C_1 - C_2) = R\cos\phi$
{R & ϕ are constants}

Then $x = e^{-\zeta\omega_n t}\left[R\sin\phi\cos\omega_d t + R\cos\phi\sin\omega_d t\right]$

$x = Re^{-\zeta\omega_n t}\left[\sin(\omega_d t + \phi)\right]$

$$\boxed{x = Re^{-\zeta\omega_n t}\sin(\omega_d t + \phi)} \quad \text{--- (2)}$$

10.

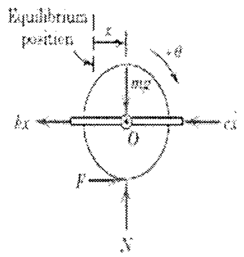
Solution. We have a choice of motion variables in that either x or the angular displacement θ of the cylinder may be used. Since the problem statement involves x, we draw the free-body diagram for an arbitrary, positive value of x and write the two motion equations for the cylinder as

$[\Sigma F_x = m\ddot{x}]$ $\qquad -c\dot{x} - kx + F = m\ddot{x}$

$[\Sigma M_G = \bar{I}\ddot{\theta}]$ $\qquad -Fr = \frac{1}{2}mr^2\ddot{\theta}$

The condition of rolling with no slip is $\ddot{x} = -r\ddot{\theta}$. Substitution of this condition into the moment equation gives $F = -\frac{1}{2}m\ddot{x}$. Inserting this expression for the friction force into the force equation for the x-direction yields

$$-c\dot{x} - kx - \frac{1}{2}m\ddot{x} = m\ddot{x} \qquad \text{or} \qquad \ddot{x} + \frac{2}{3}\frac{c}{m}\dot{x} + \frac{2}{3}\frac{k}{m}x = 0$$



Comparing the above equation with that for the standard damped oscillator, Eq. 8/9, allows us to state directly

(a) $\omega_n^2 = \frac{2}{3}\frac{k}{m}$ $\qquad \omega_n = \sqrt{\frac{2}{3}\frac{k}{m}} = \sqrt{\frac{2}{3}\frac{75}{50}} = 1 \text{ rad/s}$ $\qquad$ *Ans.*

(b) $2\zeta\omega_n = \frac{2}{3}\frac{c}{m}$ $\qquad \zeta = \frac{1}{3}\frac{c}{m\omega_n} = \frac{10}{3(50)(1)} = 0.0667$ $\qquad$ *Ans.*

Hence, the damped natural frequency and the damped period are

(c) $\omega_d = \omega_n\sqrt{1-\zeta^2} = (1)\sqrt{1-(0.0667)^2} = 0.998 \text{ rad/s}$ $\qquad$ *Ans.*

(d) $\tau_d = 2\pi/\omega_d = 2\pi/0.998 = 6.30 \text{ s}$ $\qquad$ *Ans.*

From Eq. 8/12, the underdamped solution to the equation of motion is

$$x = Ce^{-\zeta\omega_n t}\sin(\omega_d t + \psi) = Ce^{-(0.0667)(1)t}\sin(0.998t + \psi)$$

The velocity is $\qquad \dot{x} = -0.0667Ce^{-0.0667t}\sin(0.998t + \psi)$

$\qquad\qquad + 0.998Ce^{-0.0667t}\cos(0.998t + \psi)$

At time $t = 0$, x and $\dot{x}$ become

$x_0 = C\sin\psi = -0.2$

$\dot{x}_0 = -0.0667C\sin\psi + 0.998C\cos\psi = 0$

The solution to the two equations in C and ψ gives

$C = -0.200 \text{ m} \qquad \psi = 1.504 \text{ rad}$

Thus, the motion is given by

$x = -0.200e^{-0.0667t}\sin(0.998t + 1.504) \text{ m}$ $\qquad$ *Ans.*

F.B.D. = 3 M Calculations = 6 M Correct answers = 5 M	29 min.