Item 03:08 – Annexure VII

ROHINI
COLLEGE OF ENGINEERING & TECHNOLOGY
(AUTONOMOUS)
Approved By AICTE & Affiliated to Anna University
NBA Accredited for All Eligible B.E/B.Tech Programs | NAAC Accredited with A+ Grade
Near Anjugramam - Kanyakumari Main Road, Palkulam, Variyoor P.O.-629401, Kanyakumari Dist, Tamil Nadu.

Minor Degree Course

AUGMENTED REALITY AND VIRTUAL REALITY

Curriculum & Syllabus

(*2024-2025 Admitted Students Onwards*)

CREDIT INFO		
Sl.No	**Category**	**Credits**
1	Minor Courses	18

CREDIT DISTRIBUTION

Course Category	Credit/Semester								No. of Credits
	I	II	III	IV	V	VI	VII	VIII	
Minor Courses	-	-	-	-	6	6	6	-	18

MINOR COURSES						
CYBER SECURITY						
Sl.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**C**
1	24AV501	Fundamentals of Augmented Reality and Virtual Reality	3	0	0	3
2	24AV502	3D Modeling, Animation and Digital Content Creation	3	0	0	3
3	24AV601	AR/VR Application Development Using Unity	3	0	0	3
4	24AV602	Human-Computer Interaction and Immersive Experience Design	3	0	0	3
5	24AV701	Industrial Metaverse, Digital Twins and XR Applications	3	0	0	3
6	24AV702	AR/VR Capstone Project and Industry Applications	3	0	0	3

Course Code:	**24AV501**	**Course Title:**	**Fundamentals of Augmented Reality and Virtual Reality**
Credits:	**3**	**L – T – P**	**3-0-0**
Prerequisite	Basic Knowledge of Computer Applications and Engineering Graphics		

Course objectives:

The course enables the students to:

- Understand the principles, evolution, and core concepts of Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and Extended Reality (XR) technologies for immersive engineering applications.
- Apply the fundamentals of 3D graphics, spatial computing, tracking techniques, and immersive interaction to develop AR/VR environments.
- Analyze the architecture, hardware, software platforms, and visualization technologies used in modern AR/VR systems.
- Explore the use of AR/VR technologies in manufacturing, healthcare, civil engineering, education, smart cities, Industry 4.0, and digital transformation.
- Design basic immersive solutions using contemporary AR/VR development platforms for solving real-world engineering problems.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive Lectures with Industry Case Studies
2. Demonstration of AR/VR Devices
3. Hands-on Sessions using Unity and Blender
4. Project-Based Learning
5. Problem-Based Learning
6. Flipped Classroom
7. Collaborative Learning
8. Experiential Learning
9. Industrial Case Study Discussions
10. Mini Projects and Technical Seminars

UNIT I – INTRODUCTION TO AUGMENTED REALITY, VIRTUAL REALITY AND XR	**[9 hours]**
Evolution of Immersive Technologies – Fundamentals of Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and Extended Reality (XR) – Characteristics of AR and VR Systems – Immersion, Presence and Interactivity – Components of Immersive Systems – Applications of AR/VR – Emerging Trends – Challenges and Future Scope of XR Technologies – Engineering and Industrial Applications.	

UNIT II – AR/VR HARDWARE, SENSORS AND SYSTEM ARCHITECTURE	**[9 hours]**
AR/VR Hardware Components – Head Mounted Displays (HMDs) – Smart Glasses – Motion Controllers – Depth Cameras – LiDAR Sensors – Inertial Measurement Units (IMU) – Tracking Systems – Marker-Based and Markerless Tracking – Simultaneous Localization and Mapping (SLAM) – Display Technologies – Input and Output Devices – AR/VR System Architecture.	

UNIT III – 3D GRAPHICS, SPATIAL COMPUTING AND IMMERSIVE VISUALIZATION	**[9 hours]**
Fundamentals of 3D Graphics – Coordinate Systems – Geometric Transformations – 3D Modeling Concepts – Lighting – Texturing – Rendering Techniques – Spatial Mapping – Environment Understanding – Scene Reconstruction – Object Recognition – Computer Vision Fundamentals for AR – Spatial Computing Principles.	

UNIT IV – USER INTERACTION AND AR/VR DEVELOPMENT PLATFORMS	**[9 hours]**
Human-Computer Interaction in AR/VR – Gesture Recognition – Voice Interaction – Eye Tracking – Haptic Feedback – User Experience (UX) Design – Introduction to Unity – Blender – AR Foundation – Vuforia – ARCore – ARKit – WebXR – Deployment of AR/VR Applications – Best Practices for Immersive Application Development.	

UNIT V – AR/VR APPLICATIONS IN SMART ENGINEERING SYSTEMS	**[9 hours]**
AR/VR in Smart Manufacturing – Digital Twins – Industrial Training and Maintenance – Healthcare and Medical Simulation – Smart Construction and Building Information Modeling (BIM) – Automotive and Aerospace Applications – Smart Agriculture – Education and Skill Development – Cultural Heritage and Tourism – AI-Enabled AR/VR – Industrial Metaverse – Ethics, Privacy, and Future Trends in Extended Reality.	

Course outcomes:

On completion of the course, the student will have the ability to:

CO1	Explain the concepts, architecture, hardware components, and evolution of AR, VR, MR, and XR technologies
CO2	Apply 3D visualization, tracking, spatial mapping, and user interaction techniques in immersive environments.
CO3	Analyze AR/VR development platforms, rendering techniques, and immersive system architectures for engineering applications
CO4	Evaluate AR/VR solutions for manufacturing, healthcare, education, construction, transportation, and smart engineering systems.
CO5	Design basic AR/VR applications using modern development tools to address industrial and societal challenges.

COs and POs Mapping:

CO's	**PO's**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	2	2	1	1	1	3		-	-	1	2
2	1	1	1	1	2	3	-	-	-	1	2
3	1	1	1	2	2	3	-	-	-	1	2
4	1	1	1	2	2	2	-	-	-	2	2
5	1	1	1	2	2	2	-	-	-	2	2

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	**Typeof assessment**	**Max Marks**	**Reduced Marks**	**Total**	**Final marks**
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		Terminal Examination
	1	2	
Remember	60	50	60
Understand	40	50	40
Apply	0	0	0
Analyze	0	0	0
Evaluate	0	0	0
Create	0	0	0

TEXT BOOKS:

1. Dieter Schmalstieg and Tobias Hollerer, Augmented Reality: Principles and Practice, 2nd Edition, Addison-Wesley, 2024.
2. Steven M. LaValle, Virtual Reality, Cambridge University Press, Latest Edition.
3. Alan B. Craig, Understanding Augmented Reality: Concepts and Applications, Morgan Kaufmann.

REFERENCE BOOKS:

1. Jason Jerald, The VR Book: Human-Centered Design for Virtual Reality, ACM Books.
2. Tony Parisi, Learning Virtual Reality, O'Reilly Media.
3. Ralf Doerner, Wolfgang Broll, et al., Virtual and Augmented Reality (VR/AR): Foundations and Methods of Extended Realities, Springer.
4. Burdea, G. C. and Coiffet, P., Virtual Reality Technology, Wiley.
5. Grigore C. Burdea and Philippe Coiffet, Virtual Reality Systems and Applications, Wiley.

SUGGESTED SKILL ACTIVITIES

Students shall complete the following laboratory and skill-oriented activities.

1. Explore AR/VR hardware devices and compare their features.
2. Create a simple 3D model using Blender.
3. Develop a basic interactive 3D scene using Unity.
4. Demonstrate marker-based AR object visualization.

5. Create a simple VR walkthrough of an engineering laboratory.
6. Implement gesture or voice-based interaction in an immersive environment.
7. Analyze an industrial case study on Digital Twin or Industrial Metaverse applications.
8. Design an AR solution for equipment maintenance or product visualization.
9. Develop a conceptual AR/VR application for healthcare, manufacturing, education, or civil engineering.
10. Present a mini project demonstrating an immersive engineering application.

Course Code:	**24AV502**	**Course Title:**	**3D Modeling, Animation and Digital Content Creation**
Credits:	**3**	**L – T – P**	**3-0-0**
Prerequisite	**24AV501 - Fundamentals of Augmented Reality and Virtual Reality**		

Course objectives:

The course enables the students to:

- Understand the principles of 3D modeling, animation, rendering, and digital content creation for immersive AR/VR applications.
- Apply industry-standard tools and techniques to create, edit, and optimize 3D assets for real-time visualization.
- Analyze modeling workflows, animation techniques, lighting, materials, and rendering methods for interactive environments.
- Develop optimized digital content suitable for engineering visualization, simulation, digital twins, and immersive experiences.
- Design realistic 3D scenes and animations for industrial, educational, healthcare, and smart engineering applications.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive Lectures with Industry Demonstrations
2. Hands-on Laboratory Sessions using Blender and Unity
3. Project-Based Learning
4. Problem-Based Learning
5. Demonstration of 3D Content Creation Tools
6. Case Study-Based Learning
7. Collaborative Learning
8. Flipped Classroom
9. Experiential Learning
10. Mini Projects and Technical Presentations

UNIT I – FUNDAMENTALS OF 3D MODELING AND DIGITAL CONTENT CREATION	**[9 hours]**
Introduction to 3D Graphics – Digital Content Creation Pipeline – Polygon, NURBS, and Mesh Modeling – Coordinate Systems – Geometric Transformations – Primitive Objects – Object Hierarchy – Scene Organization – Engineering Visualization – Applications in AR/VR, Gaming, Digital Twins, and Industrial Design.	

UNIT II – 3D MODELING, MATERIALS AND TEXTURING	**[9 hours]**
Polygon Modeling Techniques – Surface Modeling – Sculpting Fundamentals – CAD Model Import and Optimization – UV Mapping – Texture Mapping – Procedural Textures – Physically Based Rendering (PBR) Materials – Material Libraries – Asset Optimization for Real-Time Applications – Level of Detail (LOD) Concepts	

UNIT III – LIGHTING, ANIMATION AND VISUAL EFFECTS	**[9 hours]**
Lighting Fundamentals – Types of Lights – Shadows – Cameras and Camera Animation – Keyframe Animation – Timeline and Animation Curves – Character Rigging Basics – Skeletal Animation – Particle Systems – Physics-Based Animation – Visual Effects – Motion Capture Concepts – Animation Optimization.	

UNIT IV – RENDERING AND REAL-TIME CONTENT DEVELOPMENT	**[9 hours]**
Rendering Pipeline – Rasterization – Ray Tracing Concepts – Real-Time Rendering – Rendering Engines – Scene Optimization – Environment Design – Terrain Creation – Asset Management – Exporting Assets to Unity – Performance Optimization for AR/VR Devices – Introduction to HDRP and URP Rendering Pipelines.	

UNIT V – DIGITAL CONTENT CREATION FOR IMMERSIVE ENGINEERING APPLICATIONS	**[9 hours]**
3D Asset Development for AR/VR – Virtual Product Visualization – Digital Twins – Smart Manufacturing Visualization – Medical Simulation Models – Architectural Walkthroughs – Cultural Heritage Preservation – Virtual Laboratories – Interactive Educational Content – AI-Assisted 3D Content Generation – Generative AI for 3D Asset Creation – Industry Case Studies.	

Course outcomes:

On completion of the course, the student will have the ability to:

CO1	Explain the principles of 3D modeling, animation, rendering, and digital content creation for AR/VR environments
CO2	Create 3D models, textures, materials, and animations using modern content creation tools.
CO3	Analyze rendering techniques, asset optimization, and scene composition for real-time immersive applications.
CO4	Evaluate digital content workflows for engineering visualization, industrial simulation, digital twins, and virtual training.
CO5	Design optimized 3D assets and immersive environments for AR/VR applications across multiple engineering domains.

COs and POs Mapping:

CO's	PO's										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	2	2	1	1	1	3		-	-	1	2
2	1	1	1	1	2	3	-	-	-	1	2
3	1	1	1	2	2	3	-	-	-	1	2
4	1	1	1	2	2	2	-	-	-	2	2
5	1	1	1	2	2	2	-	-	-	2	2

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	**Typeof assessment**	**Max Marks**	**Reduced Marks**	**Total**	**Final marks**
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		Terminal Examination
	1	2	
Remember	60	50	60
Understand	40	50	40
Apply	0	0	0
Analyze	0	0	0
Evaluate	0	0	0
Create	0	0	0

TEXT BOOKS:

1. Tony Mullen, Mastering Blender: A Complete Guide to 3D Modeling, Animation, and Rendering, 3rd Edition, CRC Press, 2023.
2. John Vince, Introduction to Virtual Reality, Springer, Latest Edition.
3. Kelly L. Murdock, Autodesk Maya Basics Guide, SDC Publications, Latest Edition

REFERENCE BOOKS:

1. Andrew Gahan, Game Art Complete: All-in-One, Focal Press.
2. Jason Gregory, Game Engine Architecture, 4th Edition, CRC Press.
3. David Gould, Complete Maya Programming, Morgan Kaufmann.
4. Alan Thorn, Unity Game Development Essentials, Packt Publishing.
5. Tomas Akenine-Möller, Eric Haines, and Naty Hoffman, Real-Time Rendering, 5th Edition, CRC Press.

SUGGESTED SKILL ACTIVITIES

Students shall complete the following laboratory and skill-oriented activities.

1. Create basic 3D objects and engineering models using Blender.
2. Develop a textured industrial component using UV mapping techniques.
3. Design realistic materials using Physically Based Rendering (PBR).
4. Create lighting setups for indoor and outdoor virtual environments.
5. Develop keyframe animations for mechanical assemblies or engineering products.
6. Import CAD models and optimize them for AR/VR visualization.
7. Export optimized assets from Blender to Unity for real-time rendering.

8. Create a virtual showroom or engineering laboratory with interactive 3D objects.
9. Develop a simple digital twin visualization of an engineering system.
10. Complete a mini project by designing a fully optimized immersive 3D environment for an engineering application.

Course Code:	**24AV601**	**Course Title:**	**AR/VR Application Development Using Unity**
Credits:	**3**	**L – T – P**	**3-0-0**
Prerequisite	**24AV502 - 3D Modeling, Animation and Digital Content Creation**		

Course objectives:

The course enables the students to:

- Understand the Unity game engine, XR development workflow, and immersive application architecture for AR/VR systems.
- Apply Unity tools, C# scripting, XR Interaction Toolkit, and AR Foundation to develop interactive AR/VR applications.
- Analyze scene management, user interaction, physics, animation, and optimization techniques for real-time immersive experiences.
- Develop immersive applications integrating sensors, spatial mapping, UI, multimedia, and cloud-based services for engineering applications.
- Design AR/VR solutions for manufacturing, healthcare, education, construction, digital twins, and Industry 4.0 environments

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive Lectures with Industry Case Studies
2. Hands-on Unity Development Sessions
3. Live Demonstration of AR/VR Devices
4. Problem-Based Learning
5. Project-Based Learning
6. Flipped Classroom
7. Collaborative Learning
8. Experiential Learning
9. Industry Expert Talks
10. Mini Projects and Technical Presentations

UNIT I – INTRODUCTION TO UNITY AND XR DEVELOPMENT	**[9 hours]**
Unity Interface and Project Structure – Unity Editor – Scenes – Game Objects – Components – Prefabs – Assets – Package Manager – C# Scripting Fundamentals – Unity Physics Engine – Camera Systems	

– XR Development Workflow – XR Plugin Management – XR Interaction Toolkit – Applications of Unity in AR/VR Development.

UNIT II – DEVELOPING VIRTUAL REALITY APPLICATIONS	**[9 hours]**
Virtual Reality Fundamentals – XR Rig Configuration – VR Camera Setup – Controllers and Input Systems – Object Interaction – Teleportation – Locomotion Techniques – Hand Tracking Concepts – UI for VR – Physics-Based Interaction – Audio Integration – VR Scene Development – Performance Optimization for Standalone VR Devices.	

UNIT III – DEVELOPING AUGMENTED REALITY APPLICATIONS	**[9 hours]**
Introduction to AR Foundation – ARCore – ARKit – Plane Detection – Image Tracking – Object Placement – Spatial Anchors – Environmental Understanding – Face Tracking Concepts – Object Recognition – Marker-Based and Markerless AR – Mobile AR Application Development – User Interface Design for AR Applications.	

UNIT IV – ADVANCED INTERACTION, MULTIMEDIA AND DEPLOYMENT	**[9 hours]**
Animation Controller – Timeline – Particle Systems – Lighting and Rendering – Audio and Video Integration – Gesture Recognition Concepts – Voice Interaction – Haptic Feedback – Multiplayer XR Concepts – Cloud-Based XR Services – Build Settings – Deployment to Android, iOS, Meta Quest, and Windows Platforms – Application Testing and Debugging.	

UNIT V – INDUSTRIAL AR/VR APPLICATIONS AND EMERGING TRENDS	**[9 hours]**
Digital Twin Visualization – Smart Manufacturing – Virtual Maintenance and Assembly – Medical Simulation – Construction and BIM Visualization – Smart Agriculture – Education and Training – Cultural Heritage – AI Integration in Unity – Generative AI for XR Content – Industrial Metaverse – WebXR Concepts – Ethics, Privacy, and Future Trends in XR Development.	

Course outcomes:

On completion of the course, the student will have the ability to:

CO1	Explain the Unity development environment, XR architecture, and workflow for AR/VR application development.
CO2	Develop interactive AR/VR applications using Unity, C# scripting, XR Interaction Toolkit, and AR Foundation.

CO3	Analyze user interaction, physics, animation, spatial mapping, and performance optimization techniques for immersive applications.
CO4	Evaluate AR/VR application deployment strategies for mobile, standalone VR headsets, and industrial engineering systems.
CO5	Design and implement an industry-oriented AR/VR application addressing real-world engineering challenges.

COs and POs Mapping:

CO's	PO's										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	2	2	1	1	1	3		-	-	1	2
2	1	1	1	1	2	3	-	-	-	1	2
3	1	1	1	2	2	3	-	-	-	1	2
4	1	1	1	2	2	2	-	-	-	2	2
5	1	1	1	2	2	2	-	-	-	2	2

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	Typeof assessment	Max Marks	Reduced Marks	Total	Final marks
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		Terminal Examination
	1	**2**	
Remember	60	50	60
Understand	40	50	40
Apply	0	0	0
Analyze	0	0	0
Evaluate	0	0	0
Create	0	0	0

TEXT BOOKS:

1. Nicolas Borromeo, Learning Unity XR Development, Packt Publishing, 2024.
2. Jonathan Linowes, Augmented Reality for Developers: Build Practical AR Applications with Unity, AR Foundation, ARCore, and ARKit, Packt Publishing, 2023.
3. Will Goldstone, Unity Game Development Essentials, Packt Publishing, Latest Edition.

REFERENCE BOOKS:

1. Alan Thorn, Unity in Action: Multiplatform Game Development, Manning Publications.
2. Tony Parisi, Learning Virtual Reality, O'Reilly Media.
3. Jason Jerald, The VR Book: Human-Centered Design for Virtual Reality, ACM Books.
4. Dieter Schmalstieg and Tobias Hollerer, Augmented Reality: Principles and Practice, 2nd Edition, Addison-Wesley.
5. Tomas Akenine-Möller, Eric Haines, and Naty Hoffman, Real-Time Rendering, 5th Edition, CRC Press.

SUGGESTED SKILL ACTIVITIES

Students shall complete the following laboratory and skill-oriented activities.

1. Create a Unity project with interactive 3D objects.
2. Develop a basic VR environment using the XR Interaction Toolkit.
3. Implement teleportation and object manipulation in a VR application.
4. Build a marker-based AR application using AR Foundation.
5. Develop an image-tracking AR application for engineering visualization.
6. Integrate audio, animation, and particle effects into an immersive application.
7. Optimize an AR/VR application for mobile and standalone VR devices.
8. Deploy a Unity application to Android or Meta Quest platform.
9. Design a digital twin visualization for an engineering system.

10. Develop a mini project demonstrating an industrial AR/VR solution such as virtual maintenance, product visualization, safety training, or smart education.

Course Code:	**24AV602**	**Course Title:**	**Human-Computer Interaction and Immersive Experience Design**
Credits:	**3**	**L – T – P**	**3-0-0**
Prerequisite	**24AV502 - 3D Modeling, Animation and Digital Content Creation**		

Course objectives:

The course enables the students to:

- Understand the Unity game engine, XR development workflow, and immersive application architecture for AR/VR systems.
- Apply Unity tools, C# scripting, XR Interaction Toolkit, and AR Foundation to develop interactive AR/VR applications.
- Analyze scene management, user interaction, physics, animation, and optimization techniques for real-time immersive experiences.
- Develop immersive applications integrating sensors, spatial mapping, UI, multimedia, and cloud-based services for engineering applications.
- Design AR/VR solutions for manufacturing, healthcare, education, construction, digital twins, and Industry 4.0 environments

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive Lectures with Industry Case Studies
2. Hands-on Unity Development Sessions
3. Live Demonstration of AR/VR Devices
4. Problem-Based Learning
5. Project-Based Learning
6. Flipped Classroom
7. Collaborative Learning
8. Experiential Learning
9. Industry Expert Talks
10. Mini Projects and Technical Presentations

UNIT I – INTRODUCTION TO UNITY AND XR DEVELOPMENT	**[9 hours]**
Unity Interface and Project Structure – Unity Editor – Scenes – Game Objects – Components – Prefabs – Assets – Package Manager – C# Scripting Fundamentals – Unity Physics Engine – Camera Systems	

– XR Development Workflow – XR Plugin Management – XR Interaction Toolkit – Applications of Unity in AR/VR Development.

UNIT II – DEVELOPING VIRTUAL REALITY APPLICATIONS	**[9 hours]**
Virtual Reality Fundamentals – XR Rig Configuration – VR Camera Setup – Controllers and Input Systems – Object Interaction – Teleportation – Locomotion Techniques – Hand Tracking Concepts – UI for VR – Physics-Based Interaction – Audio Integration – VR Scene Development – Performance Optimization for Standalone VR Devices.	

UNIT III – DEVELOPING AUGMENTED REALITY APPLICATIONS	**[9 hours]**
Introduction to AR Foundation – ARCore – ARKit – Plane Detection – Image Tracking – Object Placement – Spatial Anchors – Environmental Understanding – Face Tracking Concepts – Object Recognition – Marker-Based and Markerless AR – Mobile AR Application Development – User Interface Design for AR Applications.	

UNIT IV – ADVANCED INTERACTION, MULTIMEDIA AND DEPLOYMENT	**[9 hours]**
Animation Controller – Timeline – Particle Systems – Lighting and Rendering – Audio and Video Integration – Gesture Recognition Concepts – Voice Interaction – Haptic Feedback – Multiplayer XR Concepts – Cloud-Based XR Services – Build Settings – Deployment to Android, iOS, Meta Quest, and Windows Platforms – Application Testing and Debugging.	

UNIT V – INDUSTRIAL AR/VR APPLICATIONS AND EMERGING TRENDS	**[9 hours]**
Digital Twin Visualization – Smart Manufacturing – Virtual Maintenance and Assembly – Medical Simulation – Construction and BIM Visualization – Smart Agriculture – Education and Training – Cultural Heritage – AI Integration in Unity – Generative AI for XR Content – Industrial Metaverse – WebXR Concepts – Ethics, Privacy, and Future Trends in XR Development.	

Course outcomes:

On completion of the course, the student will have the ability to:

CO1	Explain the Unity development environment, XR architecture, and workflow for AR/VR application development.
CO2	Develop interactive AR/VR applications using Unity, C# scripting, XR Interaction Toolkit, and AR Foundation.

CO3	Analyze user interaction, physics, animation, spatial mapping, and performance optimization techniques for immersive applications.
CO4	Evaluate AR/VR application deployment strategies for mobile, standalone VR headsets, and industrial engineering systems.
CO5	Design and implement an industry-oriented AR/VR application addressing real-world engineering challenges.

COs and POs Mapping:

CO's	**PO's**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	2	2	1	1	1	3		-	-	1	2
2	1	1	1	1	2	3	-	-	-	1	2
3	1	1	1	2	2	3	-	-	-	1	2
4	1	1	1	2	2	2	-	-	-	2	2
5	1	1	1	2	2	2	-	-	-	2	2

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	**Typeof assessment**	**Max Marks**	**Reduced Marks**	**Total**	**Final marks**
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		Terminal Examination
	1	**2**	
Remember	60	50	60
Understand	40	50	40
Apply	0	0	0
Analyze	0	0	0
Evaluate	0	0	0
Create	0	0	0

TEXT BOOKS:

1. Nicolas Borromeo, Learning Unity XR Development, Packt Publishing, 2024.
2. Jonathan Linowes, Augmented Reality for Developers: Build Practical AR Applications with Unity, AR Foundation, ARCore, and ARKit, Packt Publishing, 2023.
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REFERENCE BOOKS:

1. Alan Thorn, Unity in Action: Multiplatform Game Development, Manning Publications.
2. Tony Parisi, Learning Virtual Reality, O'Reilly Media.
3. Jason Jerald, The VR Book: Human-Centered Design for Virtual Reality, ACM Books.
4. Dieter Schmalstieg and Tobias Hollerer, Augmented Reality: Principles and Practice, 2nd Edition, Addison-Wesley.
5. Tomas Akenine-Möller, Eric Haines, and Naty Hoffman, Real-Time Rendering, 5th Edition, CRC Press.

SUGGESTED SKILL ACTIVITIES

Students shall complete the following laboratory and skill-oriented activities.

1. Create a Unity project with interactive 3D objects.
2. Develop a basic VR environment using the XR Interaction Toolkit.
3. Implement teleportation and object manipulation in a VR application.
4. Build a marker-based AR application using AR Foundation.
5. Develop an image-tracking AR application for engineering visualization.
6. Integrate audio, animation, and particle effects into an immersive application.
7. Optimize an AR/VR application for mobile and standalone VR devices.
8. Deploy a Unity application to Android or Meta Quest platform.
9. Design a digital twin visualization for an engineering system.

10. Develop a mini project demonstrating an industrial AR/VR solution such as virtual maintenance, product visualization, safety training, or smart education.

Course Code:	**24AV701**	**Course Title:**	**Industrial Metaverse, Digital Twins and XR Applications**
Credits:	**3**	**L – T – P**	**3-0-0**
Prerequisite	**24AV602 - Human-Computer Interaction and Immersive Experience Design**		

Course objectives:

The course enables the students to:

- Understand the concepts, architecture, and enabling technologies of the Industrial Metaverse, Digital Twins, and Extended Reality (XR) for smart engineering systems.
- Apply IoT, AI, cloud computing, edge computing, and real-time data integration to develop Digital Twin-enabled immersive applications.
- Analyze Industrial Metaverse platforms, XR collaboration tools, and simulation technologies for manufacturing, infrastructure, and smart city applications.
- Evaluate Digital Twin models for predictive maintenance, process optimization, remote monitoring, and intelligent decision-making.
- Design Industrial Metaverse solutions integrating XR, Digital Twins, AI, and Industry 4.0 technologies for real-world engineering applications.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive Lectures with Industry Case Studies
2. Hands-on User Experience Design Workshops
3. Demonstration of AR/VR Interaction Devices
4. Problem-Based Learning
5. Project-Based Learning
6. Design Thinking Activities
7. Collaborative Learning
8. Flipped Classroom
9. Usability Evaluation Sessions
10. Mini Projects and Technical Presentations

UNIT I – INTRODUCTION TO INDUSTRIAL METAVERSE AND DIGITAL TWINS	**[9 hours]**
Evolution of Industry 4.0 and Industry 5.0 – Industrial Metaverse Concepts – Digital Transformation – Digital Twin Fundamentals – Physical, Digital, and Virtual Assets – Digital Thread – Cyber-Physical Systems (CPS) – Smart Factories – Components and Architecture of Digital Twins – Applications in Engineering and Industry	

UNIT II – ENABLING TECHNOLOGIES FOR DIGITAL TWINS	**[9 hours]**
Internet of Things (IoT) – Industrial IoT (IIoT) – Sensors and Data Acquisition – Cloud Computing – Edge Computing – Artificial Intelligence and Machine Learning – Big Data Analytics – Real-Time Data Streaming – 5G and Industrial Communication – Data Integration – Interoperability Standards – Cybersecurity Considerations in Digital Twin Systems.	

UNIT III – XR, SIMULATION AND IMMERSIVE COLLABORATION	**[9 hours]**
Extended Reality (XR) Technologies – Virtual Reality for Industrial Training – Augmented Reality for Maintenance and Inspection – Mixed Reality Applications – Immersive Collaboration – Virtual Commissioning – Engineering Simulation – Virtual Prototyping – Remote Monitoring – Human-Machine Interaction – Visualization Dashboards – Spatial Computing for Industrial Systems.	

UNIT IV – DIGITAL TWIN APPLICATIONS IN SMART ENGINEERING SYSTEMS	**[9 hours]**
Digital Twins for Smart Manufacturing – Predictive Maintenance – Process Monitoring and Optimization – Robotics and Automation – Smart Grids – Healthcare and Medical Simulation – Building Information Modeling (BIM) – Smart Construction – Intelligent Transportation Systems – Energy Management – Agriculture and Environmental Monitoring – Supply Chain Visualization.	

UNIT V – INDUSTRIAL METAVERSE PLATFORMS, ETHICS AND FUTURE TRENDS	**[9 hours]**
Industrial Metaverse Platforms – NVIDIA Omniverse Fundamentals – Microsoft Mesh Concepts – Siemens Xcelerator – Dassault Systèmes 3DEXPERIENCE – Cloud-Based Digital Twin Platforms – AI-Driven Industrial Automation – Sustainable Smart Manufacturing – Ethical and Privacy Issues – Data Governance – Green Digital Transformation – Future Trends in Industrial Metaverse and XR.	

Course outcomes:

On completion of the course, the student will have the ability to:

CO1	Explain the concepts, architecture, and enabling technologies of the Industrial Metaverse, Digital Twins, and XR ecosystems.
CO2	Apply Digital Twin technologies, IoT integration, and XR platforms for industrial visualization and monitoring.
CO3	Analyze industrial processes using immersive simulations, real-time analytics, and Digital Twin models.
CO4	Evaluate Industrial Metaverse solutions for predictive maintenance, smart manufacturing, healthcare, transportation, and critical infrastructure
CO5	Design AI-enabled Digital Twin and XR solutions for solving engineering and industrial challenges

COs and POs Mapping:

CO's	**PO's**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	2	2	1	1	1	3		-	-	1	2
2	1	1	1	1	2	3	-	-	-	1	2
3	1	1	1	2	2	3	-	-	-	1	2
4	1	1	1	2	2	2	-	-	-	2	2
5	1	1	1	2	2	2	-	-	-	2	2

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	**Typeof assessment**	**Max Marks**	**Reduced Marks**	**Total**	**Final marks**
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		Terminal Examination
	1	2	
Remember	60	50	60
Understand	40	50	40
Apply	0	0	0
Analyze	0	0	0
Evaluate	0	0	0
Create	0	0	0

TEXT BOOKS:

1. Michael Grieves and John Vickers, Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems, Springer, Latest Edition.
2. Erik Guilbert and John Soldatos, Building the Industrial Metaverse: Foundations, Technologies and Applications, Springer, 2024.
3. Fei Tao and Ang Liu, Digital Twin Driven Smart Manufacturing, Academic Press, 2023.

REFERENCE BOOKS:

1. Fei Tao and Qinglin Qi, Digital Twin Shop-Floor: A New Shop-Floor Paradigm Towards Smart Manufacturing, IEEE Press.
2. John Soldatos, Building Blocks for IoT Analytics, River Publishers.
3. Dieter Schmalstieg and Tobias Hollerer, Augmented Reality: Principles and Practice, 2nd Edition, Addison-Wesley.
4. Jason Jerald, The VR Book: Human-Centered Design for Virtual Reality, ACM Books.
5. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress

SUGGESTED SKILL ACTIVITIES

Students shall complete the following laboratory and skill-oriented activities.

1. Develop a conceptual Digital Twin model for an engineering system.
2. Integrate IoT sensor data into a virtual monitoring dashboard.
3. Create an AR-based maintenance assistance prototype.
4. Design a VR-based industrial safety training simulation.

5. Visualize manufacturing workflows using Unity or other XR tools.
6. Analyze predictive maintenance using Digital Twin case studies.
7. Demonstrate remote equipment monitoring through immersive visualization.
8. Evaluate an Industrial Metaverse platform for engineering applications.
9. Design an immersive Digital Twin solution for smart manufacturing or smart infrastructure.
10. Develop a mini project integrating XR, IoT, and Digital Twin technologies to solve a real-world engineering problem.

Course Code:	**24AV702**	**Course Title:**	**AR/VR Capstone Project and Industry Applications**
Credits:	**3**	**L – T – P**	**3-0-0**
Prerequisite	**24AV701 - Industrial Metaverse, Digital Twins and XR Applications**		

Course objectives:

The course enables the students to:

- Integrate the knowledge gained in AR, VR, XR, Digital Twins, and immersive technologies to solve real-world engineering problems.
- Apply design thinking, project management, and software development methodologies to develop industry-oriented AR/VR applications.
- Analyze industrial requirements, user needs, and technical constraints for developing scalable immersive solutions.
- Develop and deploy innovative AR/VR prototypes using modern development tools, cloud platforms, and XR devices.
- Demonstrate professional, ethical, entrepreneurial, and teamwork skills through the successful completion of a capstone project

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Industry Mentoring
2. Project-Based Learning
3. Design Thinking Workshops
4. Agile Development Methodology
5. Collaborative Team Learning
6. Hands-on Development using Unity/XR Platforms
7. Industry Case Studies
8. Technical Reviews and Design Reviews
9. Prototype Demonstrations
10. Project Presentations and Viva Voce

UNIT I – PROJECT IDENTIFICATION AND REQUIREMENT ANALYSIS	**[9 hours]**

Engineering Problem Identification – Industry Requirement Analysis – User Requirement Specification – Design Thinking Process – Literature Survey – Feasibility Study – Functional and

Non-Functional Requirements – Project Planning – Agile Development Concepts – Risk Assessment – Selection of AR/VR Technology Stack.

UNIT II – SYSTEM DESIGN AND PROTOTYPE DEVELOPMENT	**[9 hours]**
System Architecture Design – User Interface and User Experience Design – Storyboarding – Asset Planning – 3D Model Integration – Scene Design – Interaction Design – Database and Cloud Integration – Digital Twin Integration – Version Control – Prototype Development – Design Review.	

UNIT III – APPLICATION DEVELOPMENT AND INTEGRATION	**[9 hours]**
AR/VR Application Development – C# Scripting in Unity – XR Interaction Toolkit – AR Foundation – Sensor and IoT Data Integration – Multimedia Integration – AI-Assisted Features – Cloud Connectivity – Testing During Development – Security and Privacy Considerations – Application Optimization.	

UNIT IV – TESTING, DEPLOYMENT AND PERFORMANCE EVALUATION	**[9 hours]**
Functional Testing – Usability Testing – User Acceptance Testing – Performance Optimization – Accessibility Evaluation – Debugging – Deployment on Mobile Devices, VR Headsets, and Cloud Platforms – Documentation – Technical Report Preparation – Intellectual Property Awareness – Entrepreneurship Opportunities.	

UNIT V – INDUSTRY APPLICATIONS, PROJECT DEMONSTRATION AND CASE STUDIES	**[9 hours]**
AR/VR Applications in Smart Manufacturing – Healthcare and Medical Training – Smart Construction and BIM – Automotive and Aerospace – Smart Agriculture – Education and Skill Development – Retail and E-Commerce – Tourism and Cultural Heritage – Industrial Metaverse Applications – Startup Case Studies – Final Project Demonstration and Technical Presentation.	

Course outcomes:

On completion of the course, the student will have the ability to:

CO1	Identify and analyze real-world engineering problems suitable for AR/VR and XR-based solutions.
CO2	Design and develop an industry-oriented immersive application using appropriate AR/VR technologies and development platforms.
CO3	Integrate Digital Twins, AI, IoT, cloud services, and real-time data into immersive engineering applications where appropriate.

CO4	Evaluate the usability, performance, scalability, and impact of AR/VR applications using standard testing and validation techniques.
CO5	Present and demonstrate a professionally developed AR/VR solution with proper technical documentation, deployment, and project management practices

COs and POs Mapping:

CO's	PO's										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
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2	1	1	1	1	2	3	-	-	-	1	2
3	1	1	1	2	2	3	-	-	-	1	2
4	1	1	1	2	2	2	-	-	-	2	2
5	1	1	1	2	2	2	-	-	-	2	2

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Evaluate	0	0	0
Create	0	0	0

TEXT BOOKS:

1. Jonathan Linowes, Augmented Reality for Developers, Packt Publishing, 2023.
2. Dieter Schmalstieg and Tobias Hollerer, Augmented Reality: Principles and Practice, 2nd Edition, Addison-Wesley, 2024.
3. Jason Jerald, The VR Book: Human-Centered Design for Virtual Reality, ACM Books.

REFERENCE BOOKS:

1. Tony Parisi, Learning Virtual Reality, O'Reilly Media.
2. Michael Grieves and John Vickers, Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems, Springer.
3. Fei Tao and Ang Liu, Digital Twin Driven Smart Manufacturing, Academic Press.
4. Alan Thorn, Unity Game Development Essentials, Packt Publishing.
5. Tomas Akenine-Möller, Eric Haines, and Naty Hoffman, Real-Time Rendering, 5th Edition, CRC Press.

SUGGESTED SKILL ACTIVITIES

Students shall complete the following laboratory and skill-oriented activities.

1. Identify an industrial or societal problem suitable for AR/VR implementation.
2. Prepare a Software Requirement Specification (SRS) and project proposal.
3. Design user interfaces, interaction flow, and immersive experience using storyboards.
4. Develop a functional AR or VR application using Unity and XR development tools.
5. Integrate 3D models, animations, multimedia, and interactive components.
6. Implement AI, IoT, or Digital Twin features wherever applicable.
7. Perform usability testing, optimize application performance, and document improvements.
8. Deploy the application on mobile devices or VR headsets and demonstrate functionality.
9. Prepare complete project documentation, technical report, user manual, and presentation.
10. Present the capstone project before an evaluation committee with a working prototype and

industry use case.

SUGGESTED CAPSTONE PROJECT DOMAINS

- Smart Manufacturing and Factory Automation
- Industrial Maintenance using AR
- Digital Twin of Engineering Systems
- Virtual Safety Training
- Medical Simulation and Healthcare
- Smart Construction and Building Information Modeling (BIM)
- Smart Agriculture
- Electrical System Maintenance
- Renewable Energy Monitoring
- Robotics and Automation
- Cultural Heritage and Virtual Museums
- Tourism and Smart City Navigation
- Automotive Assembly Training
- Disaster Management and Emergency Response
- Educational Virtual Laboratories
- Retail and Product Visualization
- Aerospace Maintenance Training
- Intelligent Transportation Systems