Glendale Unified School District

High School

November 5, 2019

Department:	Career Technical Education
Course Title:	Honors Robotics Team Project 3-4
Course Code:	5477V/5478V
Grade Level(s):	10-12
School(s) Course Offered:	Clark Magnet High School
UC/CSU Approved (Y/N, Subject):	Yes, "g" General Elective credit
Co-requisites:	AP Physics (Recommended) Computer Programming or AP Computer Programming (Recommended)
Integrated Academics: (Y/N)	Yes
Recommended Prerequisite:	Robotics Team Project 1-2 (Required)

Course Overview: Honors Robotics Team Project 3-4 is the capstone course for the Robotics pathway. This laboratory-based integrated course is designed to support and facilitate second-year student participation in the global FIRST Robotics Competition. Students enrolled in this course will have previously completed the Robotics Team Project 1-2 course. Students will build upon foundational knowledge from the prior course by performing advanced level work in the areas of engineering, manufacturing, programming, and team project management. The student- centric design of the course and physical classroom lab environment promotes collaborative learning in small teams and advanced personal skill development in specialty areas while allowing all students to be involved with all aspects of this multifaceted competitive team project. Students in this Honors Robotics Team Project 3-4 course will have the opportunity to lead, guide, and mentor first-year students in the Robotics Team Project 1-2 course while embracing a learning-by-doing approach.

Course Content-First Semester

Unit 1: **<u>Advanced Engineering Challenge Analysis</u>** *(3 weeks)*

STANDARDS
Engineering and Design
Standards C 1.0
Key Standards : 1.1, 1.2
Common Core State Standards: RLST 11-12.1, 11-12.7

A. In this unit, students will analyze an advanced engineering challenge to which they will later design a solution in the form of a robotic vehicle to compete in a sports-like tournament. The challenge will include terrain, manipulation and relocation of physical objects, and navigation within a tournament arena with an emphasis on speed, reliability, and efficiency in all aspects of addressing the challenge. Students will read and interpret a detailed set of specifications in a provided technical manual and set of more than 100 engineering drawings to gather and understand key dimensional parameters of a robot competition tournament arena including the dimensions of physical objects to manipulate, terrain obstacles such as ramps or steps, scoring locations, the arena perimeter, interactive elements, and heights of various objects above the ground plane. Using these dimensional parameters, students will understand the scope of the challenge and what types of mechanized motions will be needed to address the challenge.

B. A strong emphasis is placed on time-based motion studies including vehicle route planning, sequences of events, and game scoring strategy. Students will work in collaborative teams to simulate time-based tournament match scenarios through multiple iterations to evaluate all possible outcomes based on strategic prioritized design choices. Students will consider differences in autonomous and teleoperated modes of control while developing strategies and sequences for robotic tournament match play

Unit Assignment(s): As a whole, the class will collaboratively develop a spreadsheet listing of all key dimensional parameters of the robotics tournament arena. After working in small groups to understand the challenge and formulate strategies to address it, students will then individually present an oral defense of their findings on robot starting location, navigation routes, object manipulation, scoring strategy in both autonomous and teleoperated modes, terrain and mobility considerations, and time-based scoring potential. Students will use a projected image of the tournament arena onto a dry erase board to draw, outline, and communicate their findings, determinations, and proposed strategies. After all students have presented, the floor will be open for debate and deliberation for whatever time necessary until logical consensus is reached as to the optimal strategy to address the challenge. The deliberation is not bound by a class schedule and continues until all aspects of the challenge are thoroughly understood and analyzed, all arguments have been heard and deliberated, and consensus is reached through logical fact-based engineering findings. Through this process, students will learn how to analyze an engineering challenge and defensibly communicate strategic alternatives through the presentation of evidence-based argument

Unit 2: **Conceptual Design & Systems Thinking** *(3 weeks)*

STANDARDS

Engineering and Design
Standards: C1.0, 3.0, 4.0
Key Standards: 1.1, 3.1, 4.1
Common Core State Standards: RLST 11-12.2,

A. Prioritizing the strategies achieved by analysis and consensus in the previous unit, students will begin to conceptually design a robotic vehicle to address the challenge by using a systems thinking approach. Students will consider the vehicle as a whole while exploring the interrelatedness and interdependencies between the various onboard subsystems such as the mobility system, multiple object-manipulation mechanisms, electronics, pneumatics, and auxiliary mechanisms. Students will determine key vehicle design parameters such as length, width, height, wheelbase, track width, ground clearance, center of gravity, wheel diameter, wheel quantity, gear ratios, areas of significant loading and load paths, and placement of structures, mechanisms, and joints. Students will also determine the quantity, type, and placement of actuators including motors and pneumatic cylinders, and placement of other required hardware such as the battery and onboard computer and electronics.

B. Students will resolve conflicts between placement of subsystems while determining volumetric space allocations for each. Students will investigate and determine the path and sequence of events for the physical manipulation object to follow from the ground or receiving height into the vehicle, into an onboard storage or holding location, and out of the vehicle to the arena scoring location. An emphasis is placed on elegant design that exemplifies simplicity, robustness, and mechanical reliability while allowing for the integration of sensors and control. The possibility of multi-function mechanisms such as power take-off units that may address multiple aspects of the engineering challenge will also be explored.

Unit 3: **Computer Aided Design** *(3 weeks)*

STANDARDS
Engineering and Design
Standards C3.0, C4.0, C5.0
Key Standards 3.1, 4.1, 5.1
Common Core State Standards: LS 11-12.4

A. Building upon knowledge and experience in basic computer-aided design gained in the Robotics Team Project 1-2 course, students will employ the tools and techniques of the powerful industry-standard 3D parametric modeling software Autodesk Inventor to design a complete model of a competition robot vehicle. An emphasis is placed on product design management workflows including multi-user collaboration, integration of downloaded and original CAD data, multi-site work locations, and data organization. Students will develop original component and assembly designs based upon key parameters determined in the conceptual design phase of the project. Students will use advanced software tools such as in- assembly component editing, projected geometry, and adaptive links to establish and maintain dynamic relationships between components in assemblies. Students will learn and apply software features such as rectangular patterns, freeform modeling, work planes, and multiple visual styles while also becoming proficient with multiple keyboard shortcuts and a 3D mouse input device to enhance the design workflow.

B. Students will set mas properties for components to develop a vehicle weight estimate on an ongoing basis while also employing lightweighting strategies in the design of all custom manufactured components. The student designers, having manufacturing knowledge, will embrace the concept of design for manufacturability while optimizing features such as fillet radii, hole locations and thread sizes, allowances between mating components, and selection of mechanical components such as bushings, bearings, belts, sprockets, pulleys, gears, and fasteners. Students will become familiar with navigating mechanical component vendor catalogs as they select components to use within their design. Finally, students will explore ways to enhance the aesthetic appeal of the design through CNC machining and other strategies

Unit Assignment(s): Students will develop a complete computer-aided design model of a competition robotic vehicle. The model, comprised of a large dataset of more than 100 files, will feature dozens of custom-designed components and dozens of off-the-shelf components, joined together in an assembly using proper constraints and relationships.
Individual custom component part 3D models will be “ready for manufacture” with material, stock size selection and manufacturing method and tooling taken into consideration. Three-dimensional solid models will be accompanied by a printed

dimensioned and toleranced drawing when appropriate. The vehicle's systems will be designed to a high degree of detail including individual fasteners, all hole locations, sensor placement, mounting brackets, and electronics components. The top-level assembly file will be free from constraint errors, and all mechanisms will have a high-probability of successful function based upon the efforts taken in the CAD design.

Unit 4: **Advanced Mechanism Design** *(3 weeks)*

STANDARDS
Engineering and Design
Standards C2.0, C3.0, C6.0
Key Standards: 2.1, 3.1, 3.2, 6.1
Common Core State Standards: SEP-1,

A. In this unit, students will perform advanced and detailed design of object-manipulation mechanisms for the competition robot vehicle. The object is different each year, and in the past has been sports balls, plastic crates, Frisbees, large inflatable tubes, and other such objects. Students will select materials, specify fasteners and power transmission components, and calculate gear ratios. Students will investigate speed, torque, power, and current draw parameters related to the mechanism while selecting motors and will calculate air consumption if the mechanism is to be powered by pneumatics. A close look will be taken at specialty conforming wheels, friction and grip, and durometer of various rubber materials.

B. Through iterative testing and experimentation, students will determine key quantities such as wheel spacing, pressure, force, and compression, and flywheel speed loss and recovery time. Within the various mechanism designs, students will routinely work with mechanical design components such as springs, bearings, pulleys, belts, axles, spacers, sprockets, gears, bearings, and hinges. Students will optimize the structure of the mechanism, hinge points, and load paths to prevent failure due to dynamic loading, cyclic fatigue, abrasion, and impact.

Unit Assignment(s): Students will use off-the-shelf components selected from vendor catalogs in conjunction with custom designed structures and components to design a complete assemblage of a mechanism to successfully manipulate a specified object. The mechanism will acquire the object reliably from various approach angles and speeds, hold it securely, and deposit the object to the specified scoring area in the tournament arena in a repeatable manner. Students will submit a physical prototype proof of concept model before later submitting a complete computer-aided design model.

Unit 5: **Advanced CNC Machining** *(3 weeks)*

STANDARDS
Engineering and Design
Standards C4.0, 5.0, 6.0
Key Standards 4.2, 5.4, 5.5, 6.1
Common Core State Standards: CC - 3

A. Students will use industry standard computer-numerically controlled (CNC) full size vertical machining centers, slant bed turret lathes, and 3-axis routers to produce mechanical and structural components from aluminum alloy and polycarbonate. Students will learn how to program high-speed machining toolpaths while optimizing speeds and feeds to reduce cycle time. Toolpath strategies employed include 2D and 3D adaptive machining, contouring, drilling, tapping, facing, chamfering, pocketing, and 3D surfacing. Students will become proficient in the setup and operation of the machines including tool setup, tool loading, jogging, setting work offsets, setting tool offsets, loading the program to the machine control, and verifying the program in a graphics preview. Machine G and M codes including canned cycles will be understood to the extent necessary to interpret programs generated from CAM software and to setup and operate the machine. Students will learn how to correctly interpret a job setup sheet while analyzing key program parameters such as origin point, stock offsets, speeds and feeds, depths, stock to leave, optimal loads, and maximum stepdowns.

B. Students will learn how to set machine offsets using both advanced digital probing methods as well as classical feeler touch-off methods. Students will use a variety of workholding devices including vises, collets, fixture plates, specialty tape, and clamps to securely hold workpieces. Students will understand the concept of manufacturing tolerance, and apply appropriate precision measuring techniques using calipers, gage pins, micrometers, and height gages to verify that components produced meet the specified tolerance. Students will understand and utilize machine control cuter compensation to achieve close-tolerance precision fits of bearings in bores. Students will maintain the work area by performing machine washdowns and chip removal and topping the coolant regularly while checking its concentration using a brix refractometer. Once gaining proficiency in 3-axis milling, students will have the opportunity to explore 4 and 5 axis mill setup and programming as well as automated lathe production using a bar puller.

Unit Assignment(s): Throughout this unit, students will gain extensive hands-on guided and independent practice on machine and tooling setup and programming. Students will be given a 3D solid model of a machine component, and will then proceed to program toolpaths, generate a setup sheet and G-code file, setup the machine and tooling, and machine the component, often involving two or more setups. The student will then inspect the first-article component for dimensional accuracy and report on his or her findings. If the component passes inspection, additional quantity of the same component will be produced. Over the course of the robot manufacturing project, the class as a whole typically produces in excess of 50 unique parts, each requiring tool path programming and machine setup, frequently with multiple operations and setups for each component.

Unit 6: **Advanced Electrical & Controls Wiring** *(3 weeks)*

STANDARDS
Engineering and Design
Standards C5.0, C6.0, C7.0
Key Standards 5.1, 6.1, 7.1
Common Core State Standards: LS 11-12.5, RLST 11-12.4

A. In this unit, students will build upon their basic understanding of dc circuits by learning how to wire controls systems. Students will learn the difference between analog and digital signals and will learn how to properly install wiring for a linear topology CAN bus circuit including specialized JST connectors. Due to the daisy-chain topology and single-point failure nature of the CAN bus network, inspection and reliability in crimping and wiring techniques is strongly emphasized.

B. Additionally, students will learn how to wire PWM signals including fabricating cabling to custom length. Finally, students will learn how to wire various sensors such as mechanical switches, hall effect sensors, ultrasonic sensors, gyros, and accelerometers involving different voltages and signal types.

Unit Assignment(s): Students will apply appropriate techniques of cutting, stripping, crimping, and routing to assemble a multi-device CAN bus network. Additionally, students will install signal-level wiring to a robotic vehicle's onboard sensors using various gauges and types of wire. Finally, students will install wiring between multiple digital switch inputs and an interface controller on the robot operator's console board. Students will follow proper color conventions and wire terminations and employ use of strain reliefs for system reliability. Students will verify functionality and configuration of all connected electronics, sensors, and modules through software-driven testing procedures and visual quality inspections.

Unit 7: **Advanced Controls Systems and Software Development** *(4 weeks)*

STANDARDS
Engineering and Design
Standards C3.0, C4.0,
Key Standards 3.2, 4.1, 4.2
Common Core State Standards: LS 11-12.3, RSL 11-12.4, ETS2.A

A. In this unit, students will build upon their understanding of basic controls systems and software from the Robotics Team Project 1-2 course by implementing advanced software and controls algorithms. Students will use various code libraries as well as custom functions to successfully implement and tune proportional integral derivative feedback-based control loops. Students will perform iterative testing and refinement of PID control loops to determine optimized gain constants for maximum vehicle performance. Students will utilize a variety of sensors such as quadrature encoders, gyros, and accelerometers to provide sensory input to the software control algorithms.

B. Additionally, students will develop code that utilizes time-based and equation-based acceleration and deceleration curves and throttle profiles to reduce shock loading to the robotic vehicle's mobility system and mechanisms while offering the operator a high degree of fidelity in control.

C. Finally, students will experiment with camera vision and real time image processing using an onboard computer. Students will write code and configure settings to allow the vision subsystem to recognize specific objects or vision targets on a frame-by-frame basis in streaming video from the onboard camera. This data will then be passed to PID loops to control the vehicle's movements and actions. Students will experiment with multi-threading strategies to reduce latency and improve response in control.

Unit 8: **Traditional 3D Design** *(3 weeks)*

STANDARDS
Engineering and Design
Standards 8.0, 9.0
Key Standards 8.1, 8.2, 9.1
Common Core State Standards:, G-MG-1, G-GMD-5

A. Students will learn about various techniques for conceptualizing art in three dimensions. Students will learn how to create two dimensional designs that consider three dimensional space. They will then use a variety of physical materials to create tangible designs.

B. Students will create an original design of a fictional or mythological animal. They will observe reference images of animals and combine anatomical elements to create original forms. Students will consider multiple angles and perspectives to visualize their design. They will then build a physical model that adheres to that design. Students will analyze and reflect upon the process of conceptualizing art in both two and three dimensional spaces through written and verbal critique.

Unit Assignment(s): Using a competition robot vehicle, students will write and demonstrate the function of an advanced control system code that uses tuned PID loops to perform the following functions:

Uses gyro data to maintain direction heading and make accurate turns Uses quadrature encoder data to allow a motor-driven mechanism to reach multiple set points while avoiding overshoot and oscillation. Uses camera vision to acquire and track a predefined target or object.

Students will verbally describe the structure and function of the code while coherently detailing how sensor data is taken in and processed and how it is used to drive outputs. Students will explain the development and testing process used to reach the completed code and will make recommendations for future enhancements to the code.

Unit 9: **Collaborative Project Leadership & Management** *(3 weeks)*

STANDARDS
Engineering and Design
Standards 11.0
Key Standards 11.1, 11.2
Common Core State Standards: WS- 11-12.2, 11-12.3

A. In this unit, students will learn how to set SMART goals, how to structure and schedule goals into weekly tasks and objectives, and how to lead others in the acquisition of new technical knowledge. Students in this Honors Robotics Team Project 3-4 class will serve as sub-team leaders and student mentors to students in the Robotics Team Project 1-2 class. Students will understand the meaning and value of their own contributions in the bigger picture of the collaborative team projects while developing personal mastery of specific technical skills by teaching others.

B. Students will learn to delegate and oversee work within their sub-teams while maintaining quality and timeliness in the work of the team as a whole. Student leaders will demonstrate and practice professionalism in the lab work environment while serving as role models for others. Students will realize the interdependencies between project sub-teams and will frequently communicate with adult volunteer mentors and other student sub-team leaders to resolve conflicts in project work scheduling. Students will set project milestones which represent major hard deadlines for their sub-team work, and will reflect upon their performance in meeting these milestones.

Unit Assignment(s): Sub-team SMART goals, including a written description of how the goals meet the SMART criteria. Fall training weekly calendar, indicating specific objectives and deliverables. Collaboratively-developed project Gantt chart. This chart will reflect every calendar day of a six-week period of time during which the robotic vehicle is designed, manufactured, assembled, and tested. Every discrete step and task needed in the production of the robot vehicle will be indicated, sequenced, and scheduled. Students will color code date ranges to show early, on-time, and late scheduling and will indicate hard cutoff dates at which milestones must be completed for the project's success. Performance review. Twice annually, students will participate in an individual performance review meeting with the lead instructor and adult team mentors to analyze and reflect upon his or her performance as a student sub-team leader.

Unit 10: **<u>Professional Communications & Presentation</u>** *(3 weeks)*

STANDARDS
Engineering and Design
Standards 11.0
Key Standards 11.1, 11.2
Common Core State Standards: WS- 11-12.2, 11-12.3 , SEP-6, SEP- 7

A. In this unit, students will gain extended practice in written and verbal professional communication. Students will learn how to write and speak in and clear, coherent, and logical way that engages the audience. Students will learn to consider the audience to whom they are presenting and adapt their writing or speaking accordingly. Students will maintain a professional tone in both writing and speaking and gain confidence in interacting with adults.

Unit Assignment(s):
Students will complete the following activities and assignments during this unit:
Chairman's Award Submission Essay – Students will write a 10,000 character formal essay detailing the efforts of our school's robotics team during the past three years. The essay will describe the team's technical accomplishments, community involvement, and personal accomplishments within its own student population and alumni. Woodie Flowers Award Submission Essay – Students will write a 3,000 character essay describing their interaction with one of our team's volunteer adult mentors and how that mentor has inspired a respect and appreciation for engineering through excellent communication. Lab tour – students will guide distinguished guest visitors through a 15-minute tour of our engineering, robotics, and advanced manufacturing lab space. Students will describe the classes and projects that utilize the space as well as the various types of equipment

and technologies the space includes. Community Event Presentation – Students will present to members of the general public within the local community including individuals of all age ranges and backgrounds. Students will set up a display booth and interact with visitors to inform them about our school's robotics team, competitive educational robotics, and STEM education and careers. Vehicle Technical Presentation – At the competition events, students will present the robotic vehicle's design, manufacturing, mechanisms, and controls to a series of judges who are professional engineers working in industry. Students will detail the design's concept and implementation while describing and demonstrating the vehicle's functions and unique attributes.

Chairman's Award Presentation – Students will prepare for and deliver a seven minute formal presentation to a panel of judges. The presentation may include visual aids but cannot use notes. The presentation will outline the team's major accomplishments within its own student body and local community within the past three years.

Unit 11: **Vehicle Performance Tuning and Mechanism Iteration** *(3 weeks)*

STANDARDS
Engineering and Design
Standards C3.0, C8.0, C9.0
Key Standards 3.1, 8.1, 8.2, 9.1, 9.2
Common Core State Standards: G-MG-3, SEP-4,SEP-5

A. After the robotic vehicle and preliminary control software is complete, students will perform extensive performance testing, tuning, and refinement to the vehicle's mechanical and software systems through a process of full-scale vehicle testing and iteration. Students will follow the scientific method while testing for reliability and repeatability of performance outcomes while changing only one variable factor at a time. Students will document and analyze results and make recommendations for improving the vehicle's function either by further software development, redesign of mechanical components or systems, or both.

Unit Assignment(s): Students will submit an engineering testing log book that details the parameters and results of each iterative test. The log will demonstrate an understanding of the scientific testing process, exploration of the effects of multiple variable factors on overall performance outcomes, and convergence upon optimized results

Unit 12: **Visual Media Production** *(3 weeks)*

STANDARDS
Engineering and Design
Standards C3.0, C4.0
Key Standards 3.1, 4.1
Common Core State Standards: LS 11-12.3, RSL 11-12.7

A. Using a collection of raw still and video images gathered from the Robotics Team Project 1-2 class, students in the Robotics Team Project 3-4 class will edit and produce the images into finished works. Students will follow server-based workflows while managing and organizing extensive sets of digital media files. Students will learn how to use Adobe Premier, Adobe After Effects, and/or Avid Media Composer software to import, cut, and sequence still images and video footage while learning nonlinear nondestructive editing techniques. Students will apply the fundamentals of sequencing, audio level adjustment, timing, music selection, color correction, and other post-production strategies to produce finished works made of multiple scenes, stills, or sequences. An emphasis will be placed on creating finished works that not only are of professional quality, but also appeal to the viewer's emotions.

Unit Assignment(s):

Chairman's Award video – Students will produce a three minute video outlining the team's major accomplishments within the local community and its own student body. The video will feature multiple scenes, a written script, and voice overs.

Robot reveal video – This one minute video will feature multiple camera angles including wide shots, close shots, panning shots, and onboard video to detail the robotic vehicles design, mechanisms, functions, and movements.

End of year slideshow – This ten minute video slideshow will consist of at least 100 images chronicling the team's work over the school year. The video will feature the best photographs of thousands taken to tell the story of both struggle and success. Every student and every adult must be featured in at least one photograph. The slideshow will be broken up by major events or periods of the school year such as fall training, community events, build season, and competition, will be correlated to appropriate music, and will employ effective titles and transitions.

Honors Final Exam Details:

Students will document their progress on a weekly basis to incrementally work towards building a technical portfolio that will be turned in at the end of the year. Students will describe challenges, successes, and next steps in each work log entry. A strong emphasis is placed on organizing both written and visual evidence of tangible work products and/or processes in detail. The evidence gathered will show the project work at various stages of completion over a significant duration of time, indicating a progression of skills from intermediate to mastery level as documented not only by a weekly work log, but also by strong photographic and other visual evidence of work performed over time. Photos and images will be captioned, and the portfolio should also include significant technical vocabulary and detailed descriptions of systems and processes such that the outside observer would be able to gain a clear and comprehensive understanding of the work performed. The portfolio will feature a table of contents and page numbers. All documents in the portfolio will be type-written with the exception of original field-testing notes and will be professionally printed in a V-folded and stapled format. The printed portfolio may be supplemented by but not supplanted by digital or physical work when appropriate. The portfolio will conclude in an essay in which the student reflects upon his or her experience with the robotics team project over the prior year and discusses what worked, what didn't, and what recommendations should be considered for continuing work by students in the following year.