PHYSICS 170 MECHANICS 1: Final Exam: 8:30 AM, Thursday, April 20, 2023

INSTRUCTIONS

Answer all questions in the answer booklets that are provided. Please ensure that your name, student number and lecture section are written clearly on the front page of each booklet you use.

Read each question completely and carefully before starting to answer it.

You have two- and one-half hours to complete the exam.

You may write with pen and/or pencil.

MARKS

This exam counts for a total of 60 marks towards your Final Grade for the course.

The exam consists of 4 questions, each worth 15 marks, for a total of 60 marks. You should allocate roughly 30 minutes for each question.

NUMERICAL ANSWERS

You must write numerical answers correctly to three significant figures, with correct units and using engineering notation with an appropriate SI prefix (as necessary) to get full marks for your numerical answers.

No marks are awarded for correctly solving incorrect equations.

INFORMATION SHEET

You may consult one 8 ½ by 11-inch hand-written double-sided Information Sheet.

Your Information Sheet must not contain any sample problems or solutions to sample problems.

Put your name and student number on your Information Sheet, and sign it.

You must hand in your Information Sheet with your answer booklet in order for your exam to be marked.

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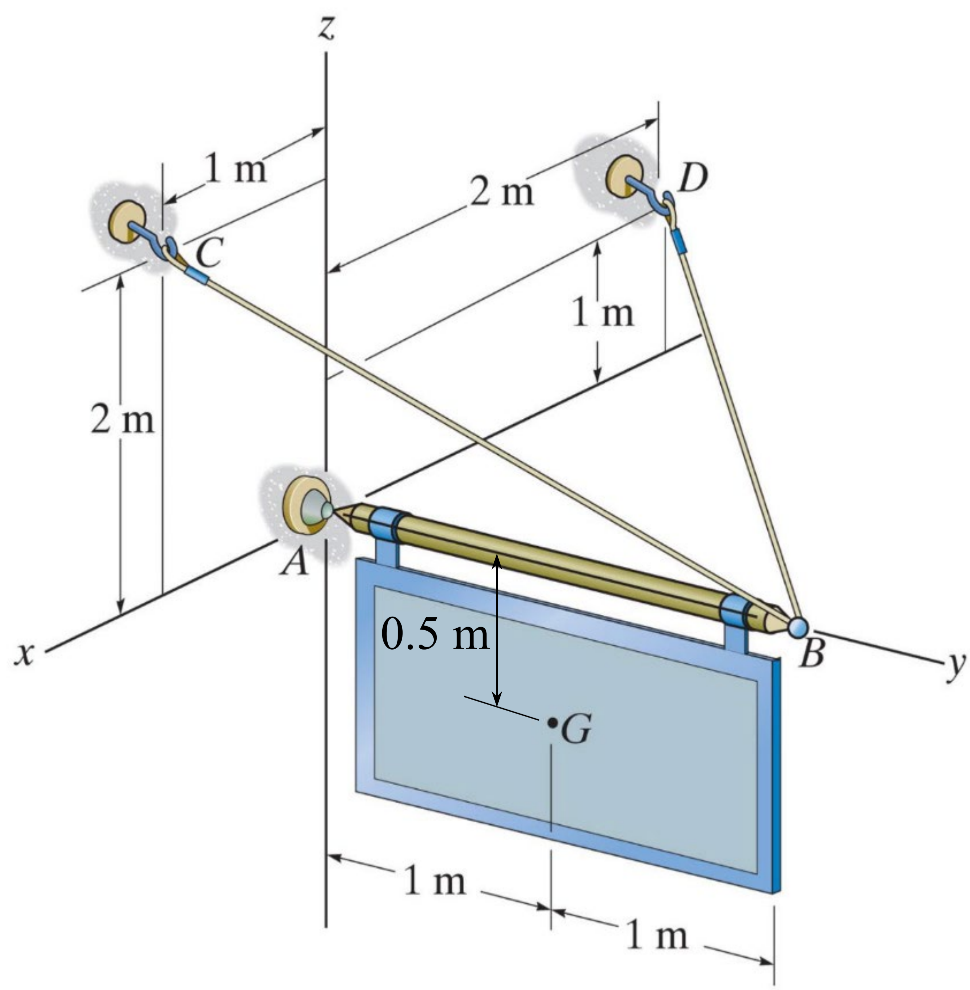
QUESTION 1 (15 marks)

The diagram below shows a rigid body *AB* which supports a 100 kg sign, and which is itself supported in equilibrium by <u>two cables</u> (*BC* and *BD*) and at *A* by a <u>ball-and-socket joint</u>. The weight of the sign acts at its center of mass, *G*. The weight of *AB* can be neglected. In the following, *ABG* refers to *AB* together with the supported sign: *ABG* is to be considered a single rigid body.

a) Draw a large, clear free-body diagram for *ABG.* (4 marks)
b) Determine Cartesian component force equations of equilibrium for *ABG*. (4 marks)
c) Determine a vector moment equation of equilibrium in determinant form for *ABG*. <u>Take moments about *A*</u>. (2 marks)
d) Determine Cartesian component moment equations of equilibrium for *ABG*. (3 marks)
e) Determine numerical values for the Cartesian components of reaction at *A* and the tensions in the cables. (2 marks)



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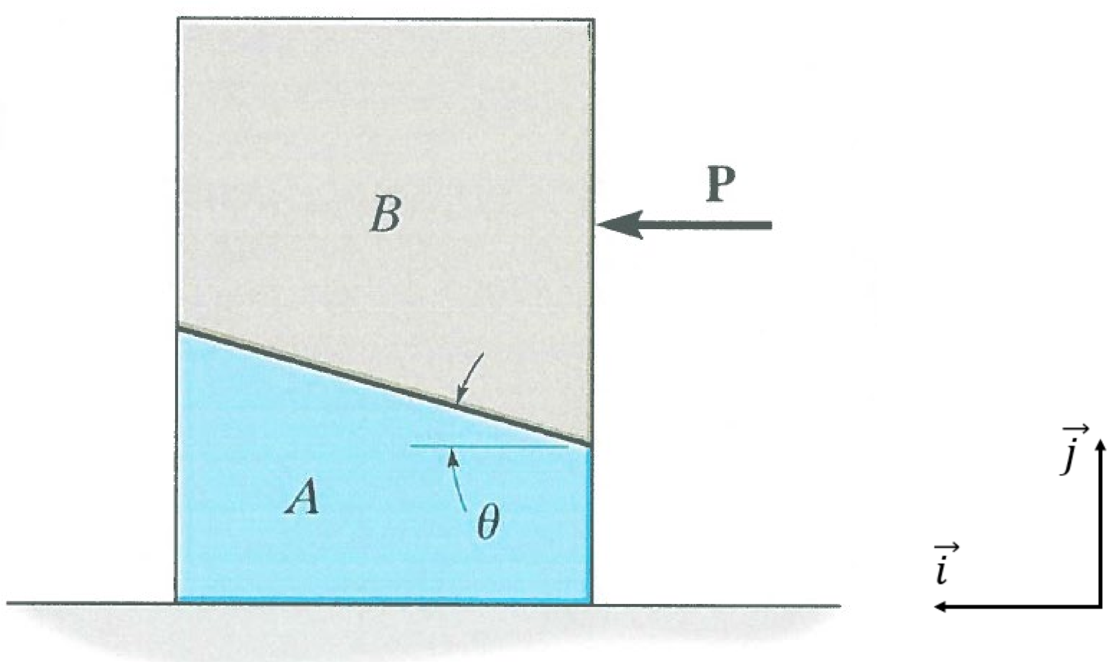
QUESTION 2 (15 marks)

In the diagram below, block A rests on a smooth horizontal surface and block B rests on the smooth inclined surface of block A. The mass of A is 5 kg, and the mass of B is 10 kg. The angle θ is 20°. Friction between A and the horizontal surface and between A and B may be neglected. A force $\vec{P}$ of magnitude 150 N acts on B. Both blocks move to the left. The magnitude of the acceleration of B relative to A is 3.2657 m/s^2. This value is supplied to you to help you solve the system of equations that arises in the solution of the problem. Beware of spending too much time trying to solve that system.

a) Draw two large, clear free-body diagrams, one for each block. (6 marks)
b) Determine equations of motion for each block. Use the axes shown in the diagram. (6 marks)
c) Determine numerical values for the acceleration of A, the normal force between A and B, and the normal force between A and the horizontal surface. (3 marks)



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QUESTION 3 (15 marks)

In the diagram below, the 2.0 kg roller R travels over the curved cam (guide) due to the counter-clockwise rotation of the forked arm. Motion is in the vertical plane. The smooth surface of the cam is defined in part by the curve $r = (0.2\sin\theta + 0.1)$ m . The spring which is attached to the roller and the base of the cam has a spring constant k = 30 N/m and an unstretched length of 0.1 m. There is no friction in the problem.

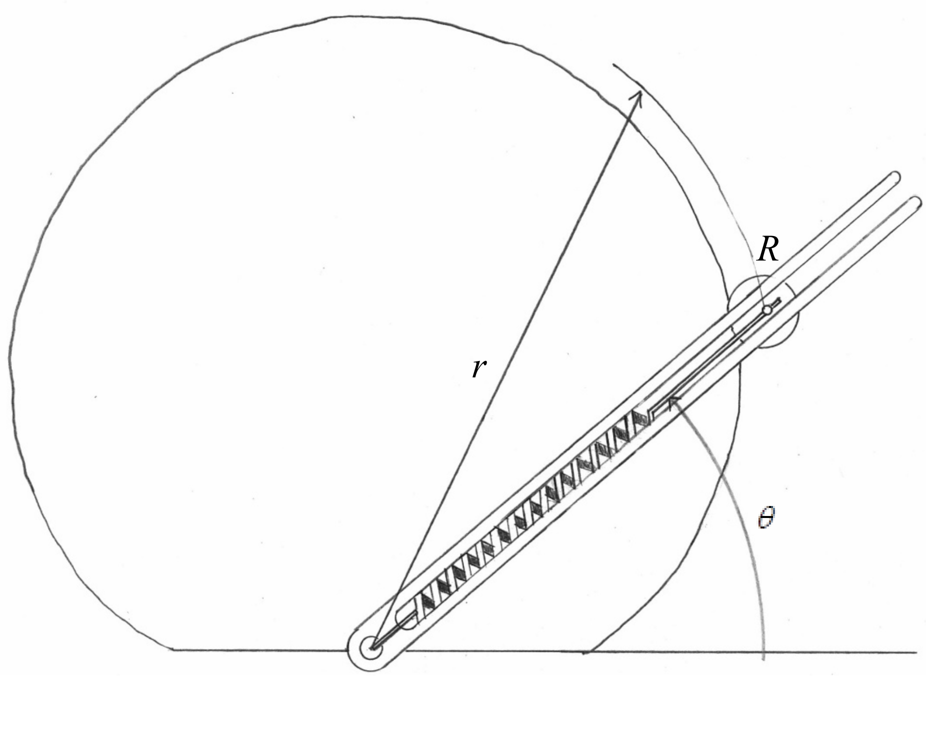
Note that in the diagram r labels the radial distance from the base of the cam to the center of the roller. The actual radial axis passes through the attachment point of the spring on the base of the cam, and the center of the roller, R (i.e. along the spring, whose stretched length is r).

At the instant shown:

$\theta = 40.000^\circ$ $\quad\dot{\theta} = 4.0000$ rad/s $\quad\ddot{\theta} = 0.0000$ rad/s^2

$r = 0.22856$ m $\quad\dot{r} = 0.61284$ m/s $\quad\ddot{r} = -2.0569$ m/s^2 $\quad dr/d\theta = 0.15321$ m

a) Draw a large, clear free body diagram for R at the instant shown. (4 marks)
b) Determine the angle, ψ, between $\vec{u}_r$ and $\vec{u}_t$ at the instant shown. (2 marks)
c) Determine numerical values for the radial and transverse (polar) components of the acceleration of R at the instant shown. (2 marks)
d) Determine radial and transverse (polar) component equations of motion for R at the instant shown. (4 marks)
e) Determine numerical values for the magnitude of the force on R from the arm and the magnitude of the normal force on R at the instant shown. (3 marks)



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QUESTION 4 (15 marks)

The diagram below shows two blocks A and B connected by a rope of fixed length. Block A rests on an inclined plane. Block B hangs vertically and touches the top of the uncompressed spring. The mass of A is 6 kg, and the mass of B is 10 kg. The spring constant is 20 N/m. The coefficient of kinetic friction between A and the inclined plane is 0.3. The masses of the pulleys and the rope may be neglected. Friction in the pulleys may be neglected.

The blocks are released from rest at $t = t_1$. Block B moves down, compressing the spring. Block A moves up the plane.

At some instant $t = t_2$ the blocks continue in motion and block B has compressed the spring 2 m.

a) Draw a large, clear free-body diagram for each block at $t = t_2$ (4 marks)

b) Determine the principle of work and energy equation that relates the energies of block A at times t_1 and t_2. (4 marks)

c) Determine the principle of work and energy equation that relates the energies of block B at times t_1 and t_2. (4 marks)

d) Determine the numerical value of the speed of block A at $t = t_2$ and the tension in the rope. (3 marks)