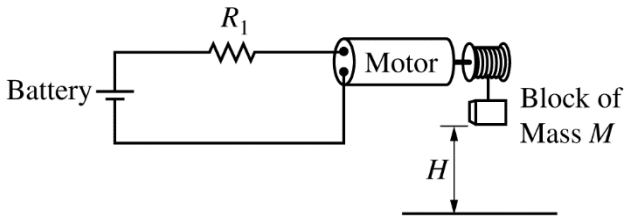

4. (7 points, suggested time 13 minutes)

A motor is a device that when connected to a battery converts electrical energy into mechanical energy. The motor shown above is used to lift a block of mass M at constant speed from the ground to a height H above the ground in a time interval Δt. The motor has constant resistance and is connected in series with a resistor of resistance R_1 and a battery.

Mechanical power, the rate at which mechanical work is done on the block, increases if the potential difference (voltage drop) between the two terminals of the motor increases.

(a) Determine an expression for the mechanical power in terms of M, H, Δt, and physical constants, as appropriate.

(b) Without M or H being changed, the time interval Δt can be decreased by adding one resistor of resistance R_2, where $R_2 > R_1$, to the circuit shown above. How should the resistor of resistance R_2 be added to the circuit to decrease Δt ?

___ In parallel with the battery

___ In parallel with R_1

___ In parallel with the motor

___ In series with the battery, R_1, and the motor

In a clear, coherent, paragraph-length response that may also contain figures and/or equations, justify why your selection would decrease Δt.

AP® PHYSICS 1
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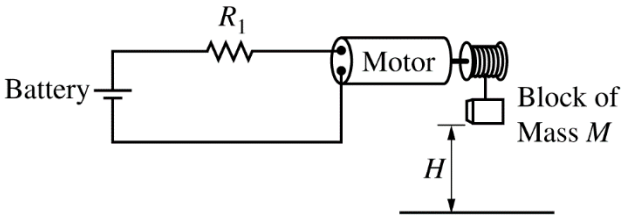
Question 4

7 points



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Mechanical power, the rate at which mechanical work is done on the block, increases if the potential difference (voltage drop) between the two terminals of the motor increases.

(a) LO 5.B.5.5, SP 2.2
2 points

Determine an expression for the mechanical power in terms of M, H, Δt, and physical constants, as appropriate.

For an expression that implies reasoning in terms of energy (as opposed to e.g., kinematics)		1 point
Example: MgH		
For a correct expression for the power generated by the motor lifting the block at constant speed		1 point
$MgH/\Delta t$		

(b) LO 5.B.9.2, SP 4.2, 6.4, 7.2; LO 5.B.9.3, SP 6.4, 7.2
5 points

Without M or H being changed, the time interval Δt can be decreased by adding one resistor of resistance R_2, where $R_2 > R_1$, to the circuit shown above. How should the resistor of resistance R_2 be added to the circuit to decrease Δt ?

___ In parallel with the battery ___ In parallel with R_1 ___ In parallel with the motor ___ In series with the battery, R_1, and the motor

In a clear, coherent, paragraph-length response that may also contain figures and/or equations, justify why your selection would decrease Δt.

Correct answer: "In parallel with R_1"		
Note: If the wrong selection is made, the justification may still earn credit.		

Question 4 (continued)

(b) (continued)

For a justification that correctly asserts that power must increase for Δt to decrease, or correctly asserting that the faster the rate of energy transfer means that works gets done in a smaller time interval		1 point
For a correct assertion that current increases as resistance of the circuit decreases *Alternate Method: Potential difference across the parallel resistors will decrease if their resistance decreases.*		1 point
For making the connection that there is an increase in current specifically in the motor because it is the same as the total current in the circuit *Alternate Method: There is an increase in potential difference specifically across the motor because the potential difference across the parallel resistors decreases (Kirchhoff's loop rule).*		1 point
For a justification that indicates that connecting R_2 in parallel with R_1 will decrease the equivalent resistance of the circuit		1 point
For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response		1 point

Example Paragraph Response 1: The work required to lift the block is *MgH*, so the rate at which the motor must do work to lift the block in the given time is $W/\Delta t = MgH/\Delta t$. The rate at which the motor does work increases with the potential difference across the motor (Note: This information is given in the question, so no points allotted in rubric for this statement.) To decrease the time, the motor must increase the rate at which the work is done, which requires a larger potential difference across the motor (or a larger current through the motor because $\Delta V = IR$). To increase the potential difference across the motor, the potential difference across R_1 must decrease, by Kirchhoff's loop rule (for a loop containing the battery, the motor and R_1). When R_2 is placed in parallel with R_1 the equivalent resistance of the combination decreases and the potential difference across that section decreases.		
Example Paragraph Response 2: Resistor R_2 should be connected in parallel with R_1. This will result in a smaller equivalent resistance in series with the battery and motor, so the current in the circuit (and through the motor) will be larger. The larger motor current results in the motor having a higher mechanical power. Because this power $MgH/\Delta t$ is larger and *MgH* is constant, the time interval Δt will be smaller.		

Question 4 (continued)

Learning Objectives

LO 5.B.5.5: The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance. [See Science Practices 2.2, 6.4]

LO 5.B.9.2: The student is able to apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule ($\Sigma\Delta V = 0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches. [See Science Practices 4.2, 6.4, 7.2]

LO 5.B.9.3: The student is able to apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. [See Science Practices 2.2, 6.4, 7.2]