UNIVERSITI MALAYSIA PERLIS

Peperiksaan Akhir Semester Pertama
Sidang Akademik 2025/2026

Januari - Februari 2026

AMJ21003 – Thermodynamics
[Termodinamik]

Masa: 3 Jam

Please make sure that this question paper has **TWELVE (12)** printed pages, including this front page before you start the examination.
*[Sila pastikan kertas soalan ini mengandungi **DUA BELAS (12)** muka surat yang bercetak termasuk muka hadapan sebelum anda memulakan peperiksaan ini].*

This question paper has **TWO (2)** sections, **SECTION A** and **SECTION B.** Answer **ALL** questions from **SECTION A** and any **ONE (1)** question from **SECTION B.**
*[Kertas soalan ini mengandungi **DUA (2)** bahagian, **BAHAGIAN A** dan **BAHAGIAN B.** Jawab **SEMUA** soalan daripada **BAHAGIAN A** dan mana-mana **SATU (1)** soalan dari **BAHAGIAN B**].*

SECTION A : This section has **FOUR** questions. Please answer **ALL** questions.
BAHAGIAN A *: Bahagian ini mengandungi **EMPAT** soalan. Sila jawab **SEMUA** soalan.*

Question 1
[Soalan 1]

(a) A can of soft drink at room temperature is put into the refrigerator so that it will cool. Would you model the can of soft drink as a closed system or as an open system? Explain.
[Satu tin minuman ringan pada suhu bilik diletakkan ke dalam peti sejuk supaya ia menjadi sejuk. Adakah anda akan memodelkan tin minuman ringan tersebut sebagai sistem tertutup atau sistem terbuka? Jelaskan.]

(4 Marks/ *Markah*)

(b) A 4 kW resistance heater in a water heater runs for 3 hours to raise the water temperature to the desired level. Determine the amount of electric energy used in both unit kWh and kJ.
[Sebuah pemanas rintangan 4 kW dalam pemanas air beroperasi selama 3 jam untuk menaikkan suhu air ke tahap yang dikehendaki. Tentukan jumlah tenaga elektrik yang digunakan dalam unit kWh dan kJ.]

(4 Marks/ *Markah*)

(c) A gas is contained in a vertical, frictionless piston-cylinder device as shown in Figure Q1(c). The piston has a mass (m_p) of 3.2 kg and a cross-sectional area (A) of 35 cm^2. A compressed spring above the piston exerts a force of 150 N on the piston. If the atmospheric pressure (P_{atm}) is 95 kPa, determine the pressure inside the cylinder.
[Satu gas dimuatkan dalam peranti piston-silinder menegak yang tanpa geseran seperti dakam Rajah Q1(c). Piston mempunyai jisim (m_p) 3.2 kg dan luas keratan rentas (A) 35 cm^2. Spring mampat di atas piston memberikan daya 150 N pada piston. Jika tekanan atmosfera (P_{atm}) ialah 95 kPa, tentukan tekanan di dalam silinder.]

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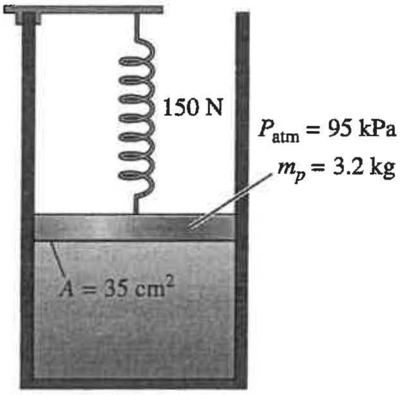

Figure Q1(c) : Piston-cyclinder device
[Rajah S1(c): Peranti piston-silinder]

(6 Marks/ *Markah*)

(d) A geothermal pump is used to pump brine whose density is 1050 kg/m^3 at a rate of 0.3 m^3/s from a depth of 200 m as shown in Figure Q1(d). For a pump efficiency of 74 %, determine the required power input to the pump. Disregard frictional losses in the pipes, and assume the geothermal water at 200 m depth to be exposed to the atmosphere.
[Sebuah pam geoterma digunakan untuk mengepam larutan garam yang ketumpatannya 1050 kg/m³ pada kadar 0.3 m³/s dari kedalaman 200 m seperti dalam Rajah S1(d). Bagi kecekapan pam 74%, tentukan kuasa input yang diperlukan oleh pam. Abaikan kehilangan geseran pada paip, dan anggap air geoterma pada kedalaman 200 m terdedah kepada atmosfera.]

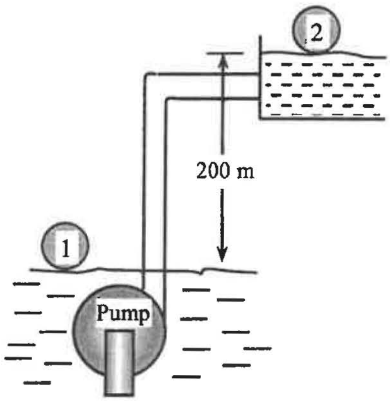

Figure Q1(d) : A geothermal pump
[Rajah S1(d): Sebuah pam geoterma]

(6 Marks/ *Markah*)

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Question 2
[Soalan 2]

(a) A piston-cylinder device contains 0.005 m^3 of liquid water and 0.9 m^3 of water vapor in equilibrium at 600 kPa. Heat is transferred at constant pressure until the temperature reaches 200°C.
[Peranti piston-silinder mengandungi 0.005 m^3 air cecair dan 0.9 m^3 wap air dalam keadaan keseimbangan pada 600 kPa. Haba dipindahkan pada tekanan malar sehingga suhu mencapai 200°C.]

(i) Determine the initial temperature of the water.
[Tentukan suhu awal air tersebut.]

(2 Marks/ *Markah*)

(ii) Determine the total mass of the water.
[Tentukan jumlah jisim air tersebut.]

(3 Marks/ *Markah*)

(iii) Calculate the final volume.
[Hitungkan isipadu akhir.]

(3 Marks/ *Markah*)

(iv) Show the process on a *P-v* diagram with respect to saturation lines.
[Tunjukkan proses tersebut pada rajah P-v berkenaan dengan garis ketepuan.]

(2 Marks/ *Markah*)

(b) A vertical piston cylinder-device contains water and is being heated on top of a range. During the process, 65 Btu of heat is transferred to the water, and heat losses from the side wall amount to 8 Btu. The piston rises as a result of evaporation, and the 5 Btu of work is done by the vapor. Determine the change in the energy of the water for this process.
[Sebuah peranti piston-silinder menegak mengandungi air dan dipanaskan di atas dapur. Semasa proses, 65 Btu haba dipindahkan ke air, dan kehilangan haba dari dinding sisi berjumlah 8 Btu. Piston naik akibat pengewapan, dan 5 Btu kerja dilakukan oleh wap. Tentukan perubahan tenaga air bagi proses ini.]

(5 Marks/ *Markah*)

(c) An object whose mass is 100 kg is located 20 m above a datum level in a location where standard gravitational acceleration exists. Calculate the total potential energy, in kJ, of this object.
[Sebuah objek yang mempunyai jisim 100 kg terletak 20 m di atas aras rujukan di lokasi di mana pecutan graviti piawai wujud. Tentukan jumlah tenaga keupayaan objek ini dalam kJ.]

(5 Marks/ *Markah*)

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Question 3
[Soalan 3]

(a) Discuss the different mechanisms for transferring energy to or from a control volume.
[Bincangkan mekanisme yang berbeza untuk memindahkan tenaga ke atau dari isipadu kawalan.]

(4 Marks/ *Markah*)

(b) An air compressor compresses 6 L of air at 120 kPa and 20 °C to 1000 kPa and 400 °C. Calculate the flow work, in kJ/kg, required by the compressor.
[Pemampat udara memampatkan 6 L udara pada 120 kPa dan 20 °C hingga 1000 kPa dan 400 °C. Kira kerja aliran, dalam kJ/kg, yang diperlukan oleh pemampat.]

(6 Marks/ *Markah*)

(c) Explain how do the energies of a flowing fluid and a fluid at rest compare by identifying the specific forms of energy associated with each case.
[Terangkan bagaimana tenaga bendalir yang mengalir dan bendalir dalam keadaan rehat dengan membandingkan bentuk tenaga tertentu yang berkaitan dengan setiap kes.]

(4 Marks/ *Markah*)

(d) A house is maintained at 1 atm and 24 °C, and warm air inside a house is forced to leave the house at a rate of 90 m^3/h as a result of outdoor air at 5 °C infiltrating into the house through the cracks. Assess the rate of net energy loss of the house due to mass transfer.
[Sebuah rumah dikekalkan pada 1 atm dan 24 °C, dan udara panas di dalam rumah terpaksa meninggalkan rumah pada kadar 90 m^3/j akibat udara luar pada 5 °C menyusup masuk ke dalam rumah melalui celah-celahnya. Nilai kadar kehilangan bersih tenaga rumah akibat pemindahan jisim.]

(6 Marks/ *Markah*)

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Question 4
[Soalan 4]

(a) Discuss how a steady-flow system is characterized.
[Bincangkan bagaimana sistem aliran tetap dicirikan.]

(4 Marks/ *Markah*)

(b) Steam is accelerated by a nozzle steadily from a low velocity to a velocity of 280 m/s at a rate of 2.5 kg/s. If the temperature and pressure of the steam at the nozzle exit are 400 °C and 2 MPa, examine the exit area of the nozzle.
[Stim dipercepatkan dengan muncung secara berterusan daripada halaju rendah kepada halaju 280 m/s pada kadar 2.5 kg/s. Jika suhu dan tekanan stim pada keluar muncung ialah 400 °C dan 2 MPa, kira kawasan keluar muncung.]

(6 Marks/ *Markah*)

(c) Explain whether the temperature of air will rise or not as it is compressed by an adiabatic compressor.
[Terangkan sama ada suhu udara akan meningkat atau tidak kerana ia dimampatkan oleh pemampat adiabatik.]

(4 Marks/ *Markah*)

(d) Steam is compressed by an adiabatic compressor from 0.2 MPa and 150 °C to 0.8 MPa and 350 °C at a rate of 1.30 kg/s. Calculate the power input to the compressor.
[Stim dimampatkan oleh pemampat adiabatik daripada 0.2 MPa dan 150 °C kepada 0.8 MPa dan 350 °C pada kadar 1.30 kg/s. Kirakan input kuasa kepada pemampat.]

(6 Marks/ *Markah*)

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SECTION B: This section has **TWO (2)** questions. Please answer any **ONE (1)** of the questions.
*BAHAGIAN B: Bahagian ini mengandungi **DUA (2)** soalan. Sila jawab mana-mana **SATU (1)** soalan.*

Question 5
[Soalan 5]

An environmental engineering firm is evaluating heat pump systems for two applications. The first system maintains a laboratory at 295 K with a heating capacity of 32,000 kJ/h while consuming 1.8 kW of electrical power. The second system heats an air-tight houseusing a heat pump with coefficient of performance (COP) 2.8 and 5 kW power input. The house initial temperature is 7 °C and needs heating to 22 °C, with its contents thermally equivalent to 1,500 kg of air. Based on this scenario, answer the following:
[Sebuah firma kejuruteraan alam sekitar menilai dua sistem pam haba untuk aplikasi berbeza. Sistem pertama mengekalkan suhu makmal pada 295 K dengan kapasiti pemanasan 32,000 kJ/jam sambil menggunakan 1.8 kW kuasa elektrik. Sistem kedua memanaskan rumah kedap udara menggunakan pam haba COP 2.8 dengan input kuasa 5 kW. Suhu awal rumah ialah 7 °C dan perlu dinaikkan ke 22 °C, dengan kandungan termalnya setara dengan 1,500 kg udara. Berdasarkan senario ini, jawab yang berikut:]

(a) For the laboratory heat pump, determine the minimum temperature of the heat source that complies with the Second Law of Thermodynamics.
[Bagi pam haba makmal, tentukan suhu minimum sumber haba yang mematuhi Hukum Kedua Termodinamik.]

(8 Marks/ *Markah*)

(b) Evaluate the time required for the residential heat pump to achieve the specified temperature rise in the house.
[Kira masa yang diperlukan oleh pam haba kediaman untuk mencapai kenaikan suhu yang ditetapkan di dalam rumah.]

(8 Marks/ *Markah*)

(c) Discuss whether the calculated time in (b) is realistic or optimistic, providing justification.
[Bincangkan sama ada masa yang dikira dalam (b) realistik atau optimistik, dengan justifikasi.]

(4 Marks/ *Markah*)

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Question 6
[Soalan 6]

A group of environmental engineers has been tasked with assessing the feasibility of a small-scale renewable energy system for a coastal environmental research station. The proposed system aims to utilise the naturally occurring temperature gradient in ocean water as a heat source and heat sink for a theoretical heat engine. Surface seawater is warmed by the sun to about 24 °C, while deep seawater below remains at about 3 °C. The engineering team proposes the idealised system shown in Figure 6, where warm surface seawater supplies heat to the boiler, and cold deep seawater absorbs the rejected heat in the condenser. The purpose of this study is to evaluate the maximum theoretical performance of such an engine and to understand the limitations imposed by the Second Law of Thermodynamics.
[Sekumpulan jurutera alam sekitar telah ditugaskan untuk menilai kebolehlaksanaan satu sistem tenaga boleh baharu berskala kecil bagi sebuah stesen penyelidikan alam sekitar di kawasan pesisir pantai. Sistem yang dicadangkan ini memanfaatkan perbezaan suhu semula jadi di dalam air laut sebagai sumber haba dan pelesap haba bagi satu enjin haba teori. Permukaan air laut dipanaskan oleh cahaya matahari dan berada pada suhu kira-kira 24 °C, manakala air laut di kawasan dalam, kekal pada suhu yang jauh lebih rendah iaitu sekitar 3 °C. Pasukan jurutera mencadangkan sistem ideal seperti yang ditunjukkan dalam Rajah 6, di mana air laut suam dari permukaan membekalkan haba kepada boiler, manakala air laut sejuk dari bahagian dalam menyerap haba buangan di dalam kondenser. Tujuan kajian ini adalah untuk menentukan prestasi teori maksimum enjin tersebut serta memahami batasan yang dikenakan oleh Hukum Kedua Termodinamik.]

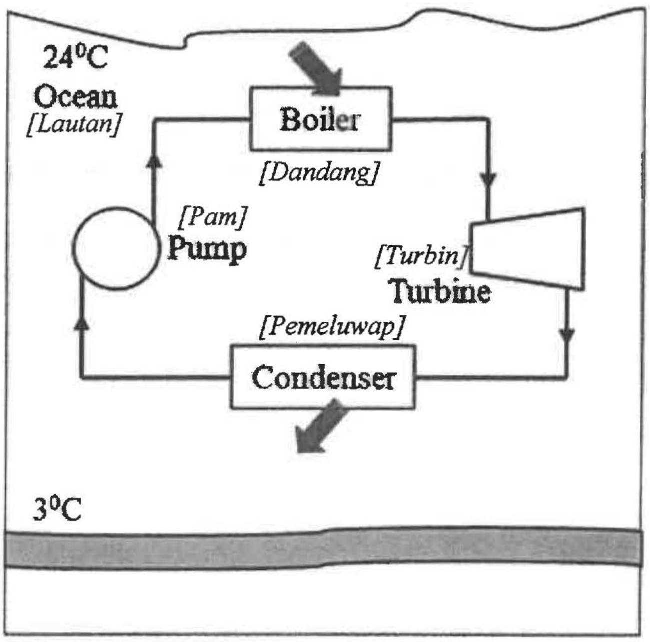

Figure 6 : Small-scale renewable energy system
*[**Rajah 6** : Sistem tenaga boleh diperbaharui berskala kecil]*

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(a) Based on the temperatures of the warm and cold ocean water, determine the maximum thermal efficiency of such an engine, assuming Carnot operation.
[Berdasarkan suhu air laut suam dan air laut sejuk tersebut, tentukan kecekapan terma maksimum enjin tersebut dengan menganggap operasi adalah mengikut kitaran Carnot.]

(6 Marks/ *Markah*)

(b) During seasonal monitoring, the engineers discover that the surface water temperature drops to 18 °C, while the deep seawater temperature remains at 3°C. Determine the new maximum thermal efficiency, and justify whether this change improves or reduces the system's performance.
[Semasa pemantauan bermusim, para jurutera mendapati suhu air permukaan menurun kepada 18 °C, manakala suhu air laut dalam kekal 3 °C. Tentukan kecekapan terma maksimum baharu, dan jelaskan sama ada perubahan ini meningkatkan atau menurunkan prestasi sistem tersebut.]

(8 Marks/ *Markah*)

(c) Evaluate whether the thermal efficiency of a Carnot heat engine can be enhanced through means other than elevating the source temperature, T_H, or reducing the sink temperature, T_L. Provide a reasoned justification based on the fundamental principles of the Carnot cycle.
[Nilaikan sama ada kecekapan terma bagi enjin haba Carnot boleh ditingkatkan melalui cara lain selain daripada meningkatkan suhu sumber, T_H, atau mengurangkan suku sinki, T_L. Berikan justifikasi berasaskan prinsip asas kitaran Carnot.]

(6 Marks/ *Markah*)

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APPENDICES
LIST OF EQUATIONS

$$\eta_{\text{pump}} = \frac{\text{Mechanical energy increase of the fluid}}{\text{Mechanical energy input}} = \frac{\Delta \dot{E}_{\text{mech,fluid}}}{\dot{W}_{\text{shaft,in}}} = \frac{\dot{W}_{\text{pump},u}}{\dot{W}_{\text{pump}}}$$

$$\eta_{\text{turbine}} = \frac{\text{Mechanical energy output}}{\text{Mechanical energy decrease of the fluid}} = \frac{\dot{W}_{\text{shaft,out}}}{|\Delta \dot{E}_{\text{mech,fluid}}|} = \frac{\dot{W}_{\text{turbine}}}{\dot{W}_{\text{turbine},e}}$$

$$\eta_{\text{motor}} = \frac{\text{Mechanical power output}}{\text{Electric power input}} = \frac{\dot{W}_{\text{shaft,out}}}{\dot{W}_{\text{elect,in}}}$$

$$\eta_{\text{generator}} = \frac{\text{Electric power output}}{\text{Mechanical power input}} = \frac{\dot{W}_{\text{elect,out}}}{\dot{W}_{\text{shaft,in}}}$$

$$\eta_{\text{pump-motor}} = \eta_{\text{pump}}\eta_{\text{motor}} = \frac{\dot{W}_{\text{pump},u}}{\dot{W}_{\text{elect,in}}} = \frac{\Delta \dot{E}_{\text{mech,fluid}}}{\dot{W}_{\text{elect,in}}}$$

$$\eta_{\text{turbine-gen}} = \eta_{\text{turbine}}\eta_{\text{generator}} = \frac{\dot{W}_{\text{elect,out}}}{\dot{W}_{\text{turbine},e}} = \frac{\dot{W}_{\text{elect,out}}}{|\Delta \dot{E}_{\text{mech,fluid}}|}$$

$$x = \frac{m_{\text{vapor}}}{m_{\text{total}}}$$

$$m_{\text{total}} = m_{\text{liquid}} + m_{\text{vapor}} = m_f + m_g$$

$$V = V_f + V_g = m_f v_f + m_g v_g$$

Compressed liquid is characterized by:

Higher pressures ($P > P_{sat}$ at a given T)
Lower temperatures ($T < T_{sat}$ at a given P)
Lower specific volumes ($v < v_f$ at a given P or T)
Lower internal energies ($u < u_f$ at a given P or T)
Lower enthalpies ($h < h_f$ at a given P or T)

Superheated vapor is characterized by:

Lower pressures ($P < P_{sat}$ at a given T)
Higher temperatures ($T > T_{sat}$ at a given P)
Higher specific volumes ($v > v_g$ at a given P or T)
Higher internal energies ($u > u_g$ at a given P or T)
Higher enthalpies ($h > h_g$ at a given P or T)

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Mass balances for a steady-flow process

$$\sum_{\text{in}} \dot{m} = \sum_{\text{out}} \dot{m} \qquad \text{(kg/s)}$$

$$\dot{m}_1 = \dot{m}_2 \quad \rightarrow \quad \rho_1 V_1 A_1 = \rho_2 V_2 A_2$$

Steady, incompressible

$$\sum_{\text{in}} \dot{V} = \sum_{\text{out}} \dot{V} \qquad (\text{m}^3/\text{s})$$

Steady, incompressible flow (single stream)

$$\dot{V}_1 = \dot{V}_2 \rightarrow V_1 A_1 = V_2 A_2$$

$$w_{\text{flow}} = Pv \qquad \text{(kJ/kg)}$$

$$e = u + \text{ke} + \text{pe} = u + \frac{V^2}{2} + gz \qquad \text{(kJ/kg)}$$

$$\theta = h + \text{ke} + \text{pe} = h + \frac{V^2}{2} + gz \qquad \text{(kJ/kg)}$$

Amount of energy transport: $E_{\text{mass}} = m\theta = m\left(h + \frac{V^2}{2} + gz\right)$ (kJ)

Rate of energy transport: $\dot{E}_{\text{mass}} = \dot{m}\theta = \dot{m}\left(h + \frac{V^2}{2} + gz\right)$ (kW)

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{dE_{\text{system}}/dt}_{\text{Rate of change in internal, kinetic, potential, etc., energies}} \overset{\nearrow 0\text{ (steady)}}{} = 0$$

Energy balances for a steady-flow process

$$\dot{Q}_{\text{in}} + \dot{W}_{\text{in}} + \underbrace{\sum_{\text{in}} \dot{m}\left(h + \frac{V^2}{2} + gz\right)}_{\text{for each inlet}} = \dot{Q}_{\text{out}} + \dot{W}_{\text{out}} + \underbrace{\sum_{\text{out}} \dot{m}\left(h + \frac{V^2}{2} + gz\right)}_{\text{for each exit}}$$

$$\dot{Q} - \dot{W} = \dot{m}\left[h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right]$$

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$$q - w = h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)$$

Deceleration of Air in a Diffuser

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right) \quad (\text{since } \dot{Q} \cong 0,\ \dot{W} = 0,\text{ and } \Delta\text{pe} \cong 0)$$

$$h_2 = h_1 - \frac{V_2^2 - V_1^2}{2}$$

$$h_2 = h_1 - q_{out} - \frac{V_2^2 - V_1^2}{2}$$

Acceleration of Steam in a Nozzle

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{W}_{in} + \dot{m}h_1 = \dot{Q}_{out} + \dot{m}h_2 \quad (\text{since } \Delta\text{ke} = \Delta\text{pe} \cong 0)$$

$$\dot{W}_{in} = \dot{m}q_{out} + \dot{m}(h_2 - h_1)$$

Compressing Air by a Compressor

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{W}_{in} + \dot{m}h_1 = \dot{Q}_{out} + \dot{m}h_2 \quad (\text{since } \Delta\text{ke} = \Delta\text{pe} \cong 0)$$

$$\dot{W}_{in} = \dot{m}q_{out} + \dot{m}(h_2 - h_1)$$

Power Generation by a Steam Turbine

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{system}/dt}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc., energies}}} \overset{0\ (\text{steady})}{} = 0$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}\left(h_1 + \frac{V_1^2}{2} + gz_1\right) = \dot{W}_{out} + \dot{m}\left(h_2 + \frac{V_2^2}{2} + gz_2\right) \quad (\text{since } \dot{Q} = 0)$$

$$w_{out} = -\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right] = -(\Delta h + \Delta\text{ke} + \Delta\text{pe})$$

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