

The Importance of Translating Physics Terminology Between English and Uzbek: Challenges, Significance, and Educational Implications

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Abstract. Translation is a principal channel through which scientific knowledge crosses linguistic and cultural boundaries. Physics occupies a special place among the sciences because of its international character, conceptual complexity, and highly precise terminology. This article examines the significance of translating physics terminology between English and Uzbek and its implications for scientific communication, education, terminology development, and access to knowledge. As English continues to dominate international scientific publishing and higher education, Uzbek students, teachers, and researchers face growing difficulty in understanding physics concepts and rendering them accurately in their native language. Using a qualitative, comparative linguistic design, the study analyzes a purposive sample of approximately 100 frequently used English physics terms and their Uzbek equivalents drawn from mechanics, thermodynamics, electricity and magnetism, optics, atomic physics, and modern physics. Each term was coded for lexical meaning, morphological structure, semantic equivalence, contextual usage, and translation strategy. Four strategies were identified: direct borrowing (45%), semantic equivalence (30%), functional adaptation (15%), and hybrid creation (10%). The analysis further shows that polysemous everyday words with specialized physical meanings, such as *work*, *field*, *power*, and *current*, and scalar–vector distinctions, such as *speed* versus *velocity*, are the main sources of translation difficulty. The choice of strategy depends on the lexical form of the source term, the availability of an established Uzbek equivalent, and the need to preserve scientific meaning; no single strategy is adequate for all terms. The study concludes that coordinated terminology policies and a concept-oriented approach to physics translation are needed to strengthen scientific communication, improve the quality of educational materials, and support the development of Uzbek scientific language.

Keywords: Physics Terminology, English–Uzbek Translation, Translation Strategies, Lexical Borrowing, Semantic Equivalence

1 Introduction

Translation is one of the principal instruments through which scientific and technological achievements are transmitted across nations. Modern research depends on international communication, and English has become the dominant language of scientific discourse worldwide [1]. Consequently, countries in which English is not the primary language face a growing need for accurate and efficient scientific translation [2].

Physics, as the discipline that investigates the laws governing matter, energy, motion, and the structure of the universe, depends heavily on precise vocabulary and conceptual clarity. Translation in physics is therefore not a matter of simple linguistic substitution; it is an intellectual process that requires conceptual equivalence and scientific precision [3]–[5].

Educational reforms and expanding international cooperation have increased the need for high-quality translations of physics textbooks, research articles, and instructional materials in Uzbekistan. Although university students and instructors make wide use of English-language resources, rendering technical concepts into Uzbek accurately and naturally remains difficult, partly because much of the existing Uzbek scientific terminology was formed through Russian mediation during the twentieth century [6].

This article investigates the importance of physics translation between English and Uzbek and examines how translation contributes to scientific literacy and educational effectiveness. It extends the author's earlier work on the translation, classification, and morphology of physics terms [7]–[9] and on the compilation of an English–Uzbek explanatory dictionary of physics terms [10].

As the analysis presented in this article shows, translating physics terminology from English into Uzbek involves more than linguistic transfer: it must also preserve conceptual accuracy and make scientific knowledge accessible. Terms such as *force* (*kuch*) and *velocity* (*tezlik*) require semantic or functional equivalence, whereas internationally used terms such as *energy* (*energiya*) and *quantum* (*kvant*) can be borrowed. These examples show that, when translation is performed correctly, scientific ideas can be conveyed while retaining their intended meaning.

Previous research in physics education indicates that consistent, conceptually accurate terminology supports students' understanding of physics, whereas ambiguous or everyday-sounding terms can foster or mask misconceptions [11]–[13]. Unambiguous terminology can therefore improve communication between students and teachers, reduce conceptual misunderstandings, raise the quality of translated textbooks and instructional materials, and promote scientific literacy [14]. The present study does not measure learning outcomes directly; rather, it examines the linguistic basis on which such educational benefits depend.

The main evidence is presented in the form of terminology pairs, translation strategies, structural features, and the distribution of translation procedures. The results of the terminology analysis and the observed use of standardized equivalents are then used to inform the discussion of educational implications.

The remainder of the article is organized as follows. Section 2 outlines the theoretical background, Section 3 describes the method, Section 4 presents and discusses the results, and Section 5 presents the conclusions, limitations, and directions for future research.

1.1 Literature Review

Scientific translation has received considerable attention in translation studies and applied linguistics. Classic linguistic theories define translation as the replacement of textual material in one language by equivalent textual material in another [3] and distinguish formal correspondence from dynamic, or functional, equivalence [4]. Jakobson described equivalence in difference as the cardinal problem of language and the pivotal concern of linguistics [15], and later scholars have framed translation norms and strategies as ideas that spread and evolve within the discipline [16], [17].

Scholars generally agree that scientific and technical texts differ from literary texts because clarity, precision, and terminological consistency take priority over stylistic effect [5], [18]. Newmark observed that technical translation is distinguished above all by its terminology [5], and Baker showed how nonequivalence at the word level can be addressed through strategies such as using a loan word, a more general word, cultural substitution, or paraphrase [19]. At the level of individual terms, Vinay and Darbelnet's taxonomy of direct and oblique procedures (borrowing, calque, literal translation, transposition, modulation, equivalence, and adaptation) remains a standard framework for describing how terms are transferred between languages [20]. Research on lexical borrowing further shows that loanwords are adapted phonologically, orthographically, and morphologically to the recipient language [21].

Terminology science offers a complementary perspective. Cabré describes terminology as an interdisciplinary field concerned with the concepts of specialized domains and the terms that designate them [22], and the international standard for terminology work requires that terms be transparent, consistent, and appropriate to the language system in which they are used [23]. Sociocognitive approaches have also shown that many scientific categories have fuzzy boundaries and change over time, which complicates one-to-one equivalence across languages [24].

Research on the language of science shows that scientific discourse relies on technical vocabulary, nominalization, and dense noun phrases that construe the world differently from everyday language [25], [26], and that learning physics involves learning to talk and write in this specialized register [13], [14], [27]. In physics education, Brookes and Etkina demonstrated that the grammar and metaphors embedded in terms such as *heat* and *force* influence how students reason about the underlying concepts [11], [28], and Clerk and Rutherford showed that language can act as a confounding variable in the diagnosis of student misconceptions [12]. For Uzbek, language-planning research documents how scientific terminology was shaped by successive reforms and by extensive borrowing through Russian [6], and recent studies have begun to classify Uzbek physics terms and describe their morphology [8], [9]. However, systematic comparative analyses of English–Uzbek physics terminology that link translation strategies to conceptual accuracy and educational use remain scarce. This gap motivates the present study.

1.2 Research Questions

This article addresses the following research questions:

- a. Why is the translation of physics terminology between English and Uzbek important?
- b. What linguistic challenges emerge when physics terminology is translated between the two languages?
- c. Which translation strategies best preserve conceptual accuracy?
- d. How does the translation of physics terminology influence physics education?

2 Theoretical Background

2.1 Physics Translation as Scientific Communication

Physics translation acts as an intermediary between international scientific production and local educational systems [2]. Translation supports:

- a. access to global scientific discoveries;
- b. development of educational materials;
- c. international academic collaboration; and
- d. formation of national scientific terminology.

2.2 Characteristics of the Language of Physics

The language of physics differs from everyday English in several respects. The first is *precision*. Physics describes natural phenomena that require exact and unambiguous descriptions, so scientists deliberately choose words and phrases with a single, well-defined meaning [25]. Whereas everyday words may take on many meanings depending on the situation, physics terminology is designed to minimize misunderstanding. This precision allows researchers, educators, and students to communicate scientific concepts consistently and effectively.

A second characteristic is *terminological stability*. Physics relies on standardized vocabulary that is used consistently in research articles, textbooks, and instructional materials. Once a concept has been assigned a term, that term is normally used without modification in order to avoid confusion [22], [23]. Stable terminology also facilitates international collaboration, translation, and knowledge sharing, because scientists around the world can refer to the same concepts using equivalent standardized terms.

The language of physics is also characterized by *objectivity*. Scientific writing aims to report facts, observations, experimental findings, and reasoned arguments without expressing the writer's personal feelings or opinions. Physics texts therefore tend to adopt an impersonal, neutral, and formal style, frequently using passive constructions, technical vocabulary, and evidence-based statements to foreground the scientific content rather than the individual researcher [18], [26].

A further distinctive feature is *symbolic integration*. Physics conveys information through verbal explanations together with mathematical equations, symbols, graphs, diagrams, and numerical data. Mathematical formulas express scientific relationships more exactly than words alone, while diagrams and graphs help visualize complex physical processes. The language of physics is thus a distinctive combination of natural language and mathematical representation, and understanding physics requires the ability to interpret both linguistic and symbolic modes of communication [27].

These characteristics create specific difficulties for translation. They include variation in terminology across educational sources, differences between everyday and specialized meanings, mismatches in lexical and morphological structure, and the absence of established Uzbek equivalents for some newer scientific concepts. In physics, for example, words such as *work*, *field*, *power*, and *current* have specific meanings that cannot always be rendered by straightforward lexical substitution [7]. Structural differences between English and Uzbek also matter: English passive constructions and noun-heavy phrases often need to be restructured in Uzbek [9], [26].

3 Method

This study examines the linguistic features of physics terminology in English and Uzbek using a qualitative, comparative research design. Rather than relying on numerical or statistical data, the qualitative approach examines the meanings, structures, functions, and contextual usage of physics terms. It enables the researcher to identify patterns in term formation, semantic characteristics, translation techniques, and the function of terminology in scientific discourse.

The study focuses on physics terminology in the English–Uzbek language pair, a relatively unexplored area of scientific translation studies. Approximately 100 frequently used physics terms from mechanics, thermodynamics, electricity and magnetism, optics, atomic physics, and modern physics were examined. The

terms were selected from dictionaries, glossaries, scientific journals, textbooks, and other educational resources. A comparative technique was used to identify similarities and differences between English and Uzbek physics terminology. The comparison focused on how scientific terms are translated and adapted from one language to the other and on their lexical, morphological, semantic, and structural characteristics. It also assessed the adequacy and equivalence of the translated terms, identifying cases in which direct translation is feasible and cases in which borrowing or adaptation is more appropriate.

Data were collected from English and Uzbek physics textbooks, scientific articles, dictionaries, glossaries, and other academic sources and examined systematically to determine how physics terminology functions in both languages and to identify effective methods for translating and standardizing scientific terms. Together, these techniques provide a comprehensive picture of the similarities, differences, and translation difficulties associated with English and Uzbek physics terminology.

The study classifies English–Uzbek physics terms into four categories: (1) direct borrowing, (2) semantic equivalence, (3) functional adaptation, and (4) hybrid creation. Building on established taxonomies of translation procedures [5], [20] and on the author’s earlier classification of physics terms [8], this classification offers a systematic way to explain how international physics terminology is translated into Uzbek and how terms are modified to conform to Uzbek scientific and linguistic norms. The study combines comparative terminology analysis with explicit translation evaluation criteria. Each term was evaluated for lexical meaning, morphological structure, semantic equivalence, word formation, contextual usage, clarity, terminological consistency, and conformity with accepted scientific usage. The study therefore assesses how well each translated term captures the underlying scientific concept rather than merely listing alternative translations. The analytical procedure comprised eight stages: (a) selection, (b) extraction, (c) coding, (d) comparison, (e) evaluation, (f) classification, (g) calculation of frequencies, and (h) interpretation.

Each term was assessed using a predetermined coding scheme comprising the following categories:

- a. *Source term*—the English physics term selected for analysis.
- b. *Target equivalent*—the corresponding Uzbek term identified in scientific and educational sources.
- c. *Physics domain*—the subfield to which the term belongs (mechanics, thermodynamics, electricity and magnetism, optics, atomic physics, or modern physics).
- d. *Lexical meaning*—the basic scientific meaning of the term.
- e. *Morphological structure*—the structural and word-formation characteristics of the English and Uzbek terms.
- f. *Semantic equivalence*—the degree to which the Uzbek equivalent preserves the scientific meaning of the English source term.
- g. *Contextual usage*—the use of the term in textbooks, scientific articles, dictionaries, glossaries, and educational materials.
- h. *Translation strategy*—the procedure used to transfer the term from English into Uzbek.

3.1 Sample

The study is based on a purposive sample of written scientific and educational materials in English and Uzbek. Because the study focuses on terminology rather than on human participants, the sample consists of authentic texts commonly used in physics education and scientific communication. The materials analyzed include the following:

- a. English physics textbooks used in secondary schools and universities, covering both fundamental and advanced concepts.
- b. Uzbek educational materials, including physics textbooks, teaching manuals, lecture notes, and curriculum-based resources used in schools and universities.
- c. Scientific articles published in English and Uzbek, including translated articles, used to examine how physics terminology is transferred between the two languages and to identify common translation strategies and challenges.
- d. Physics terminology databases, dictionaries, and glossaries that provide standardized definitions, accepted equivalents, and technical vocabulary used in academic and professional contexts [10].

Approximately 100 frequently used terms from the major subfields of mechanics, thermodynamics, electricity and magnetism, optics, atomic physics, and modern physics were examined. The selected terms represent a range of linguistic forms, including simple terms, compound terms, multiword expressions, borrowed terms, and recently adapted scientific vocabulary.

Terms were selected according to how frequently they appear in instructional materials, how important they are for explaining fundamental physical concepts, and whether a comparable Uzbek equivalent exists. For each term, the lexical meaning, morphological structure, semantic features, translation equivalent, and use in scientific discourse were examined. This sample provides sufficient material to analyze how physics terminology is formed and used in the two languages, to identify recurring linguistic patterns, and to assess translation accuracy.

3.2 Instruments

Several research instruments were used to collect and analyze the data systematically. Because the study is qualitative and comparative, the instruments were analytical frameworks rather than questionnaires or standardized tests. They were chosen to ensure a uniform analysis of English and Uzbek physics terminology.

3.3 Comparative Terminology Analysis

The main research instrument was a comparative terminology analysis framework designed to compare physics terms in English and Uzbek. The framework analyzed each term according to its lexical meaning, morphological structure, semantic equivalence, word formation, and contextual usage [22]. This instrument enabled the researcher to compare the two languages and to determine how each linguistic system represents scientific concepts. To ensure uniformity, all of the approximately 100 terms were examined using the same criteria.

3.4 Translation Evaluation Criteria

A translation evaluation framework was used to assess the quality and adequacy of the English–Uzbek term equivalents. The criteria were semantic accuracy, terminological consistency, equivalence, clarity, and conformity with accepted scientific usage [5], [23]. Particular attention was given to translation techniques such as direct translation, borrowing, transliteration, calque, adaptation, and descriptive translation [20]. The purpose of this instrument was to determine whether translated terms faithfully convey the original scientific meaning while remaining comprehensible and appropriate in the target language.

3.5 Linguistic Observation

Linguistic observation was used as an additional instrument to examine the natural occurrence and usage of physics terminology in authentic scientific discourse. Physics terms were observed in textbooks, scientific articles, dictionaries, glossaries, and educational materials published in English and Uzbek. These observations allowed contextual differences, preferred terms, and recurring linguistic patterns in scientific communication to be identified, and they supplemented the comparative analysis and the translation evaluation.

Conventional measures of validity and reliability, such as Cronbach's alpha or test–retest reliability, were not applicable because the instruments were researcher-designed analytical frameworks rather than psychometric instruments. Instead, the credibility of the analysis was strengthened by drawing on authoritative sources, including established physics textbooks, bilingual dictionaries, scientific glossaries, and peer-reviewed publications, and by applying the same analytical criteria to all selected terms. This systematic and consistent procedure enhanced the trustworthiness of the results.

3.6 Data Collection Procedures

Data were collected systematically in four sequential stages to ensure the reliability and validity of the linguistic analysis. In Stage 1 (selection of English physics materials), authentic English-language physics resources were chosen from reputable scholarly and instructional sources, including university-level physics textbooks, scientific articles, multilingual scientific dictionaries, online learning platforms, and glossaries of physics terminology. The selected resources covered mechanics, thermodynamics, electromagnetism, optics, quantum physics, and nuclear physics, with the aim of assembling a representative set of frequently used English physics terms. In Stage 2 (term extraction), candidate terms were extracted from these materials and screened against the inclusion criteria described in Section 3.7. In Stage 3 (identification of equivalents), the Uzbek equivalent of each term was identified in Uzbek physics textbooks, teaching manuals, and bilingual dictionaries [10]. In Stage 4 (verification), each English–Uzbek pair was cross-checked across several sources before being coded.

The selection process should be understood as deliberate and criterion-based rather than statistically representative. No formal expert-panel rating or automated corpus-frequency analysis was conducted. The practical selection criteria were cross-linguistic comparability, curricular relevance, and frequency of occurrence in the consulted materials. This sampling approach was considered appropriate for the qualitative, comparative aims of the study.

3.7 Data Analysis

The collected English and Uzbek physics terms were analyzed using a qualitative comparative approach. After data collection, each term pair was examined closely to determine the translation strategy used and the degree of equivalence between the source and target terms. The main goals were to identify linguistic patterns, semantic relationships, and morphological changes that occur during translation.

To support systematic analysis, the terms were divided into four main categories. The first, *direct borrowing*, included terms such as *photon* (*foton*) and *laser* (*lazer*) that entered Uzbek from English or through Russian with little or no change in form. These terms typically retain their original pronunciation and spelling, with minor orthographic adjustments to conform to Uzbek norms [21]. The second category, *semantic equivalence*, comprised terms translated according to their lexical meaning rather than their original form. This method uses equivalent Uzbek lexical elements to preserve the conceptual meaning of the English term; examples include *electric field* (*elektr maydoni*) and *gravitational force* (*tortishish kuchi*). For Uzbek-speaking learners, this approach emphasizes semantic precision and facilitates comprehension.

The third category, *functional adaptation*, comprised terms whose translations were modified to conform to Uzbek linguistic, educational, or scientific norms. These translations prioritize clarity and natural usage in the target language over faithful reproduction of the source structure. Functional adaptation was especially evident in complex scientific statements that had to be restructured to convey the concepts accurately. The fourth category, *hybrid creation*, comprised terms that combine borrowed international elements with native Uzbek lexical or morphological elements. These forms show how the Uzbek language system interacts with international scientific terminology and illustrate the continuing evolution of scientific vocabulary as foreign technical concepts are incorporated into the national language. Following this classification, the frequency of each strategy was calculated, and representative examples were selected for detailed discussion. The results were interpreted by contrasting the linguistic features of English and Uzbek physics terminology, with particular attention to semantic accuracy, morphological structure, and lexical equivalence. This procedure made it possible to identify the most prevalent translation patterns and to highlight the advantages and limitations of each strategy.

Terms were identified in terminology databases, glossaries, scientific publications, teaching manuals, English and Uzbek physics textbooks, dictionaries, and other scholarly resources. Multiple source types were consulted to reduce dependence on any single source and to capture terminology used in both educational and scientific contexts.

Five inclusion criteria were applied. First, priority was given to terms that appeared frequently or regularly in the consulted instructional materials. Second, terms were chosen for their relevance to fundamental physics concepts and commonly taught course content. Third, each English term had to have a distinct Uzbek counterpart that could be compared. Fourth, the sample had to include a variety of linguistic forms, such as simple terms, compound terms, multiword expressions, borrowed terms, and recently adapted scientific terms. Fifth, terms were drawn from several major subfields of physics to ensure disciplinary diversity. The final sample comprised approximately 100 terms from mechanics, thermodynamics, electricity and magnetism, optics, atomic physics, and modern physics. Lexical meaning, morphological structure, semantic features, translation equivalent, translation strategy, and contextual usage were examined for each term. The 100 terms do not constitute a statistically representative sample of all physics terminology; they form a purposive, stratified analytical sample rather than a corpus-based statistical one.

4 Results and Discussion

4.1 Results

The analysis shows that English and Uzbek share a large number of international scientific terms. Representative examples are given in Table 1.

Table 1. Examples of English–Uzbek translation of physics terms

English Term	Uzbek Equivalent	Translation Strategy
Energy	Energiya	Direct borrowing
Momentum	Impuls	Functional adaptation
Force	Kuch	Semantic equivalence
Velocity	Tezlik	Semantic (functional) equivalence
Quantum	Kvant	Direct borrowing

Many international scientific terms are shared by English and Uzbek, reflecting the universality of scientific communication. Many physics terms have been taken over from international scientific terminology, whereas others have been translated or modified to fit the grammatical structure of Uzbek. The comparison of English

physics terms with their Uzbek equivalents revealed several distinct translation techniques, each of which contributed to the successful transfer of scientific meaning.

As shown in Table 1, terms such as *energy–energiya* and *quantum–kvant* were transferred through direct borrowing. With only slight phonetic or orthographic changes, these terms have entered Uzbek and are now widely accepted scientific designations. Direct borrowing ensures consistency with international scientific nomenclature while maintaining the original scientific meaning [3], [21].

Other terms required adaptation to the linguistic conventions of Uzbek. For example, *momentum* is rendered as *impuls*, which is widely accepted in Uzbek scientific discourse even though it differs from the English lexical form. This strategy keeps the translated term understandable and technically accurate in the target language. Several concepts were translated through semantic equivalence, in which the Uzbek term conveys the same scientific meaning using native vocabulary. For instance, *force* is rendered as *kuch*, a well-established Uzbek word that represents the physical concept accurately without relying on borrowed terminology. Similarly, *velocity* is translated as *tezlik*, a choice that reflects the scientific function and meaning of the concept rather than its lexical form [4], [16].

To classify the terms, the following operational criteria were used to assign each English–Uzbek physics term to one primary category:

- a. *Direct borrowing* applies when an English or international scientific term is retained in Uzbek with little or no phonological or orthographic modification. Examples include *energy* → *energiya*, *quantum* → *kvant*, *photon* → *foton*, and *laser* → *lazer*.
- b. *Semantic equivalence* applies when an established Uzbek lexical item expresses the same scientific concept as the English term even though the lexical forms differ. The decisive condition is that the scientific meaning is preserved using existing Uzbek vocabulary. Examples include *force* → *kuch*, *velocity* → *tezlik*, and *field* → *maydon*.
- c. *Functional adaptation* applies when a direct lexical counterpart is unavailable, inadequate, or potentially misleading, so that the target term must be selected or modified in accordance with Uzbek linguistic and scientific conventions to fulfill the same terminological function. An example is *momentum* → *impuls*, where the established Uzbek scientific term does not formally correspond to the English lexical form.
- d. *Hybrid creation* applies when an internationally borrowed element is combined with Uzbek lexical or morphological material. The coexistence of foreign and native elements within a single term is the defining feature of this category [9], [21].

Quantitative analysis of the coded data showed that borrowing was the most frequently used strategy, accounting for 45% of all analyzed terms. This high proportion reflects both the broad acceptance of borrowed technical terms in scientific communication and the strong influence of international scientific terminology on the Uzbek language of physics. Semantic equivalence accounted for 30% of the terms, indicating that many physics concepts can be expressed effectively with existing Uzbek lexical resources. Functional adaptation accounted for 15%, suggesting that some concepts must be modified to be linguistically and conceptually compatible with the target language. Finally, 10% of the terms were classified as hybrid creations, which combine native Uzbek morphological or lexical elements with borrowed international elements. These hybrid forms show how Uzbek scientific terminology evolves dynamically, incorporating international scientific concepts while preserving the features of the national language. The distribution is shown in Fig. 1.

Overall, the results indicate that no single translation technique is adequate for all scientific terminology. Depending on the linguistic structure of the source term, the availability of an established Uzbek equivalent, and the need to maintain scientific accuracy, translators use a combination of borrowing, equivalence, adaptation, and hybrid creation. This combined approach maintains coherence with international physics terminology while contributing to a standardized and comprehensible Uzbek scientific language.

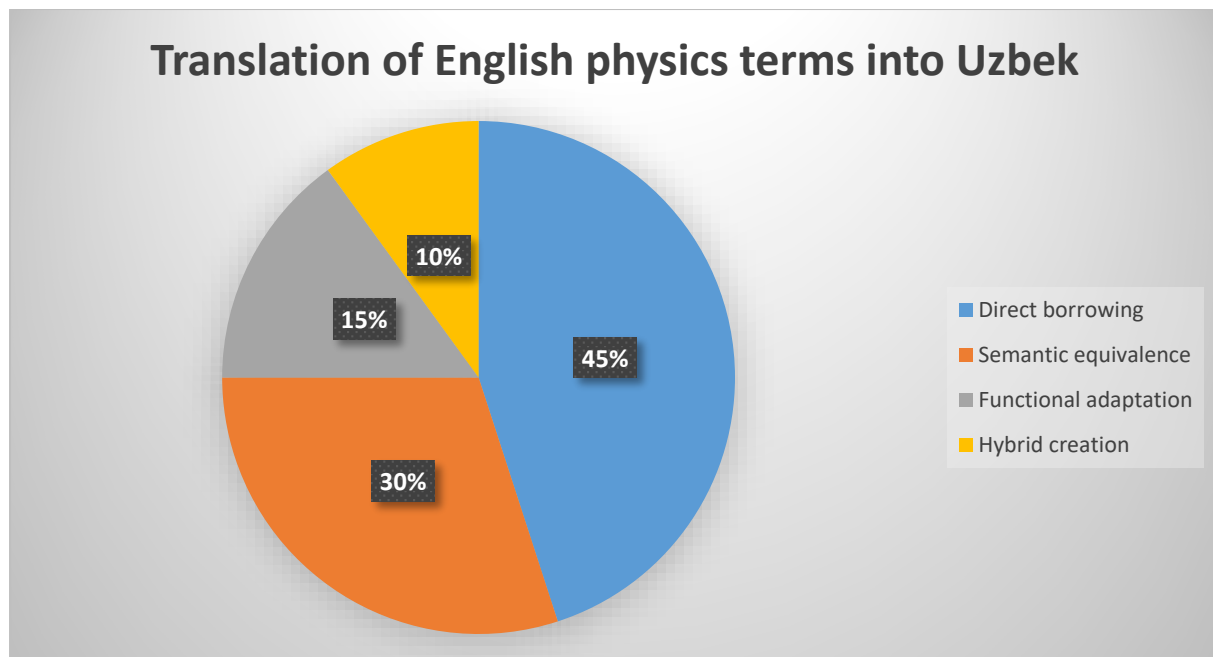


Figure 1. Distribution of translation strategies for English physics terms rendered into Uzbek ($n \approx 100$)

The four main translation strategies—direct borrowing, semantic equivalence, functional adaptation, and hybrid creation—were identified, and their relationship to conceptual accuracy was examined. Terms for which Uzbek already possesses established lexical resources were better suited to semantic or functional equivalence, whereas internationally recognized terms such as *photon–foton* and *laser–lazer* were better suited to direct borrowing.

The numerical distribution of the strategies (45% borrowing, 30% semantic equivalence, 15% functional adaptation, and 10% hybrid creation) is descriptive and should not be interpreted as evidence of the relative effectiveness of any strategy. Because the sample contained approximately 100 coded items, these percentages correspond to roughly 45, 30, 15, and 10 terms, respectively.

Each term was assigned to a single primary strategy category using the predetermined coding scheme. Coding took into account (1) the lexical form of the source term, (2) the Uzbek equivalent, (3) morphological structure, (4) semantic equivalence, (5) contextual usage, and (6) the translation technique. These criteria were applied uniformly to all selected terms.

4.2 Discussion

The results demonstrate the important role of physics translation in improving educational quality, promoting scientific communication, and widening access to scientific information in Uzbek. As the comparative analysis shows, effective translation is not simply a matter of replacing words with their lexical equivalents; it requires the accurate transfer of scientific concepts, technical interpretations, and contextual information. This supports the view that scientific translation is a specialized activity in which conceptual clarity and accuracy matter more than formal correspondence [4], [5], [19].

One of the most significant findings concerns the importance of conceptual rather than lexical equivalence. In many cases, a word-for-word translation of an English physics term would lead to misinterpretation or loss of meaning. Because scientific concepts are embedded in theoretical frameworks, translators must consider the function of a term in its specific context. For instance, the English word *work* denotes a precisely defined physical quantity in physics but has a broad meaning in everyday speech. Similarly, *field*, *power*, and *current* have scientific definitions that differ considerably from their everyday usage [12], [28]. Before selecting the most suitable Uzbek equivalent, translators must therefore understand both the scientific content and the linguistic structure of the source text. This finding shows that successful physics translation requires both linguistic proficiency and subject-matter expertise.

Some term pairs require particular care. In physics, *velocity* is a vector quantity with both magnitude and direction, whereas *speed* is a scalar quantity equal to the magnitude of the instantaneous velocity. In Uzbek, *tezlik* is defined as a vector quantity in the *O'zbekiston Milliy Ensiklopediyasi* [29], and this distinction is clearly recognized in Uzbek physics terminology. The present analysis indicates that *tezlik* is a legitimate conceptual equivalent of *velocity*, but that *speed* requires contextual qualification, such as *tezlikning moduli* (magnitude of velocity) or *tezlik miqdori*, when the scalar concept must be explicitly distinguished from velocity [10]. For

example, when a car travels around a circular track at constant speed, its *speed* remains constant, but its *velocity* changes continuously because its direction changes.

Another significant finding is the extensive use of international scientific vocabulary. Many scientific terms derive from Greek and Latin roots and are now shared by many languages, for example, *energy*, *atom*, *electron*, *quantum*, *proton*, *neutron*, and *photon* [1], [30]. Such internationally recognized terms support scientific communication by enabling researchers, educators, and students from different countries to share scientific ideas. Many of them, such as *energiya*, *atom*, *kvant*, *elektron*, and *foton*, are borrowed into Uzbek with only slight phonetic or orthographic modifications. Although this approach promotes consistency with the international scientific literature, translators must still ensure that borrowed terms are understood by Uzbek readers through appropriate context and explanation.

The study also showed that different translation procedures are required depending on the linguistic features of individual terms. Direct borrowing is usually adequate for internationally recognized terminology, whereas descriptive translation, functional equivalence, or semantic adaptation may be necessary for newly introduced concepts or highly specialized expressions. Complex technical sentences, for instance, often need to be restructured to remain intelligible in Uzbek. No single translation approach is therefore sufficient for all scientific texts; translators should apply flexible techniques suited to the intended audience and communicative purpose [16], [17].

The educational implications of these findings are significant. Accurate translation can improve students' comprehension of scientific concepts by presenting information in language that is both linguistically natural and scientifically precise. Physics education research shows that the wording of physics terms can shape how students conceptualize the underlying ideas [11], [28], which suggests that students who learn physics from well-translated textbooks may encounter fewer conceptual misunderstandings and develop stronger scientific literacy. Clear terminology may also help learners connect theoretical explanations with practical applications, thereby supporting academic performance and critical thinking [14].

High-quality translation may also improve classroom communication between teachers and students. Teachers rely on standardized terminology when explaining scientific concepts, conducting laboratory work, and assessing students' understanding. Consistent translation helps establish a shared scientific vocabulary in the classroom and reduces uncertainty during instruction [13], [27], which may in turn improve both learning outcomes and teaching effectiveness.

Improved quality of textbooks and teaching materials is another educational benefit. Well-translated textbooks present scientific material logically and coherently while preserving the accuracy of the source. Such materials become reliable teaching resources for schools and universities, particularly where students learn mainly in their native language. The availability of professionally translated physics resources also supports curriculum development and broader participation in science education. It should be noted, however, that the present study did not test these potential effects empirically.

An equally important implication concerns the development of Uzbek scientific terminology. As new discoveries are made in contemporary physics, translators play a key role in creating and defining new terms. By expanding its technical vocabulary while preserving its linguistic distinctiveness, scientific translation enriches the Uzbek language [6]. The development of precise, standardized equivalents will enable future generations of students, researchers, and teachers to express scientific knowledge effectively in their native language.

Despite these positive findings, the study identified several persistent difficulties. A major challenge is the lack of standardized terminology. Different textbooks, dictionaries, and translators sometimes use different Uzbek equivalents for the same English term, which creates inconsistency and confusion among students. Because the absence of widely accepted norms complicates scientific communication, national terminology guidelines are needed [22], [23].

The rapid emergence of new scientific concepts presents a further difficulty. Advances in quantum physics, nanotechnology, astrophysics, and related fields continually introduce terms that may not yet have established Uzbek equivalents. Translators must then decide whether to retain the original term, coin a new equivalent, or provide a descriptive explanation, a decision that requires collaboration among linguists, physicists, educators, and terminologists [24]. The study also found that structural differences between English and Uzbek can complicate translation. English scientific writing frequently uses passive constructions, long noun phrases, and highly condensed expressions [26], whereas Uzbek, an agglutinative language with subject-object-verb word order, favors different grammatical patterns. Literal translation of English structures can therefore produce awkward or unnatural Uzbek sentences, and translators must restructure sentences while preserving logical coherence and scientific accuracy [17].

Finally, the study highlights the continuing reliance on borrowed vocabulary. Although international borrowings promote global consistency, excessive use of foreign words may make texts harder to understand for students with limited scientific background. Translators should therefore balance international standardization with the development of clear and accessible Uzbek terminology wherever possible.

Overall, the results show that physics translation is a complex process that requires linguistic proficiency, scientific knowledge, pedagogical awareness, and terminological consistency. Precise translation strengthens science education, makes international research more accessible, expands the scientific vocabulary of Uzbek, and facilitates effective interaction between local students and the international scientific community. The accuracy, accessibility, and pedagogical value of future scientific translations will depend on continued cooperation among translators, physicists, educators, and language planners.

The comparative analysis of approximately 100 English–Uzbek physics terms shows that the choice of translation strategy is influenced by the lexical form of the source term, the availability of an established Uzbek equivalent, the degree to which the concept is internationalized, and the need to preserve scientific meaning. The four strategies identified—direct borrowing, semantic equivalence, functional adaptation, and hybrid creation—reflect different degrees of lexical and conceptual change between English and Uzbek.

Direct borrowing was the most common strategy, accounting for approximately 45% of the terms examined. It was especially prevalent for internationally recognized scientific terms whose conceptual meaning is shared across languages. Examples are given in Table 2.

Table 2. Examples of direct borrowing

English term	Uzbek equivalent	Strategy	Explanation
energy	energiya	direct borrowing	The international scientific term is transferred with phonetic and orthographic adaptation to Uzbek.
quantum	kvant	direct borrowing	The international term is retained because of its established scientific status.
photon	foton	direct borrowing	The term is transferred with minor phonological and orthographic adaptation.
electron	elektron	direct borrowing	The international scientific form is preserved in Uzbek.
atom	atom	direct borrowing	The form is essentially identical in both languages.
laser	lazer	direct borrowing	The international term is adapted to Uzbek orthographic conventions.

These examples show that borrowing is appropriate when a foreign term already has an established form in Uzbek and a stable scientific meaning. In such cases, replacing the borrowed term with an entirely new lexical equivalent could undermine terminological consistency with the international scientific literature. The analysis thus identifies *energy–energiya* and *quantum–kvant* as instances of borrowing and shows that internationally recognized terms such as *photon–foton* and *laser–lazer* can be transferred with minimal formal change [7], [10].

Borrowing is not, however, always the best choice for every physics term. An internationally recognized form may still be confusing for students without a scientific background, so borrowed terms may need contextual clarification, especially in school textbooks and introductory university materials.

Semantic equivalence accounted for approximately 30% of the terms analyzed. This strategy is used when an existing Uzbek lexical item can adequately express the scientific concept without retaining the English lexical form (Table 3).

Table 3. Examples of semantic and functional equivalence

English term	Uzbek equivalent	Strategy	Explanation
force	kuch	semantic equivalence	The Uzbek lexical item directly expresses the relevant physical concept.
velocity	tezlik	functional/semantic equivalence	The Uzbek term represents the scientific function and meaning rather than the English form.
work	ish	semantic equivalence with contextual specification	The ordinary Uzbek word acquires a specialized physical meaning in context.
field	maydon	semantic equivalence	The Uzbek term represents the scientific concept when used with the appropriate modifier.
power	quvvat	semantic/functional equivalence	The established Uzbek physics term expresses the scientific concept rather than the everyday meaning of power.

The pair *force–kuch* is particularly instructive because the English lexical form is not carried over into Uzbek; instead, the same physical concept is expressed by an existing Uzbek lexical item. Similarly, *velocity–tezlik* shows that functional meaning can matter more than formal similarity. These two pairs therefore exemplify semantic and functional equivalence, respectively.

This strategy becomes particularly important when a literal lexical translation would produce an expression that is linguistically possible but scientifically misleading or incorrect. Because terminological precision is a hallmark of physics, the translator must focus on the scientific concept rather than on word-for-word correspondence. Functional adaptation accounted for approximately 15% of the items analyzed. This strategy is required when a direct lexical equivalent cannot adequately reproduce the scientific function of the source term in Uzbek; the translator then selects or modifies a target expression in accordance with Uzbek linguistic norms and the conceptual requirements of the discipline. A representative example from the data is *momentum* → *impuls*. Because *momentum* cannot be rendered adequately by searching for an everyday Uzbek equivalent, the translation rests on conceptual and terminological correspondence rather than on formal similarity; in Uzbek scientific discourse, *impuls* is the established term for this physical quantity [10].

Polysemous English words whose everyday meanings differ markedly from their meanings in physics form another important group, including *work*, *field*, *power*, and *current*. In physics, these words denote specific scientific concepts, so a literal translation that ignores context can cause conceptual misunderstanding or ambiguity [12], [28]. The analysis identifies these terms as particularly problematic because ordinary lexical substitution does not always transfer their specialized meanings [7].

For example:

- work* → *ish*: the Uzbek word *ish* is acceptable in physics only when it is interpreted as a defined physical quantity rather than in its everyday sense;
- field* → *maydon*: the term must be understood within combinations such as *electric field* and *gravitational field*;
- power* → *quvvat*: the scientific concept corresponds to *quvvat* rather than to the broader everyday meanings of the English word; and
- current* → *tok*: in an electrical context, the target term must denote electric current rather than the general sense of “current” as “present” or “up to date.”

These examples show why conceptual interpretation must precede lexical selection: a direct translation can preserve the dictionary meaning of a word while failing to preserve its scientific meaning. Potentially ambiguous cases were therefore subjected to a second round of review by the researcher, conducted separately from the initial coding. Cases in which the lexical form and the underlying physical concept did not correspond precisely were either reclassified or marked as context-dependent.

Hybrid creation accounted for approximately 10% of the terms analyzed. In hybrid formations, Uzbek lexical or morphological resources are combined with an internationally borrowed element. Such formations show that scientific translation between English and Uzbek is more than the substitution of one language for another; rather, the Uzbek structural and morphological system can absorb concepts from international science [9], [21].

Hybrid forms are especially relevant when a borrowed scientific concept must be combined with Uzbek grammatical or lexical elements in order to function naturally in an Uzbek scientific expression. As defined in this study, hybrid creation is the blending of foreign scientific elements with native Uzbek morphological or lexical features.

This technique is important for terminology development because it allows Uzbek to generate terms that conform to its own linguistic conventions while remaining consistent with international scientific discourse. As the comparison shows, direct translation is not always the most accurate approach, and three kinds of difficulty are particularly noticeable.

First, the everyday meanings of several English words differ from their specialized meanings, so contextual and conceptual analysis is necessary before an Uzbek equivalent is chosen for terms such as *work*, *field*, *power*, and *current*. Second, some terms already have international standard forms, and in such cases borrowing may be preferable to coining an artificial native equivalent, as the pairs *energy–energiya*, *quantum–kvant*, *photon–foton*, and *laser–lazer* demonstrate. Third, some concepts require adaptation because the established Uzbek scientific term does not formally correspond to the English term, as in *momentum–impuls*. In such cases, retaining the English lexical form would not necessarily yield the most natural or standardized Uzbek term; the appropriate translation is determined by the scientific concept and by the norms of Uzbek physics discourse.

5 Conclusions

Physics translation between English and Uzbek performs a vital educational and scientific function. Effective translation broadens access to scientific knowledge, strengthens higher education, and supports terminology development. The study demonstrates that successful translation requires linguistic competence, subject expertise, and consistent terminology policies.

The analysis supports a concept-oriented model of physics translation in which the translator first identifies the scientific concept and determines whether an established Uzbek equivalent exists, and then chooses borrowing, semantic equivalence, functional adaptation, or hybrid creation according to the communicative and terminological requirements. The distribution of the four strategies (45% borrowing, 30% semantic equivalence, 15% functional adaptation, and 10% hybrid creation) should be read descriptively rather than as evidence that one strategy is inherently superior. The choice of strategy depends on the lexical, semantic, structural, and terminological features of individual physics terms, a conclusion consistent with the qualitative, comparative design of the study.

This study has several limitations. The sample of approximately 100 terms was purposive rather than corpus-based, the coding was carried out by a single researcher, and the educational effects of standardized terminology were inferred from the literature rather than measured directly. Future research should test the classification on a larger bilingual corpus, assess intercoder agreement, and examine experimentally how different translation strategies affect students' conceptual understanding of physics. A national, regularly updated English–Uzbek physics terminology database developed jointly by physicists, linguists, and educators would also support more consistent translation practice.

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Author Contributions

The sole author was responsible for the conception and design of the study, data collection and analysis, interpretation of the results, and preparation of the manuscript, and approved the final version.

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Conflict of Interest

The author declares no financial, professional, or personal conflicts of interest that could have influenced the research, the interpretation of the results, or the preparation of this manuscript.

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Artificial Intelligence (AI) Use Statement

Mendeley was used for reference management. Generative AI tools (ChatGPT, OpenAI; Claude, Anthropic) were used only to improve the language, formatting, and presentation of references. No AI tool was used to generate data, analyze results, or draw conclusions, and the author reviewed all content and takes full responsibility for it.

Data Availability Statement

The data supporting the findings of this study are included in the article. The complete list of coded English–Uzbek physics terms is available from the corresponding author upon reasonable request.

Ethics Statement

Ethical approval was not required for this study.

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